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Nadi Tantra Approaches for Pulse Assessment: The Role of Ayurvedic History and Machine Learning Tools

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Abstract. Physicians regard pulse assessment as critical in assessing the type and severity of diseases. Without knowledge of pulse examination, a physician cannot diagnose the patient effectively. It is prioritised over other diagnostic aids for all types of illnesses. Numerous investigations have conclusively proved that the pulse-measuring ethics of ancient Indian systems prohibited the use of tools, even though current pulse wave analysis makes considerable use of equipment for therapeutic and scientific objectives. The purpose of this study is to assess the utility of modern tools in investigating the classic pulse's characteristics and to analyse Nadi Tantra approaches in terms of their dosha characteristics, pulse parameters and their locations, modern and traditional pulse examination techniques, pulse diagnosis, and research gaps to develop a novel pulse examination technique with increased detection capability.
Keywords: Pulse Examination, Machine learning, Deep learning, Nadi Tantra, Disease diagnosis

1. Introduction

Medical practices have existed around the world since the dawn of ancient civilizations. There are many types of medical systems including folk medicine, modern scientific medicine, and traditional proven medicine. Ayurveda is one of India's ancient medicine that has been in continuous use for 3000 years. Ayurveda derives from the Sanskrit words ayur (life) and veda (science). Thus, Ayurveda is synonymous with the knowledge of life. Ayurveda advocates various lifestyle modifications and natural remedies to restore harmony between the body, mind, spirit, and environment. This is based on the belief that sickness is caused by an imbalance or stress in a person's awareness. Similarly, other ancient civilizations like Japan, Korea, China, and Arabia have been using their own traditional medicines. Despite the advent of scientific medicine, many people from developed nations utilize the traditional medicine system for basic healthcare needs. A report says that 70% of India, 80% of Africa, 71% of Chile, 40% of China, 40% of Colombia, 42% oftheUS, 48% of Australia, 49% of France, 70% of Canada's population are using the traditional medicine for the basic healthcare needs. The interest behind the usage of the traditional healthcare system is due to its easy availability and the non-invasive nature of the pulse sensing method. In addition, the painless and bloodless nature and the no side effects inspire traditional medicine.

One of the methods that Ayurveda finds its symptoms is by pulse sensing. It is employed through the detection of Tridoshas[1].Sphygmology is the branch of science that details pulse science, which is also termed *nadivigyan*. It is utilized for the detection of the health of the entire human body through the *Vata, Pitta, and Kaphadoshas*[2]. The variation of the above-mentioned *tridhosas* occurs due to several factors that are present inside and outside the human body such as age, diet, and seasonal effects. Nadi Pariksha is the pulse signal acquisition technique utilized for the prognosis and diagnosis of the disease based on the *tridhosas* such as *Vata, Pitta, and Kapha*[3].It can diagnose both physical and mental illnesses, as well as imbalances with pinpoint accuracy. The term *Nadi* refers to the pulse, nerves, veins, and arteries, as well as any type of channel throughwhich physiological and biological impulses travel through [4]. It is thorough and addresses the underlying causes of health problems, rather than only the symptoms. Nadi Pariksha alerts you of possible health hazards. It teaches you how to enhance your health by identifying the ingredients that are prevalent in your body. It offers you a complete and accurate customised and individual prognosis [5, 6]. Numerous chronic problems including diabetes, infertility, obesity, hypertension, paralysis, mental disorders, severe joint pains, and skin ailments can be recognised by the use of this Nadi Pariksha[7, 8]

A physician should gently palpate the patient's pulse using his or her right hand's three index, middle, and right fingers at the central spot located at the base of the thumb. Vata, Pitta and Kapha doshas are represented by the index finger, middle finger, and ring finger respectively. [9]. Generally, females' left-hand pulses are palpated, while males' right-hand pulses are palpated[10]. However, establishing an exact link between pulsation and disease type takes highly skilled technical hands [11]. The diagnosis of sickness is contingent upon the presence of Vata, Pitta, and Kapha pulses. Thus, today, utilising sensors, these pulses are collected, processed, and analysed to determine the disease [12].The ultimate goal of this paper is to analyse the traditional Nadi tantra practices based on several factors, such as

  i.   analysing the characteristics of doshas,
 ii.   pulse parameters and their locations,
iii.   Traditional and modern pulse examination techniques,
 iv.   pulse diagnosis techniques
  v.   research gaps along with the discussion for the development of modern more accurate pulse examination techniques.

The remainder of the study article is structured as follows: The second section presents the relevant existing research surrounding the Nadi tantra practisesextensively. The third section details the research gap and discussion. Section 4 concludes the paper and suggests research for the future.

2. Related Study

The literature based on the Nadi Tantra is reviewed and analysed in this section along with the characteristic behaviour, parameters utilized, location of Nadi, techniques utilized in the modern era, and diagnosis methods along the research gaps are analyzed in this section. The overview of the study is depicted in Fig.1 given below.
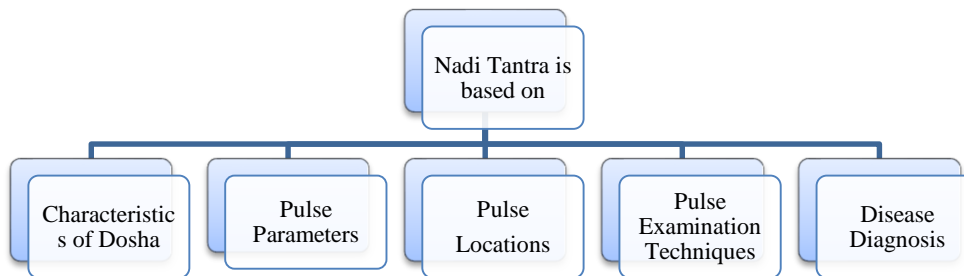
Fig. 1. Overview of Study based on Nadi Tantra

2.1 Analysis based on Characteristics of Doshas

As per the traditional spirit, the correlation between the spirit, body, and mind defines the health and wealth of the people[13]. When all the three above-mentioned factors polyphony with the universe then the health of the body is good, else the health condition is not good. For good health, attributes such as climate, seasonal changes, emotions, injuries, age, birth defect, and genetics are responsible[14]. Thus, the balanced and imbalanced condition of the human body depends on the universe, spirit, mind, and body. The universe comprises five major elements, such as air, water, earth, space, and fire, as per the Ayurveda. Here, space refers to hearing, air refers to touch, fire refers to sight, water refers to taste and earth refers to smell. The five elements of the Universe control the three energies named Vata, Pitta, and Kapha of the body[15].These five elements control the body by three forces or energies, Vata, Pitta, and Kapha, called tridoshas.The tridoshasare detailed in this subsection.

Vata: The most important dosha of the tridosha is the Vata, which is comprised of space and air. It consists of all the waste products and tissues of the body and is considered the driver of the human body[16]. The mental and physical movements of the human body are controlled by the Vata, hence it assists all metabolic activities. The waste products elimination of the human-like sweat, urine, faeces, and fetus are governed by the Vata and also it transfers the sensory inputs to the sense organs. The Vata pulse motion is very thin and irregular and moves like the snake's motion and ranges between 80-95 Beats Per Minute (BPM). The Vata pulse signal is felt on the index finger.

Pitta: The fire and the water constitute the Pitta dosha. The braveness and courage are controlled by Pitta. The digestion of the human body is controlled by Pitta and it employs all the transformations. The skin complexion, appetite, and vision are controlled by pitta and it helps in thermogenesis[17]. The frog's jump is the characteristic behaviour of the Pitta pulse and is excited. The pulse range of the pitta dosha is 70-80 BPM. The Pitta pulse signal is felt on the middle finger.

Kapha: The earth and the water constitute the Kapha dosha. The excess friction reduction through lubrication and moistness, stability, to do several physical tasks are responsible for the Kapha. In addition, virility and fertility are governed by the Kapha dosha for the production of offspring and are considered the heaviest of the tridosha[18]. The floating swan is the pulse representation of the Kapha and it ranges between 55-70 BPM. The Kapha pulse signal is felt on the ring finger[19].

The variation in the tridosha may cause variation in regularity, shape, rhythm, thickness, and frequency indicating the disease diagnosis.

Fig. 2. Nadi (Radial Pulse Method) – Index for Vata, Middle for Pitta, and Ring for Kapha

2.2 Analysis based on Parameters Utilized for Nadi Pariksha

Pulse palpation is utilized for pulse acquisition using the Nadi pariksha technique for the detection of the doshas by sensing the radial artery at three locations. The properties associated with the pulse are considered the most significant aspect to identify the doshas using the Nadi pariksha technique. The pulse movement, which is also termed *gati* plays a significant role in disease detection [20–22]. The traditional pulse parameters such as vega (fast) and manda (slow) are associated with the velocity of the pulse. Besides, sthira (stability), kathina (hard), and capala (unstable) are also the parameters utilized for disease diagnosis. The modern Nadi pariksha technique utilizes the pulse parameters such as arterial stiffness, pulse rate variability, pulse wave velocity, and pulse movement[23, 24].

i) Pulse Movement: The movement of the Vata pulse is the same as the movement of the snake and is termed sarpagati. Likewise, the movement of the pitta is the mandikagati, which resembles the movement of the frog. The frog's movements are in the form of jumping and hopping and are also referred to as Utplutya and Capal in the traditional system and the movement of the kapha is the Manda gati, which is the slow movement and it resembles the swan movement.Thus, pulse movement is very essential for the detection of tridoshas to diagnose the disease[25].

ii) Pulse Speed: The speed of the pulse is also termed the vega. The pathological, psychological, and physiological characteristics of the human can be detected using the vega. The Nadi is faster for some feelings like lustand anger, according to historical texts like Bhavaprakasha and Sarangadhara[26, 27]. Similarly, the Vata is slower for some feelings like fear and sorrow. According to Sarangadhara, the digestive action is also represented in terms of vega. When the digestive action is slow then the vega is slow and for the active digestion fire, the vega is fast. In modern medicine, the speed of the pulse is

measured through the pulse rate measurement. The Pulse Wave Velocity (PWV) is measured and it may range from 5-15m/s and is utilized for the detection of cardiovascular risk. However, the PWV is not closely related to the traditional pulse speed detection named vega. As per the traditional system of Nadi pariksha, vega is slow for the Kapha, medium for the pitta, and fast for the Vata dosha. Also, in childhood the Kapha dosha is dominant, in middle age the pitta dosha is dominant and in old age Vata dosha is dominant. The modern technique of pulse detection indicates that PWV increases with the age[28].

iii) Pulse Stability: The sthiratva is another term utilized in the traditional Nadi pariksha for the detection of the stability of the pulse. The irregularity of the Nadi is measured in terms of sthiratva, which may be slow, fast, or in between them. When the intermittent nature and location of the Nadi is changed, it leads to death. According to ancient texts like Yoga Ratnakara[29] and Basavarajeeyam[30], the sthiratvaNadi is denoted as the asadhyaNadi. The sthiratva of the pulse is associated with the psychological and physiological behaviour of the human[31]. In the modern method of pulse signal acquisition, the pulse rate variability is measured for the detection of the heart rate variability[31]. It is identified based on beat-to-beat variations that may vary according to the disorders and age group [32]. The beat-to-beat variability is measured through the arterial pulse interval (API) to measure the disorders based on frequency, time, and nonlinear measures [33].

iv) Artery Stiffness: The PWV is utilized for the measure of the artery stiffness and due to age factors,artery stiffnessoccurs. The MrithyuNadi is closely related to the measure of artery stiffness. The stiffness index is utilized for the measurement of artery stiffness and it is negatively correlated for non-diabetic patients. The pulse acquisition provides an inaccurate measure due to the pulse amplification process devised in the Nadi tarangini, thus the measure of SI through the peripheral artery needs to be avoided[34, 35].

2.3 Analysis based on Pulse Location

The Ayurveda senses the tridoshas very effectively and also it locates eight different locations of the pulse to sense the Nadi. The eight locations (Fig.3) for sensing the Nadi are two nasal regions, two ankle regions, two neck regions, and two radial arteries as per the Basavarajeeyam text. For the Nadi pariksha and the diagnosis of the radial artery,Nadi is utilized by the detection of tridoshas[32]. TheNadi at the nasal region is considered the disease prognosis and the Nadiat the neck region is considered as the diagnosis of the disease. The neck Nadi is utilized for sensing fever, lust, anger, sorrow, and fear.

Likewise, the Nadi at the nasal region is utilized to detect the ears, eyes, and head disease diagnosis[36].
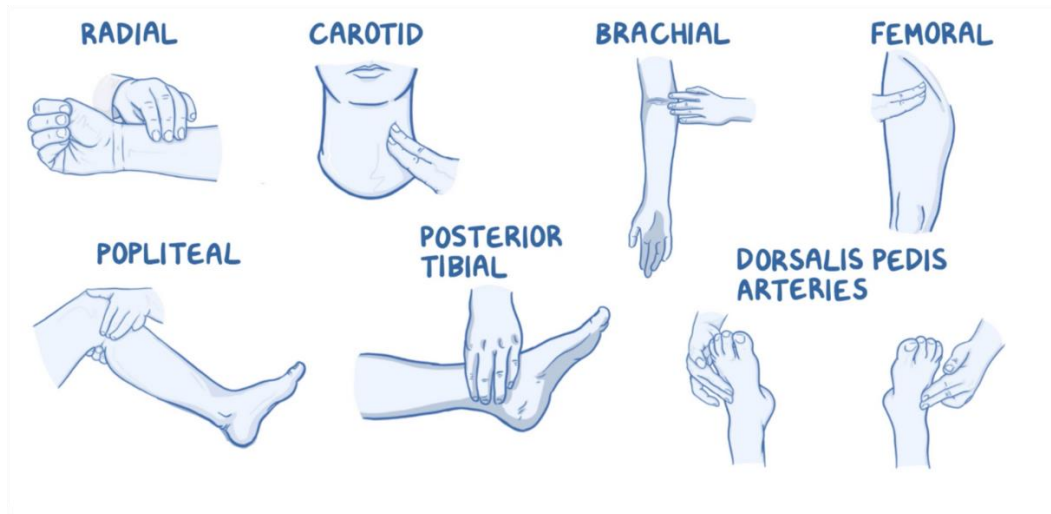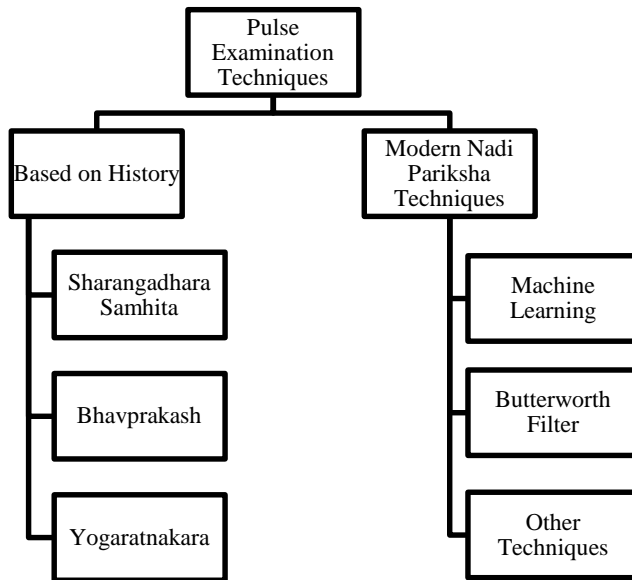

Fig. 3. The Eight Pulse Locations / Sites

The Nadi at the ankle is utilized to detect the status of fever and its relief, and health and life. The modern disease diagnosis technique uses pulse acquisition through the ankle, brachial, femoral, carotid, and radial arteries [37, 38]

The traditional method does not mention the femoral artery and the modern diagnosis is not highlighted about the nasal Nadi [39]. However, Ayurvedic medicine utilizes and explored widely the radial artery location compared to the others. Modern medicine uses the PWV for disease diagnosis, while the role of Nadi is limited.

2.4 Analysis of the existing Nadi Pariksha techniques

The Nadi pariksha techniques are categorized into two types, such as analysis based on History and analysis based on modern techniques. Further, the analysis based on History is categorized into Sharangadhara Samhita, Bhavprakash, and Yogaratnakara. In the same way, the analysis based on modern techniques is categorized into machine learning, Butterworth filter-based techniques, and others. The detailed analysis is given below and is presented in Fig.4.

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              ┌──────────────┐
              │    Pulse     │
              │ Examination  │
              │  Techniques  │
              └──────────────┘
        ┌────────────┴────────────┐
┌──────────────┐           ┌──────────────┐
│Based on      │           │ Modern Nadi  │
│History       │           │  Pariksha    │
│              │           │  Techniques  │
└──────────────┘           └──────────────┘
     │  ┌──────────────┐        │  ┌──────────────┐
     ├──│ Sharangadhara│        ├──│   Machine    │
     │  │   Samhita    │        │  │   Learning   │
     │  └──────────────┘        │  └──────────────┘
     │  ┌──────────────┐        │  ┌──────────────┐
     ├──│  Bhavprakash │        ├──│  Butterworth │
     │  │              │        │  │    Filter    │
     │  └──────────────┘        │  └──────────────┘
     │  ┌──────────────┐        │  ┌──────────────┐
     └──│ Yogaratnakara│        └──│    Other     │
        │              │           │  Techniques  │
        └──────────────┘           └──────────────┘
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Fig. 4. Literature review for the pulse examination Techniques

2.5 History of Indian pulse examination

Some scholars believed that the Indian pulse examination was incurred from Chinese and Egyptian medicine, while Indian medicine has contributed to the contemporary Greeko-Arabian and Greek medicine, which is believed by some other scholars such as Benjamin walker (1968) and Jolly (1951). Besides, some others believed that the Ayurvedic medicine of India was developed from the pulse work of South Indian Siddhas. Several histories are available for the pulse examination utilized by Indians. Some of them are detailed below.

2.5.1 Sharangadhara Samhita

In Sowa-Rigpa, the Nadi pariksha is termed as 'che pa thungyirigpa', which means diagnosis based on the intuitive knowledge. The madhyam khanda of the sharangadharasamhita deals with the Bhaishajyakalpana, but the kaya-chikitsa is considered as one of its contributions in the field of Ayurvedic devised through the Nadi pariksha. The first history that details the Nadi pariksha is the Sharangadhara, which is described detailed in its third section.

2.5.2 Bhavprakash

During the 16th century, a famous physician named Bhavamishra wrote the Bhavaprakash. In the work, 'Rogipariksha' was detailed in 'Dwitiya bhaga', which provides information regarding the pulse examination of the patient. In addition to the pulse examination, the urine, tongue, and eyes examination were also indicated. The information regarding the pulse examination is detailed in 12 verses. The pulse examination should not be done immediately after taking the bath or if tired after doing the exercise or just coming from the sunlight or after taking the bath. The pulse examination needs to be done on the left hand for the female and the right hand for the male at the root of the thumb.

2.5.3 Yogaratnakara

The name of the author for the text Yogaratnakara was unknown and it may belong to the period 1650 A.D and 1725 A.D as per the scholar P. K. Gode. The first chapter of the book details the pulse examination under the title Rogipariksha, which means examining the patient. The information regarding the pulse examination is detailed in 48 verses. For the death and bad prognosis, 14 pulses are considered and 1 pulse depicts the good prognosis for clinical significance. In addition, 18 types of pulses denote pathological and physiological characteristics[40].

2.6 Modern Nadi Pariksha Techniques

In the early days, Ayurvedic practitioners use three fingertips for pulse detection. Nowadays in the modern era, a more accurate wearable pulse detection device is essential for monitoring the health status of the patient for the prevention of fatal disorders[29]. The usage of the portable device enhances efficiency as continuous monitoring is possible through these devices. In addition, various types of sensors are utilized for the acquisition of the pulse in the modern Nadi Pariksha techniques. The modern Nadi pariksha techniques can be performed usingmainlymachine learning techniques andfilter-based techniques. The main filtering technique used isButterworth filter. The techniques are explained in the sections below.

2.6.1 Based on Machine learning

Pulse detection and its classification are essential for disease diagnosis by medical practitioners. Machine learning and deep learning techniques are utilized by medical practitioners for the classification of pulse types. Some of the existing techniques for the diagnosis of the pulse are detailed below.

Roopini*et al.,*[20]employed a Nadi pariksha system for the diagnosis of the health of humans. The design aims to assist the doctors and also can be used by the not well-trained practitioner. The developed nadi yantra for the detection of the pulse is portable and was useful for the cardiac disorder prognosis. Here, the optical sensors were utilized for the

acquisition of the pulse signal and are placed in radial fossa, the misplaced sensor may produce inaccurate detection. Then the pre-processing, feature extraction, and then classification was performed for the classification of Vata, Pitta, and Kapha. The best performance is measured in terms of sensitivity. Besides, the developed method can be used as a home-based health monitoring device.

Narang et al., [41]employed a Nadi pariksha technique for the detection of prashna, darshana, and sparshana. In this, the prakritis such as Vata, Pitta, and Kapha were determined using artificial neural networks (ANN). The acquisition of the Prakriti was employed through the optical sensors, in which a Velcro strap was utilized for wrapping the sensors in the wrist. The performance of the proposed method was evaluated based on accuracy. They failed to utilize the training data, which enhances the accuracy of the system further.

Kong *et al.,*[42] employed a Nadi pariksha technique based on the deep learning approach using Tactile Robotic Fingers. Here, the three different sensing fingers were utilized for the pulse acquisition and then the signal is pre-processed using the filter and then classification was done through the convolutional neural network (CNN). In addition in the introduced method, both the temporal and the spatial information were utilized for the detection of the signal and obtained better performance in terms of accuracy based on prediction and validation. The usage of the algorithm may enhance the detection accuracy further, which was not utilized by the developed method.

Basavaraj & Balaji[43] employed a Nadi yantra for the detection of the disease through pulse pressure. In this, machine learning is utilized for the detection of the pulse signal. The signal acquisition is employed through the sonic microphone sensor module. Then the most informative features were extracted for the classification of the signal based on the tridoshas. The k-nearest neighbour (KNN) classifier was utilized for the classification of the signal. The performance of the developed method was evaluated based on specificity, sensitivity, and accuracy. However, the developed device is not portable and cannot able to diagnose all diseases.

2.6.2 Based on Butterworth filter

A filtering technique known as Butterworth is used to achieve a smooth frequency response in the passing band of a signal. Maximally flat magnitude filter is another name for it. The Butterworth filter-based Nadi pariksha technique is utilized for the removal of noise from the gathered signal for the diagnosis of the disease. The noise-removed signal obtained from the Butterworth filter provides more accurate detection. Some of the

conventional techniques that utilize the Butterworth filter for the detection of the pulse signal are discussed in this section.

Chaudhari & Mudhalwadkar,[19]hasemployed a Nadi pariksha device for sensing the pressure pulses to diagnosedisease and is portable. In this, the photoelectric sensors have been utilized for the measurement of the pulse and were mounted on the belt to wrap it around the wrist. Here, the radial pulse signals such as Vata, Pitta, and Kapha were evaluated using the Butterworth filter. In addition, the parameters such as blood viscosity and volume were utilized for disease detection. The developed device is suitable to diagnose renal disease and was not suitable for monitoring other diseases.

Bawankar et al., [22] hasemployed a Nadi pariksha device based on the Internet of things (IoT) for the detection of the disease based on the tridosha. In the developed method, the authentication of the patient information is provided by the registration. After registering in the server, the sensor has been utilized for the detection of the pulse signals. Then, signal pre-processing has been employed for the redundancy removal and normalizing of the input signal. Then, the features were extracted for the classification of the signal under three classes of trridosha namely, Vata, Pitta, and Kapha.

Pavana*et al.,*[40]hasemployed a Nadi pariksha yantra based on the Butterworth filter. Here, the sensors were utilized for the acquisition of the signal and it works based on the photoplethysmography principle. The microcontroller was utilized for signal digitization. The signal detection was employed through the Butterworth filter and obtained better performance compared to the Bessel filter and the developed method removed the overshooting and the ringing effects. Besides, the periodicity of the signals was also retained by the developed method.

2.6.3 Other techniques

Some of the Nadi Pariksha techniques other than machine learning and the Butterworth filter are elaborated in this section.

Kalange*et al.,*[44]hasemployed a Nadi pariksha yantra for the collection of the pulse signal based on the personal computer (PC). In this, the ultrasonic pressure sensors were utilized for the pulse acquisition and Velcro tape is used for positioning the sensors in the wrist. The analysis of the developed method was employed based on the time domain, frequency domain, and relative amplitude. From the analysis based on amplitude, it detects only the pradhan dosha. The time and frequency analysis were employed for the enhancement of the correlation percentage, which failed to show a significant improvement.

Shashi et al., [1]hasemployed a pulse acquisition system, in which five steps were utilized for the classification of the doshas. Initially, the sensing of the signal is employed and then it is pre-amplified using the operational amplifier for the signal conditioning. Then, the signal processing was devised for the extraction of the most significant features for the detection of the signal variation and is interpreted with the traditional pulse detection technique. However, the developed method failed to interpret several parameters such as the reflection index,and stiffness index.

Bhasgaran et al.,[45]employed aNadi pariksha technique based on the biostatic method. In this, the Grove-Piezo vibration sensor was utilized for signal acquisition for the detection of the pulse pressure of the artery. Followed by the signal acquisition, pre-processing, feature exaction, and the detection was devised for the detection of the Vata, Pitta, and Kapha doshas. Here, the dhosa separation was employed based on the frequency range. Besides, it interprets that the suitable sensor selection provides the best accurate result.

2.7 Nadi Diagnosis

The diagnosis of the pulse or Nadi is utilized for the detection of the health conditions of patients in Ayurvedha as it is considered a non-invasive technique. In the Prakruti Nidana also termed as diagnosis, the three basic conditions of the Nadi such as Vata, Pitta, and Kapha of the patients are collected[5].In modern medicine, pulse measurement is devised using sensors of various kinds. There are several pulse diagnosis methods, one such Nadi diagnosis technique is the Nadi pranayama, which is detailed below.

2.7.1 Nadi shodhana pranayama

Pranayama is a combination of two words which are Prana and Ayama[46, 47]. Here prana means 'life force' or 'vital energy', which is the expansion of prana sakthi. The extra oxygen is introduced into the lungs through the breathing exercise for the proper functioning of the human body is the prana. The energy flow into the nadi or the energy channel is obtained through the pranayama. The expansion is the meaning of the ayama. Thus, pranayama means the expansion of the prana sakthi, which means the regulation or the activation of the vital energy above the limitations to regulate the breathing of the human body. The pranayama is performed through four different such as kumbhaka, rechaka, and pooraka, in which the kumbhaka is further categorized into Bahir and Antar. The retention of the external breath is termed Bahir and the retention of the internal breath is termed as Antar. The exhalation of the breath is referred to as Rechaka and the inhalation of the breath is referred to as Pooraka[48]. The faulty lifestyle affects Nadi and it can be improved through physical activities[49]. The stress in life and the irregularities based on the diet also affect the flow of prana. In addition, sexual behaviour, sleep, work,

food habit, and all activities affect the prana flow. All the above-mentioned issues are balanced and energize the pranic flow through the pranayama technique. The most important aspect that needs to be considered is: the pranayama should not be practised when the patient is affected by fever, flu, or cold [50].

2.7.2 Disease diagnosis

The disease diagnosis using the pulse is employed using the wrist pulse signal in modern medicine, using this, the pulse pressure, pulse wave velocity, blood pressure, the rhythm of the heart, and several other factors are detected[9, 14]. Based on the pulse variations several diseases can be diagnosed and treated. In addition, the imbalances of emotion [39] can be detected, which needs to be maintained for healthy condition. Some of the existing techniques utilized for disease diagnosis are detailed below.

Kumar *et al.,*[51] detailed the Hyperventilation Syndrome management through the Nadi Shodhana Pranayama. Hyperventilation Syndrome is a psychological disorder that makes breathing imbalance such as breathing too rapidly or too deeply. The Nadi Shodhana Pranayama is the breathing purification technique employed through three stages such as kumbhaka, rechaka, and pooraka. The intake of oxygen is termed as pooraka and the exhale is termed as rechaka, while the kumbhaka refers to the holding of breath. Thus, the Pranayama persists the carbon dioxide retention and slows the respiration, and enhances the capability to withstand. The daily practice of the Pranayama relaxes and controls the brain and mind and strengthens it.

Sinha*et al.,*[52] detailed the nasal dominance detection technique for the heart rate and pulmonary function study. Here, the finger pulse oximeter was utilized for the detection of the pulse rate and the oxygen saturation. In addition to this, left nasal dominant (LND) and right nasal dominant (RND) were acquired from the participants. Then, the pulmonary parameters were estimated and were helpful to detect chronic diseases such as cardiac dysfunctions, hyperthyroidism, migraine, and asthma.

Tanima*et al.,*[53] detailed the classification of the Physiological Characteristics using the pulse signals based on the radial arterial system. In this, the sensor was utilized for the acquisition of the pulse signal, which is interfaced with the microcontrollers. Then the signal pre-processing was done through the Butterworth filter for the removal of the unwanted noise and then the informative features were extracted for the detection of the stiffness of the artery using the Vata, Pitta, and Kapha pulse. Weight gain and obesity occur due to the increased amount of Kapha.

Ghorpode-Aher*et al.,*[54]employed an effect of Surya namaskar prediction using the Nadi tarangini based on the machine learning approach. In this, 12 different asanas were

performed, and then, the pulse acquisition was employed using the Nadi trangini device, a Nadi pariksha device for generating the Vata, Pitta, and Kapha doshas. Then the feed-forward neural network was utilized for the prediction of pulse after Surya namaskar. From the analysis based on the detected output, Surya namaskar benefits humans and balances three doshas.

Liu*et al.,*[55]employed a blood pressure (BP) estimation using the pressure pulse wave signals. Here, the piezoelectric sensors were utilized for the pulse acquisition, and then the signal pre-processing, and feature extraction were devised for the removal of noise and the extraction of the most informative features. Finally, the BP estimation was done using the regression model. The developed method obtained higher accuracy and failed to utilize the machine learning approach, which may enhance the accuracy using the training data.

3. Research Gap and Discussion

From the analysis based on the Nadi pariksha techniques, the selection of the sensor plays a major role in the accurate detection of the pulse signal. Several sensors such as Doppler sensors, Acoustic sensors, PVDF sensors, Infrared Sensors, Strain gauge sensor, Piezoelectric Sensor, Optical Sensor, Force Sensitive Resistor Sensor, and several others. However, the acoustic sensor is easily influenced by the vibration, for the small variation of temperature PVDF sensors get affected, the Doppler sensors are less accurate and the infrared sensors are utilized for the limited range of communication and control one device at a time. The piezoelectric sensors were widely used for the Nadi pariksha because it captures the dynamic pressure variation and converts it into electrical energy from mechanical energy [45]. It was utilized by existing researchersfor the pulse detection of Nadi tarangini[34, 35, 54]. In addition, the optical sensor was utilized byRoopini et al., [56], and Force Sensitive Resistor Sensor was utilized by Baisware & Joshi, [57] for the pulse acquisition based on the Nadi pariksha yantra and obtained better performance [58].

Analysis of the Nadi pariksha techniques based on machine learning, Butterworth filtering, and other techniques, several challenges are faced by the conventional Nadi pariksha techniques. Initially, the pre-processing is devised by many methods for the removal of noise from the input signal. Then, the feature extraction is made before the classification of the signal into tridoshas for the reduction of the computation complexity. Finally, classification is employed for the detection of the pulses. The method employed by [20] may have the capability of producing inaccurate results due to sensor misplacement, and the method utilized by Basavaraj & Balaji, [43] is not applicable to diagnose several diseases. The failure in classifier training [41] and the utilization of the algorithm [42] degrades the performance of the system. Besides, inaccurate detection [44],

failure to diagnose some diseases [1], and choosing inappropriate features degrade the performance of the system. A detailed analysis of the Nadi pariksha techniques is included in Table 1.

Table 1.: Analysis of Nadi Pariksha techniques

Reference	Method	Pulse Acquisition	Pre-processing	Feature Extraction	Classifier
[20]	Nadi Pariksha	Photoplethysmography based sensor	✓	✓	NN
[41]	Prakirthi Prediction	Optical Sensor	×	×	ANN
[43]	Prakruthi and vikruthi detection	sonic microphone sensor	✓	✓	KNN
[42]	Digitalizing arterial pulse patterns	Tactile sensor	✓	×	CNN
[19]	Nadi diagnosis	plethysmography sensor	×	✓	Butterworth Filter
[22]	Disease Prediction	N. R.	✓	✓	N. R.
[40]	Nadi Pariksha	Optical Sensor	×	✓	Butterworth Filter
[44]	Nadi Pariksha	Pressure sensors	×	×	Analyzed based an amplitude and frequency
[45]	Disease diagnosis	Pressure sensors	✓	✓	

N.R. : Not Reported

Thus, from the research gaps of Nadi Pariksha techniques, a novel technique needs to be developed with a more accurate result for the diagnosis of several diseases. Initially, the sensor needs to be selected more carefully, from the analysis the optical sensors are more reliable and provide more accurate results. Then, the most significant features need to be

extracted for the diagnosis of the disease more accurately. Finally, the classifier needs to be trained for obtaining the accurate result and it should be optimized with the optimization algorithm for the diagnosis of the disease more accurately.

4. Conclusion

This research analyzed several kinds of literature regarding the Nadi tantra practices and the analysis is detailed. The Nadi tantra practices were utilized for the acquisition of the pulse signals based on the tridoshas for disease diagnosis. The analysis regarding the characteristics of the dhosas, parameters utilized for measuring the dhosas along with the nadi locations isanalyzed. The pulse parameters are used for the detection of the Vikaras or diseases in the human body; hence the localization and the accuracy of detection are essential. In addition, the Nadi tantra techniques utilized in history and the modern pulse examination techniques are analyzed and detailed, in which several techniques utilized for the detection of the pulse based on machine learning, Butterworth filtering, and other methods are reviewed. Also, the Nadi diagnosis techniques for disease diagnosis are analyzed based on its application.Finally, the research gaps are analyzed for the future development of more accurate pulse detection techniques for disease diagnosis.

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