

# Non-Invasive Thyroid Risk Detection and Smart Drug Delivery System for Automated Hormonal Therapy

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**Abstract**— Thyroid diseases- affect everyone- one of the commonest endocrine disorders is thyroid disorder or thyroid disease. It is difficult to identify thyroid dysfunction early since diagnosis is confirmed following blood testing (which is not available for routine or mass screening). In this paper, a non invasive technique to Pre-screening of thyroid risk has been proposed using indirect physiological parameters such as pulse rate, respiratory rate, skin temperature and level of activity. Thyroid hormone imbalance can affect metabolism. It leads to observable changes in cardiovascular, respiratory and thermoregulatory functions. Through the employment of wearable sensor technology, the proposed system continuously monitors the parameters of interest and subject the achieved data to a rule-based decision logic as well as a multi-parameter scoring system. According to their deviations from normal metabolic ranges, people can then be assigned to the Normal, Low Risk, Moderate Risk, and High Risk groups. An LCD displays the extent of risk and relevant guidance, including recommendations for further clinical assessment when applicable. The system does not diagnose thyroid disease but an early warning tool to enable timeous consultation with a medical doctor. The suggested solution is portable, inexpensive, non-invasive, and user-friendly, making it ideal for implementation in community health camps, rural healthcare settings, and individual health monitoring. The purpose of this system is to create awareness at an early stage of metabolic imbalance and also promote safety and ethicality in medical practices.

**Keywords**— Thyroid disease screening, non-invasive monitoring, metabolic imbalance, pulse rate, respiratory rate, skin temperature, activity monitoring, rule-based classification, early risk assessment, biomedical sensors.

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## I. INTRODUCTION

Thyroid disease screening is non-invasive monitoring of metabolic imbalance by measuring pulse rate, respiratory rate, skin temperature and activity monitoring using rule-based classification of early risk assessment through biomedical sensors. Through the secretion of thyroid hormones, the thyroid gland regulates metabolism, heart rate as well as the rate of respiration. It also helps body temperature regulation and energy metabolism [1]. An imbalance in thyroid hormones, such as hypothyroidism and hyperthyroidism, can lead to serious physiological and metabolic disturbances when unrecognized. Identifying a thyroid dysfunction early on will prevent complications such as cardiovascular abnormalities, metabolic condition, low energy, and low quality of life [2]. None the less, traditional diagnostic methods rely heavily on laboratory blood tests such THYROID, STIMULATING HORMONE (TSH), TRIIODOTHYRONINE (T3), and THYROXINE (T4). Diagnosis accuracy is present with these methods of detection but they are invasive, expensive, and not suitable for repeated and large-scale screenings, especially in rural healthcare. Thyroid hormone imbalance drastically alters metabolic rate and thus indirectly changes physiological parameters like pulse rate, respiratory rate, body

temperature, and physical activity levels. Clinical studies have indicated that patients suffering from hyperthyroidism show an elevated heart rate, and correspondingly their metabolism is more active. On the other hand, those with hypothyroidism display a slower heart rate and a lower body temperature along with decreased physical activity [4]. Such physiological changes can be utilized for the non-invasive evaluation of thyroid, related metabolic disorder. Nowadays, the development of wearable sensor technology, along with advanced biomedical monitoring systems, has made it possible to continuously record vital signs such as heart rate, respiration rate, and skin temperature through non-invasive methods. These highly sophisticated systems may well revolutionize the process of early risk detection and health screening [5]. Still, the majority of current monitoring systems are designed around general health parameters, and hence, they do not have a specific feature for thyroid risk pre-screening. Considering the above, this paper presents a non-invasive thyroid risk pre-screening system that leverages indirect physiological parameters for the risk assessment. The system offers a neat rule, based logic and multi, parameter scoring technique to effectively categorize individuals based on their thyroid risk levels and also issue early warning signals. It is envisaged that the proposed

solution will foster early detection, raise awareness, and facilitate timely clinical referral, all the while retaining simplicity, affordability, and ethical medical practice.

## II. LITERATURE REVIEW

Early detection and treatment of thyroid diseases always pose a big challenge in the medical field due to their mild symptoms and thus dependence on invasive diagnostic methods. This review article analyses different methods for diagnosing a thyroid condition, monitoring physiological aspects and non-invasive health monitoring systems that can be used for thyroid risk evaluation.

**2.1 Existing Thyroid Diagnostic Techniques** Traditionally, the diagnosis of thyroid disease has been heavily reliant on laboratory investigations and imaging methods, which, although give precise results, are not suitable for frequent or large, scale screening.

### 2.1.1 Blood Test- Based Diagnosis

The diagnostic strategy most frequently utilized for identifying thyroid dysfunction is the biochemical examination of thyroid stimulating hormone (tsh), triiodothyronine (t3), and thyroxine (t4) levels in blood samples. These tests represent the diagnostic benchmarks for thyroid disease and find extensive application in the medical field [6]. None the less, blood testing is an invasive procedure, necessitates laboratory equipment and may not be readily available to rural or underprivileged areas. Moreover, repeated testing is not practical for continuous monitoring or early risk detection purposes.

### 2.1.2 Imaging, Based Thyroid Assessment

Typically, ultrasound imaging is used to evaluate the morphology of the thyroid gland, nodules, and structural abnormalities. Ultrasound examination gives an excellent insight into the anatomy of the thyroid gland but does not provide information on its functional or metabolic state, or on the level of hormones in the blood [7]. Besides, personnel with the necessary skills and specialized facilities are required for imaging procedure.

## 2.2 Physiological Effects of Thyroid Hormone Imbalance

Thyroid hormones play a crucial role in regulating metabolic rate and energy expenditure. Any deviation in hormone levels results in measurable changes in physiological parameters.

### 2.2.1 Cardiovascular and Respiratory Changes

Certain studies point to the fact that thyroid dysfunction significantly influences the cardiovascular and respiratory systems. One of the studies showed that hyperthyroidism causes an increase in the heart rate, cardiac output, and respiratory rate, while hypothyroidism leads to a very slow heartbeat and low respiratory activity [8]. The findings mean that heart rate and respiration rate might be very good

indirect markers of metabolic disorders associated with the thyroid.

### 2.2.2 Thermoregulation and Activity Level Variations

Thyroid hormones are instrumental in not only controlling the body temperature but also in defining the level of physical activities. In general, hyperthyroidism patients are very active and, besides, they suffer from heat intolerance. On the contrary, those with hypothyroidism get cold easily, are tired, and engage in lesser physical activities [9]. Hence, skin temperature coupled with an activity pattern, if measured, can provide hints about the state of metabolism and the functionality of the thyroid gland.

## 2.3 Wearable and Non-Invasive Physiological Monitoring Systems

Continuous and non-invasive monitoring of health, related physiological parameters has become feasible thanks to wearable sensor technology. Temperature and Activity Monitoring Systems Skin temperature sensors and accelerometer-based activity trackers have been integrated into wearable health devices to assess metabolic and physical activity patterns [11]. Such systems have demonstrated effectiveness in detecting physiological deviations related to metabolic disorders, although they are generally designed for general wellness rather than specific endocrine conditions.

## 2.4 Importance of Preventative Measures in Screening for Thyroid Disorders

While the field of medical diagnostics is progressing rapidly, preventative screening systems for thyroid disorders still constitute a gap in many health care facilities. Since the symptoms of a thyroid disorder are often so mild or non-specific that the condition gradually gets worse without the patient's knowledge, preventative monitoring plays a pivotal role in early diagnosis.

### 2.4.1 Vital Function of Thyroid Hormones in the Regulation of Metabolism

Thyroid hormones play an essential role in regulating metabolic rate. They function practically everywhere in the body, cardiovascular activity, respiration, body heat generation, and muscle work. Even a slight imbalance in hormone production can throw the whole body off track, which will first show as unexplained tiredness and then later chronic heart problems and metabolic diseases. The undetected thyroid dysfunction can even lead to acutely ill systemic states, which further confirms the importance of screening early on.

### 2.4.2 Potential Consequences of Late Diagnosis

It is a common problem that thyroid diseases are only discovered quite late when getting a blood test is the only

way to find out, and people are hardly ever getting checked for it. The longer it goes on without being detected, the more negative effects it has on metabolism, thus raising the likelihood of chronic complications, particularly in marginalized communities where the healthcare system is either not present or too expensive.

### 2.4.3 The Necessity of Periodic and Non-invasive Monitoring:

The traditional medical screening techniques lack the ability to offer a continuous wearable, type health assessing service. However, indirect physiological factors such as heartbeat, breathing rate, body temperature, and physical activity level that are monitored in real time provide a Consciousness of changing metabolic states toward thyroid dysfunction.

### 2.5 Proposed Non-Invasive Thyroid Risk Pre-Screening System:

The concept system consists of a microcontroller, based embedded platform, which is combined with non, invasive sensors. It keeps a check on pulse rate, respiratory rate, skin temperature, and activity level. Rule, based multi, parameter scoring methods help to analyze physiological data in order to categorize the subjects into Normal, Low Risk, Moderate Risk, and High Risk. In addition to the risk levels, users receive the clinical evaluation guidance on the LCD device. With comprehensive community and personal health monitoring, this system, due to its low cost, portability, scalability, and user, friendliness, is also suited for such uses.

## III. CHALLENGES

### 3.1 Variability in Physiological Parameters

#### 3.1.1 Individual Metabolic Differences

Physiological parameters including heart rate, respiratory rate and body temperature differ to a great extent among individuals. Such differences are mainly due to the inherent differences in the metabolism of individuals belonging to different age groups, gender, physical fitness, and lifestyle. These natural characteristics cause a major problem in trying to define a universal set of baseline values for thyroid risk assessment and, moreover, may deteriorate the accuracy of the pre-screening systems [7].

#### 3.1.2 Influence of External and Environmental Factors

External factors such as ambient temperature, emotional stress, physical activity, and circadian rhythm can cause variations of physiological measurements. Such temporary fluctuations may be completely unrelated to thyroid problems thus increasing the likelihood of false risk signals if proper measures are not taken [8].

### 3.2 Sensor Accuracy and Reliability

#### 3.2.1 Limitations of Non-Invasive Sensors

Non-invasive sensor devices for monitoring pulse, breathing, and skin temperature can be highly sensitive to unintended movement, incorrect positioning of the sensor,

and loose contact with the skin. Such vulnerabilities can cause the data recorded to be noisy and erroneous thus the reliability of thyroid risk assessment may be diminished [9].

#### 3.2.2 Calibration and Long-Term Stability

Continuous monitoring sensors have to be calibrated from time to time to make sure that they provide precise measurements. Sensor drift and gradual wear of sensor components can lead to fluctuating readings thus limiting the benefit of long, duration thyroid risk monitoring systems [10].

### 3.3 Data Interpretation and Decision Logic

#### 3.3.1 Threshold Selection and Risk Classification

Individual differences being very significant can make it very challenging to find a suitable threshold value for physiological parameters. The misidentification of the threshold will make the system result in false positives or false negatives, reducing the sensitivity and specificity of the risk pre-screening system [11].

#### 3.3.2 Limitations of Rule, Based Analysis

Although rule, based decision logic provides simplicity and transparency, it cannot always capture complex physiological interactions in all individuals. The design and validation of the system should be done carefully to ensure that the risk classification is accurate and clinically meaningful.

### 3.4 Ethical and Clinical Limitations

#### 3.4.1 Non-Diagnostic Nature of the System

First, the system is a tool that pre-screens the risk of thyroid issues only and it is our intention to reiterate that it cannot replace a clinical diagnosis. The users should be made aware that an abnormal risk indication on their part would entail them getting a medical check, up and laboratory testing for the confirmation of the thyroid dysfunction.

#### 3.4.2 Data Privacy and User Awareness

Collection of physiological data impinges on the issues of data privacy and ethical use of data. Obtaining informed consent, secure management of data, and interpreting the results responsibly are requirements for the implementation of such screening systems in the real world.

## IV. EXISTING SOLUTIONS AND THEIR LIMITATIONS

Many techniques have been invented for the detection and diagnosis of thyroid disorders. Although these methods have helped in providing very accurate clinical information, they have been found to have drawbacks in terms of how invasive they are, how accessible and costly they are, and how appropriate they are for early or large, scale screening of people.

### 4.1 Conventional Thyroid Diagnostic Methods

Detection of thyroid disorders by conventional means is dependent on laboratory tests and imaging methods which are the most frequently used ones in clinical settings.

### 4.1.1 Blood Test, Based Diagnosis

Blood tests that measure the level of THYROID, STIMULATING HORMONE (TSH), TRIIODOTHYRONINE (T3), and THYROXINE (T4) are still the most reliable way of diagnosing thyroid disorders. These diagnostic tests, despite their high level of accuracy, are invasive and cannot be used for continuous or frequent screening as they require laboratory facilities. Besides, in the cases of rural or resource, poor healthcare settings, people might still find it challenging to have access to laboratory testing [6], [7].

### 4.1.2 Imaging and Clinical Examination

Ultrasound imaging and physical examination are the two mainstream methods that are used to check and assess the thyroid gland for the presence of nodules and enlargement. Imaging helps to give anatomical information only, whereas it does not show directly the metabolic or the hormone, disruptive imbalance. Besides, the use of imaging procedures is dependent on having special devices and well, trained staff, thus, it is not very easy to apply them in a regular screening or self, health monitoring situation [8].

### 4.2 Wearable and Technology, Based Health Monitoring Systems

Recent progress in wearable devices has made it possible to non, invasively monitor a variety of physiological parameters that are closely linked to metabolic health.

#### 4.2.1 General Health Monitoring Wearables

Wearable gadgets which can measure heart rate, physical activity, and body temperature have become very popular for fitness and wellness purposes. Even though these devices can generate ongoing data, they are principally meant for general health monitoring and do not have features for specific thyroid risk assessment [9].

#### 4.2.2 Sensor, Based Physiological Monitoring Systems

Numerous sensor, based devices have been introduced to monitor single physiological parameters like heart rate or breathing rate. Nonetheless, most of the existing devices are geared towards single, parameter tracking and do not combine multiple physiological signs to check the overall metabolic disorder that accompanies thyroid malfunction [10].

### 4.3 Limitations in Automation and Decision, Making

Even with the aid of advanced technology, a lot of the present, day methods still fall short when it comes to offering effective automation and decision support features.

#### 4.3.1 Lack of Integrated Risk Classification

The majority of the present technological solutions merely provide raw physiological data and do not process it into understandable risk categories. The inexistence of automated risk classification renders it challenging for users to comprehend the outcomes and seek medical help in time

for preventive measures even without having any medical knowledge [11].

#### 4.3.2 Dependency on Complex Algorithms

Some of the most advanced health risk prediction systems use machine learning to accurately predict health risks. However, such methods generally require extensive datasets, higher computational resources, and complex model training, thus raising system costs and reducing transparency. These factors make it difficult to deploy such systems practically for low, cost and community, level screening [12].

#### 4.4 Cost, Accessibility, and Scalability Challenges

Most high, end diagnostic and advanced monitoring equipment are not only costly but also dependent on a certain kind of infrastructure. This gives rise to their unavailability to the small and rural clinics as well as the large, scale community screening. Clearly, there is a demand for the development of affordable, scalable, and user, friendly solutions that would provide early indications of the risk of thyroid without substituting clinical diagnosis [13].

## V. DESIGN AND ARCHITECTURE

The indirect physiological parameters associated with metabolic activity that were to be changed by the thyroid are monitored by the non-invasive thyroid risk pre-screening system. The system provides a preliminary indication of a possible thyroid problem.

Several preliminary health assessment studies have already employed such indirect monitoring methods for various health parameters. The main reasons being they are non-invasive and hence suitable for continuous observation [15]. The system architecture re-centers on a low number of components, low cost, and serviceability. Moreover, the system is user, friendly and portable so that it can be used for health screening at the community level, rural healthcare, and even for health monitoring at home.

The system implements a modular and scalable design approach and non, invasive sensors for measuring pulse rate, respiratory rate and skin temperature are integrated with a microcontroller, based processing unit.

It is reported that changes in these physiological parameters reflect thyroid hormone imbalance, induced metabolic changes [16].

Collected data is continuously analyzed by means of a rule based multi parameter scoring logic. In this logic real time values are compared with predefined baseline ranges to detect abnormal metabolic patterns.

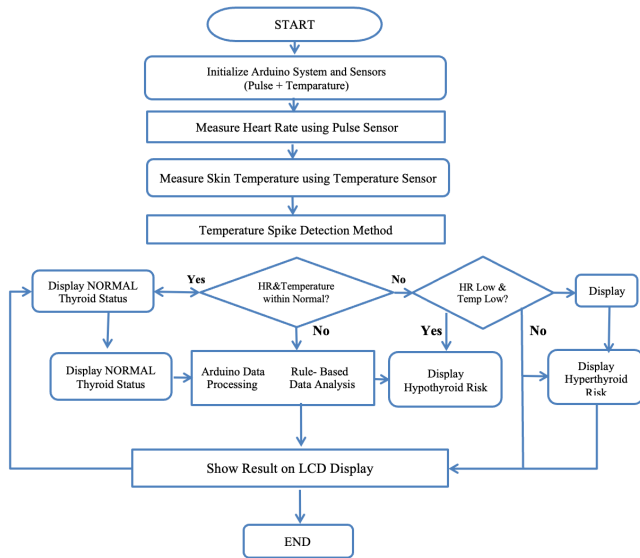
According to the sum of the deviation of multiple parameters, different thyroid risk levels can be assigned to the user, e.g., Normal, Hyper or Hypo Thyroid.

The risk level that has been assessed is shown on an LCD together with the appropriate instructions, e.g., if clinical evaluation is necessary, the patient should be given guidance to do so.

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The architecture provides real, time monitoring, transparent decision, making, and ethical medical practice while keeping low cost and system complexity at a minimum [17].

## 5.1 Block Diagram



## 5.2 Key Features

### 5.2.1 Non-Invasive Physiological Monitoring

The system uses non, invasive sensors for physiological parameter monitoring without user discomfort or risk to the skin. Monitoring of heart rate, respiratory rate, skin temperature, and activity level at intervals allows estimating indirectly the metabolic changes due to thyroid hormone imbalance.

### 5.2.2 Rule, Based Risk Assessment Logic

The system utilizes a rule, based decision logic to determine the degree of deviation of physiological parameters from baseline values of healthy individuals. Each parameter is part of a multi, parameter scoring system which decides the level of thyroid risk overall. This method offers better interpretability, clarity, and simplicity than complicated black, box models.

### 5.2.3 Real, Time Processing and User Feedback

The microcontroller is capable of real, time processing of sensor signals and the risk level classification is also updated continuously. The thyroid risk level computed is shown on an LCD display, thus, the user gets instant feedback and, if the risk level is high, a recommendation for clinical evaluation is also given.

### 5.2.4 Portable, Low, Cost, and Scalable Design

The system is based on an affordable single, board computer plus other low, cost components, hence it is a cost, effective and extendable solution. A normally sized and portable unit can serve different scenarios such as community health camps, primary healthcare units in rural areas, or individual health monitoring without the need for any special infrastructure.

### 5.2.5 Ethical and Safe Medical Use

The system is strictly built only as a tool for pre, screening and raising awareness and it does not substitute a doctor's clinical diagnosis. Users are given comprehensive instructions to ensure the proper use of the results and to foster seeking medical advice if the need arises.

## VI. IMPLEMENTATION AND SYSTEM CONFIGURATION

### 6.1 Installation of Physiological Sensors

Various non, invasive physiological sensors are delicately integrated into the system to track a few indirect markers of metabolism related to thyroid function. Among these are a pulse rate sensor, respiratory rate sensor, skin temperature sensor, and an activity monitoring sensor. The sensors are arranged in such a way as to satisfy user convenience and at the same time allow accurate data acquisition in real, time [21].

### 6.2 Real, Time Data Collection and Monitoring

The physiological sensors nonstop relay both analog and digital signals to the central processing unit. These signals represent real, time variations in heart rate, breathing rate and body temperature. Continuous monitoring allows detecting metabolic fluctuations that are dynamic and associated with the imbalance of thyroid hormones [22].

### 6.3 Multi Parameter Analysis and Risk Evaluation

The microcontroller runs a rule based multi parameter scoring algorithm which is previously programmed in it to analyze the physiological data collected. Each measured parameter is checked against the predefined normal baseline thresholds. Changes from the normal ranges are given weighted scores, and the total score is utilized to determine the thyroid risk level of the user [23].

### 6.4 Risk Classification and Guidance Generation

The system assigns the user to one of the thyroid risk categories that have been defined beforehand, such as Normal, Low Risk, Moderate Risk, or High Risk according to the risk score calculated. In cases of moderate or high risk, the system produces recommendations that advise the user to visit a doctor and get a blood test for thyroid function, thus facilitating timely medical intervention relying on the user care [24].

### 6.5 Visual and Alert System Activation

The assessed thyroid risk level along with the corresponding system status are shown live on an LCD screen. Furthermore, if the risk levels get raised, optional audible alerts can be set to go off thereby supplying instant feedback to the user and also raising their awareness of possible metabolic abnormalities [22].

## SYSTEM CONFIGURATION:

The proposed thyroid risk pre-screening tool is basically a small and low power system that is primarily aiming at real, time human health monitoring to facilitate fast metabolic Condition detection. The system is a microcontroller, based embedded platform which is continuously running to support

## Non-Invasive Thyroid Risk Detection and Smart Drug Delivery System for Automated Hormonal Therapy

sensor data acquisition, rule, based analysis functions, and output control [21].

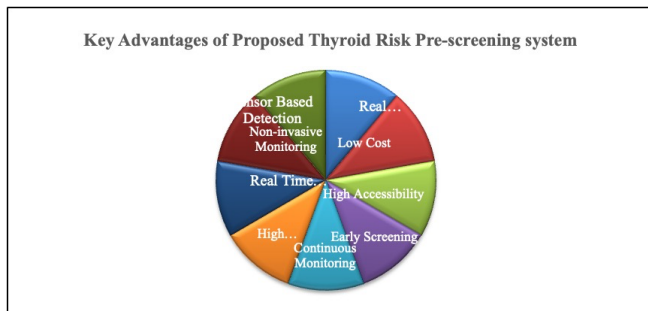
Physiological sensors for pulse rate, respiratory rate and skin temperature which do not require invasive methods, are directly connected to the microcontroller by suitable analog and digital input channels. The selection of these sensors is based on their high sensitivity and low power consumption as they are expected to deliver accurate and reliable physiological measurements [22].

Real, time physiological values and thyroid risk categorization results are presented on a 162, character LCD display module. If the elevated risk level condition is detected, the Lcd can provide an visible alert. For more functionalities, the system can be equipped with wireless communication modules such as Bluetooth or Wi, Fi for data logging, remote monitoring, or mobile health applications [23], [25].

The microcontroller has been programmed using Embedded C through Arduino IDE, thus ensuring the most efficient execution of the risk assessment algorithm and a very responsive system performance. The power is supplied by a regulated DC source to guarantee stable operation of all system components. The simple, cheap, and highly scalable system design makes it suitable for use at community health camps, rural healthcare centers, and for personal health monitoring [24], [25].

## VII. RESULTS AND DISCUSSIONS

### 7.1 Performance Comparison:



Pie Chart.1..proposed non-invasive thyroid risk pre-screening system

The pie chart.1. illustrates the key advantages of the proposed non-invasive thyroid risk pre-screening system, highlighting its effectiveness and practicality in healthcare applications. A significant portion emphasizes sensor-based detection and non-invasive monitoring, indicating that the system can assess thyroid risk without the need for invasive procedures, thereby improving patient comfort and compliance. Another major advantage is real-time monitoring and response, which enables continuous tracking of physiological parameters and immediate analysis for early detection of abnormalities. The system is also characterized by low cost and high accessibility, making it suitable for widespread use, especially in resource-limited settings. Features such as early screening and continuous

monitoring ensure timely diagnosis and long-term health tracking, reducing the risk of severe thyroid conditions. Additionally, high automation minimizes the need for manual intervention, enhancing efficiency and reliability. Overall, the chart demonstrates that the proposed system is a cost-effective, accessible, and technologically advanced solution for early thyroid risk detection and proactive healthcare management.

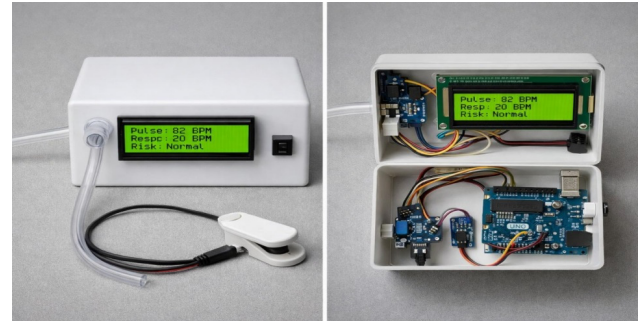


Figure.2. prototype of a non-invasive thyroid risk detection device

The Figure.2. presents the prototype of a non-invasive thyroid risk detection device, shown in both its external and internal configurations. On the left side, the fully assembled unit is displayed with a compact enclosure, featuring a digital LCD screen that shows real-time parameters such as pulse rate, respiratory rate (RPM), and risk status (e.g., “Normal”). A finger clip sensor is connected to the device, indicating the use of optical or physiological sensing for data acquisition. This setup highlights the system’s portability, ease of use, and suitability for home-based health monitoring.

On the right side, the internal hardware components are visible, revealing the core electronics of the system. It includes a microcontroller board (such as an Arduino), sensor modules, connecting wires, and a display interface. These components work together to collect physiological signals, process the data, and generate a risk assessment output in real time. The integration of sensors with embedded processing enables continuous monitoring and immediate feedback. Overall, the figure demonstrates a practical implementation of a low-cost, user-friendly, and non-invasive healthcare device designed for early thyroid risk screening and real-time physiological monitoring.

## VIII. CONCLUSIONS

The preventive healthcare measure described in this article is based on diagnosing thyroid and metabolic disorders early through non, invasive physiological monitoring and rule, based analysis. The system, by continuously monitoring indirect indicators like pulse rate, respiratory rate, skin temperature, and activity level, can detect abnormal metabolic patterns in real time; thus it

identifies potential thyroid risks even before they become serious clinical conditions. The multi, parameter evaluation method enables early warning production by recognizing subtle physiological changes associated with thyroid hormone imbalance. By employing continuous monitoring and real, time data analysis, this platform is capable of giving timely feedback and automated risk classification without the need for invasive tests. This instant assessment is useful for planning healthcare in advance and it also encourages the patient to consult a doctor when the risk level is high. The neat and straightforward rule, based logic not only guarantees reliable decisions but it is also very understandable. Moreover, a small and inexpensive device can be a great choice for community health camps, rural healthcare centers, and personal health monitoring. The proposed method leads to an increase in the availability of healthcare, early diagnosis is made easier, and the use of preventive healthcare is supported. By integrating non, invasive sensing with real, time monitoring, the system is a great tool to help people become aware of the risk of thyroid and thus they can manage their health better, which means that such a system should not be considered a replacement for traditional medical diagnosis.

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