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Design of Wearable Cardiac Monitor for Morbidly Obese Person Using Embedded Controller and Internet of Things

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Abstract: Morbid obesity is a class III disease and a complex chronic disease spread across the globe over several years. In 1963 a pair of healthcare providers named "Payne and Dewind" introduced the term morbid obesity, in order to claim insurance for the cost of bariatric surgery to reduce the body weight of people with a BMI over 40 until then it was un noticed by the society. Over the few decades, they cooked up this term, and they could label it extreme obesity. It's the kind where serious health risks are associated with it, but it also makes people eligible for medical procedures to help them lose weight and improve their health. It was explicit about how severe the condition is and the importance of using medicine to manage it. Your body uses every single calorie you consume to power itself when you eat. Even when you're not moving, your heart needs calories to pump, and digesting food also requires them. Your body will start storing fat if these calories aren't used. At rest or during any physical activity, if the amount of food eating is greater than the amount of energy use, body will create fat reserves. If this happens too often, obesity and morbid obesity will result. Weight gain is sometimes caused by certain medications such as antidepressants. Medical conditions like hypothyroidism can also cause it, but they generally don't lead to obesity if they are managed effectively. Body stores fat when eat more calories (energy) than it needs for daily activities like breathing and moving around. This extra energy gets stored as fat, leading to weight gain. It's all about the balance between how much you eat and how much your body uses. The causes of the overweight can be various circumstances, like lack of physical activity, an imbalanced diet, health conditions, medicines, emotional issues, stress, and genetics. There is several kind of instruments fabricated over the five decades, but still no comprehensive devices or instruments takes lead role to find and solve morbid obesity issues. The proposed research analyzes the key factors influencing morbid obesity, diagnostic methodologies using state of art sensors like FSR,SPO2, heart functional characteristics and ECG to find out biological reasoning behind this issue. The research emphasis on-line measurements of all vital signals and transmits over to a medical centre using Internet of Things (IoT) for professional approach and remedial measures to solve the morbid obesity to the maximum possible extent.

I. INTRODUCTION

Eating more and working less leads always to obesity because not burning the energy intake and surplus energy stays in the body as fat. This intern creates more health risks by many forms at different ages. The major reasons behind obesity are Alcohol , more processed food intake, intake of more sugary drinks ,eating more than the required, less physical activity ,genetic and other medical conditions.
When obesity is uncared for longer duration that become morbid obesity but the reason behind this is still not understood. The symptoms of morbid obesity in a longer way are sweating, tiredness, back pain, difficulty in breathing ,sleeping disorders like snoring, difficulty in physical activity, lack of confidence etc,. The morbid obesity leads to severe health risk like metabolic syndrome, sleeping disorder, diabetes, lipid abnormalities in blood, osteoarthritis, stroke, gallstone and other disease.

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As per Centers or decease control and Prevention (CDC) the definition of Body Mass Index (BMI) is a person's weight in kilograms divided by the square of height in meters or feet. As per standards and mentioned in the figure (1 and 1a) , BMI of 18 – 25 considered as normal,25 – 30 over weighted, 30 – 39 obese and 40 and above are morbidly obese.

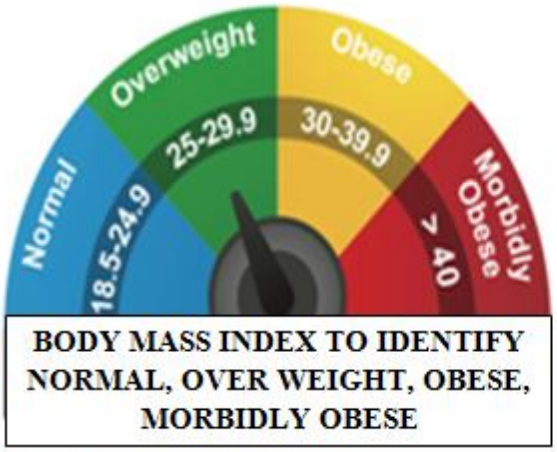

Figure 1 BMI index Identification

Figure 1a BMI index Identification by look

A body mass index (BMI) greater than 40 is considered morbidly obese in most cases. The body weight and size can be determined by our Body Mass Index, which is used to assess our body fat deposition. The ideal weight range for a person of a certain height can be determined in part by their BMI, which is not a perfect assessment. The calories consumed while eating help the body function, human body needs energy to digest food and pump heartbeat, even when at rest. If the body doesn't use those calories, it stores them as fat. Keep on consuming more calories than can burn off through exercise, routine life and daily activity, the body will begin to store them as fat. It leads to obesity and if not cared become the possibility to create morbid obesity.

In clinical practices some medications likeantidepressants,hypothyroidism have the possibility of obesity, if it is noticed in time and manage the parameters within the limit will not lead to obesity or morbid obesity. Many researches exposed that genetic factors could be a remarkable reason for obesity related issues. The BMI for adults shows in figure 2 height in term of feet versus weight interns of kilogram, similarly centimeters versus pounds are clearly indicated to find out the person is underweight ,healthy, overweight, obese or morbid obese

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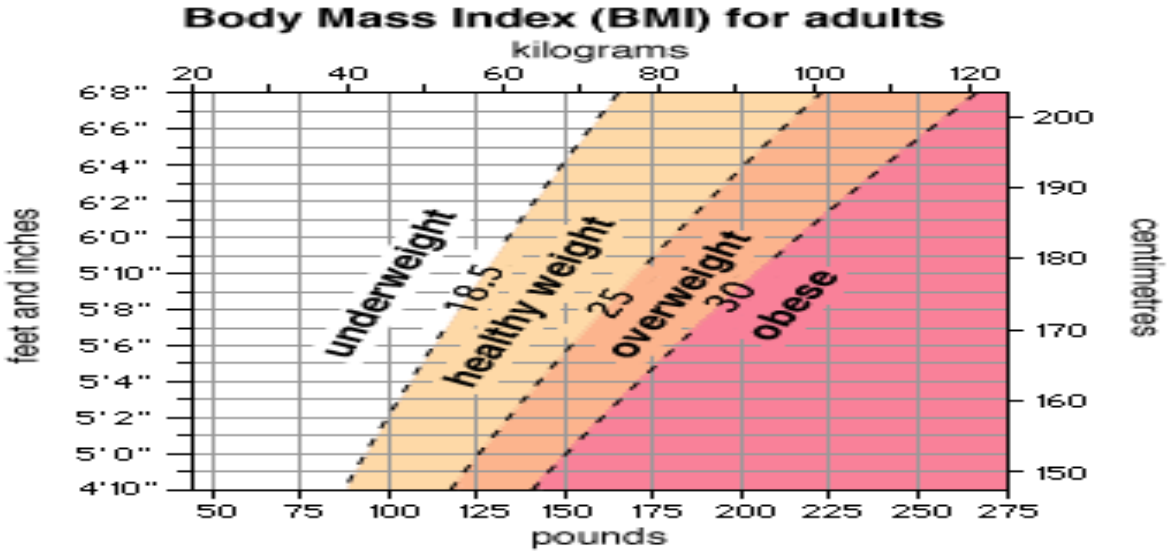

Figure 2 BMI index Identification based on kilogram,pounds,feet and centimeters

In USA as per the data of the year 2017 – 18 (Figure 3) nearly 30.7% are overweight, 34 % Men, 27.5% Women are over weight,43% of adults are in severe obesity and 9% adults are in severe morbid obesity. The men obesity(34%) is greater than women(27.7%) , at the same time severe obesity factor for women (11.5%) is higher than men(6.9%) as mentioned t=in the graph figure no 3.

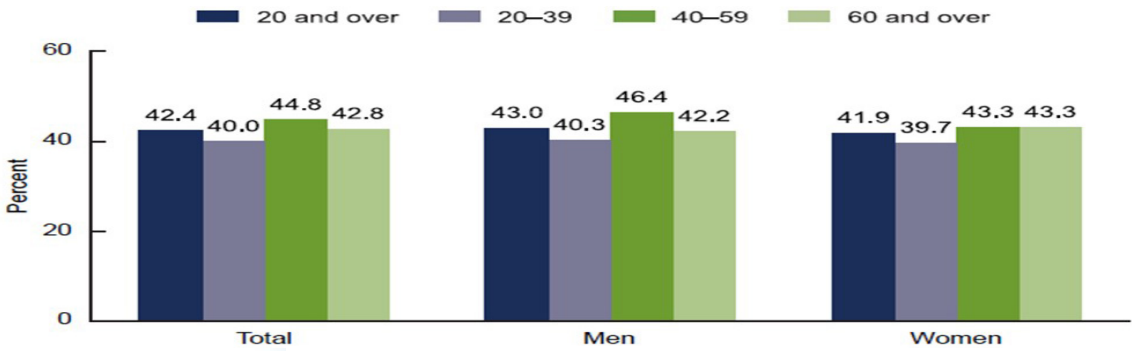

Figure 3 USA age and sex wise obesity percentage

The survey taken to control the obesity and morbid obesity United states conducted by their Centre for disease control from 1999 to 2017 are plotted in figure 4 both obesity and morbid obesity patients are increased year wise from 30.5 – 42.4% (11.9% increased over 17 years)as obesity. In real case there is a marginal increase of 39.66% compared with the early years in general obesity conditions. The graph shows 4.7–9.2% (4.5% increased over 17 years) as severe obesity,In real case there is a marginal increase of 95% compared with the early years in severe obesity conditions.

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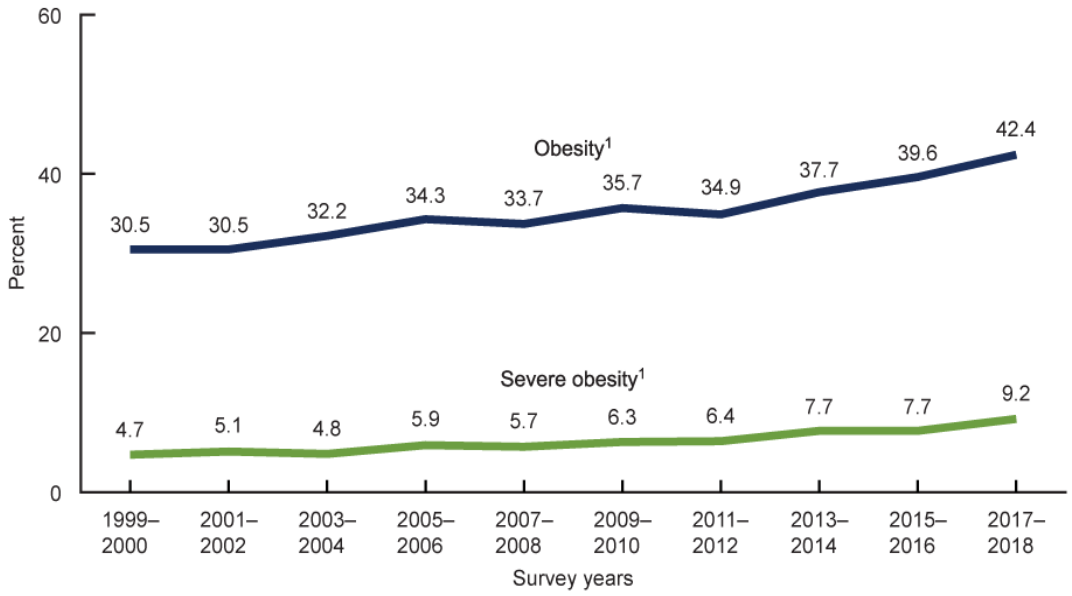

Figure 4 Obesity Survey from 1999 – 2018 by CDC USA

The above data (Figure 4) alert worldwide and more steps have been taken to educate people for a systematic food and life style but all the government fails in this because of modernization and anthropology changes in the world. These situation makes the thing more worsen and people fall on obesity and morbid obesity rates are increasing dynamically everyday in the world. To keep the obesity rate in present level or decreasing from today rate is absolutely based on the food , work culture and sleeping nature with calm mind.

Obesity or morbid obesity,based on the magnitude of obesity the vital parameter values will be changed from the normal person and deviates time to time with more uncertainty. The heartbeat, ECG value, body tightness and $SPO_2$are the essential factors determines the obesity issues will change as per the magnitude of the obesity.

Obesity may create or raise the risk of an elevated resting heart rate issue associated with more cardiovascular health problems , possibility of other factors can also influence a role like body heat, stress level due to obesity and some medications. A high RHR is one of several indicators that cardiovascular system is under stress, which can lead to heart problems.

A 2018 study suggests that people with obesity aren't just more likely to have an elevated heart rate, but they are at a higher risk of developing a potentially dangerous heart rhythm problem called atrial fibrillation (AFIB). AFIB is a major risk factor for blood clot formation and stroke.A 2021 studyTrusted Source suggests that healthy people with obesity (those without any major medical conditions and who didn't drink excessively or smoke) who had an elevated RHR also faced higher risks of inflammation and heart disease risk factors, including high blood pressure and high cholesterol.A 2016 studyTrusted Source also notes that being overweight raises the risk of pre-

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diabetes and type 2 diabetes, and that having an elevated RHR increases the risk of those blood glucose (sugar) disorders.

ECG of normal (table 1)and morbid obese patients differs on all waves with respect to time, ECG value of normal men, women values are presented below. In case of morbidly obese persons vary based on the magnitude of the issue and their physical activities.

MEASURING	MEN	WOMEN
HEART RATE	49 – 100 BPM	55 – 108 BPM
P WAVE LENGTH	81 – 130 ms	84 – 130 ms
PR INTERVAL	119 – 210 ms	120 – 202 ms
QRS DURATION	74 – 110ms	78 – 88 ms

Table 1. ECG Values of Normal Person

The key parameter to be observed of a morbid persons are body or skin tightness, Excess weight puts more strain on joints and on the cartilage that protects the ends of bones, causing pain and stiffness. More body fat also triggers more inflammation. Just losing 5% of your body weight will take pressure off of your hips, lower back, and knees. The body tightness resulting sleeping apnea and some complex cardio vascular disorder.

Normal level of oxygen level of common persons is usually 95% or higher. People with chronic lung disease or sleep apnea issue can have normal levels around 90% or less. For morbidly obese persons the values are always lower with high risk related to the lungs functions. It is essential to measure and keep this parameter is more important and less life threat will be assured.

To overcome the all above, the real time data related to the health on obesity aspects have to be acquired using appropriate sensors , processed, computed, analyzed and communicated to a health professional opinion is inevitable and carried out in this proposed research. A detailedmodule description and its significant role in this research is emphasized with appropriate diagrams below in the proposed system.

II. PROPOSED SYSTEM

The proposed system emphasis all the obese or morbid obese patients issues and approaching scientifically to solve or postpone the issues for wellness of the patient concern. Once the data abnormalities are found, remedial measures can be prescribed to them about their life and food style for wellness for long.

The proposed research consists of five modules namely A. Data Collection system from patients using relevant sensors, B. Electronic signal conditioning or processing circuits to convert sensor data in to analog form acceptable by ADC (0 – 5V for the minimum to maximum parameter changes). C.Embedded Micro controller to convert analog data in to digital data , then digital to serial using internal USART and final serial in to RS232 standards to transmit this signals to computer through Zigbee or RF wireless or IoT. D. The fourth module of the proposed system is data manipulation to achieve presentable and understandable data called USER INTERFACE for visualizing the magnitude of the issue in a numerical as well as graphical representation. E. The fifth or communication module is a essential module in this research to transmit the finally processed data sent to medical

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professionals for a expert opinion for the present situation and future projections.

The proposed system Block diagram (Figure 5) shows a systematic approach of the various issues a,b). SPO_2 , Heart Beat sensors have to be placed like figure (7 c) ,the patient finger can be kept between emitter and detector and single sided sensors also available in the market. Body tightness can be measured using a precision Force Sensible Resistor (FSR) by fixing it close to the chest as mentioned in figure (7 d).

All the sensors will be powered by the device designed using a voltage regulators to avoid fluctuations in values, repeatability, with higher discussed in this context with accurate solution. For ECG data acquiring AgCl electrode have been employed and connected to the patient at appropriate places mentioned in (figure 7 degree of accuracy. Except ECG all other measurements are made through passive transducers, so power supply plays the key role in all reliability matters. High attention given on designing the power source to eliminate RFI,EMI and Harmonics for a reliable failure free work execution.

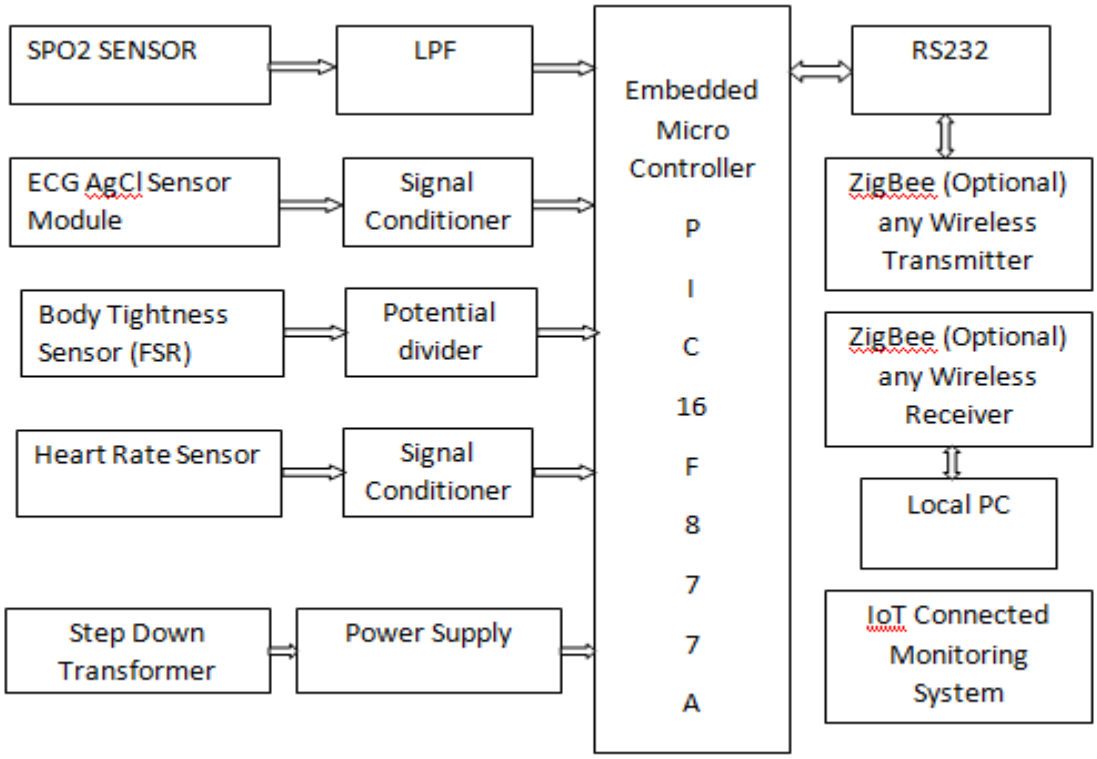

Figure 5 Proposed Detailed Block Diagram

III. ECG SIGNAL CONDITIONER

This is a very sensitive stage. Inputs to this stage are going to be from the sensors attached to the patient. There are some very critical requirements that must be met for this stage. The requirements and the reasoning behind those requirements are given below.The amplitude of the ECG signal is

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approximately 25 – 100 µV.Frequency of the normal ECG signal is approximately 5 Hz and thus the Hz.When two electrodes are placed at widely separated location on our skin, out epidermis acts like a crude battery, generating a continuously shifting potential difference that can exceed two volts. Moreover, body and wires in the device make wonderful antennas, which readily pick up the 60 Hz hum that emanates from every power cable in your home.

amplifier should have a frequency response from 0.1 -100

This adds a sinusoidal voltage that further swamps the tiny pulses from your heart. And because these oscillations lie so close to the frequency range needed to track you heart's action, this unwanted signal is hard to filter out. Thus, to make sure that these signals don't add to our ECG signal, we need to use an instrumentation amplifier with Common Mode Rejection Ratio (CMRR) of more than 100 decibels as per circuit diagram Figure 6.

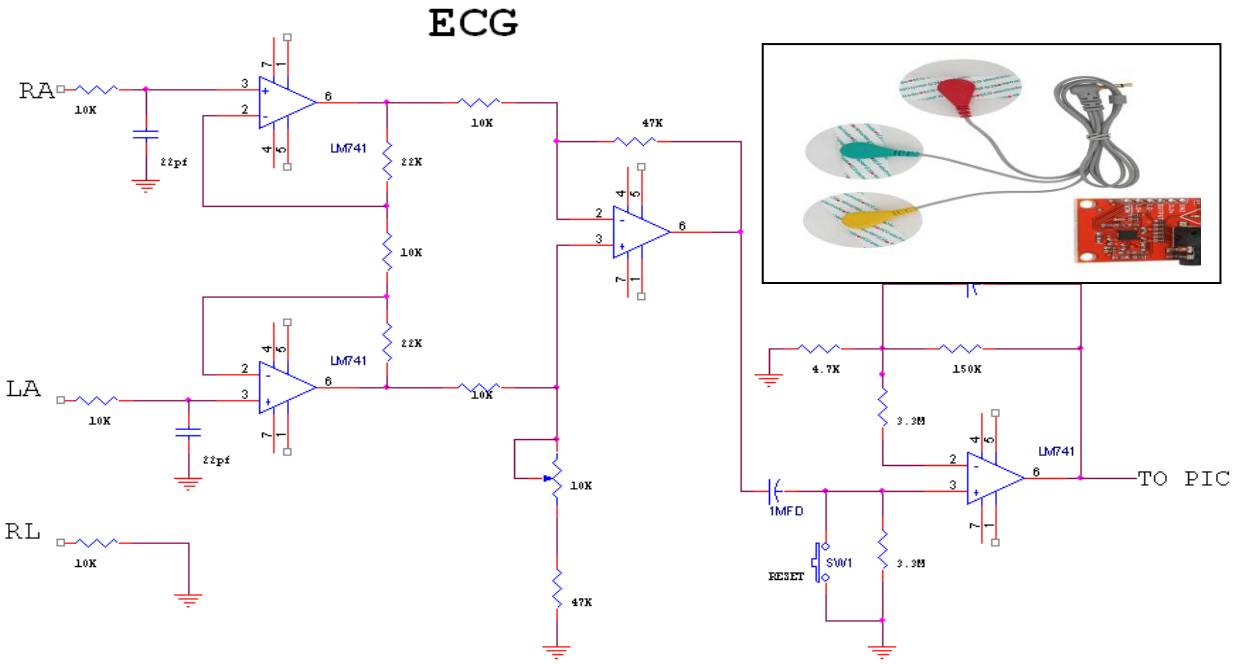

Figure 6 ECG circuit Diagramand module

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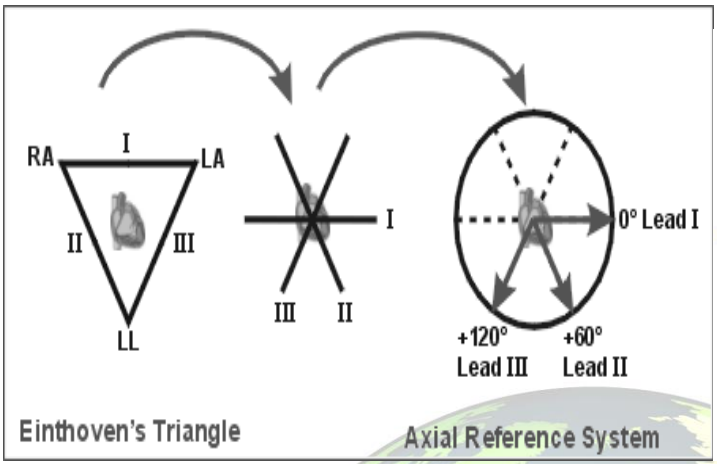

Figure 7a ECG Positioning

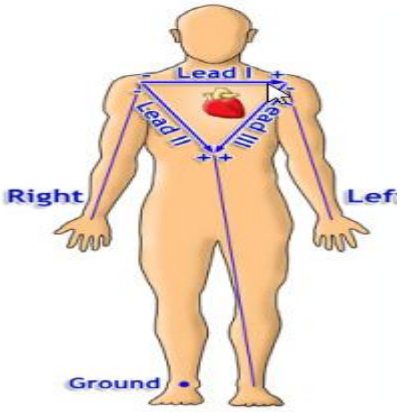

Figure 7b ECG Electrode Positioning

Working of a Heartbeat Sensor

The heartbeat sensor Generally consists of a light-emitting diode or infrared and a detector like a photodiode (Figure 8). The heartbeat pulses cause a variation in the flow of blood to different regions of the body as per the anatomical functions. When tissue is illuminated with the light , i.e. light emitted by the LED light source, it either produce reflection (a finger tissue) or transmits the light (earlobe)based on the application. During this phenomena some amount of light can be observed by the blood and the transmitted or the reflected light is received by the light detector. The amount of light absorbed depends on the blood volume in that tissue. The detector output is in the form of the linear electrical signal and is proportional to the heartbeat rate of the person undergo the diagnostics.

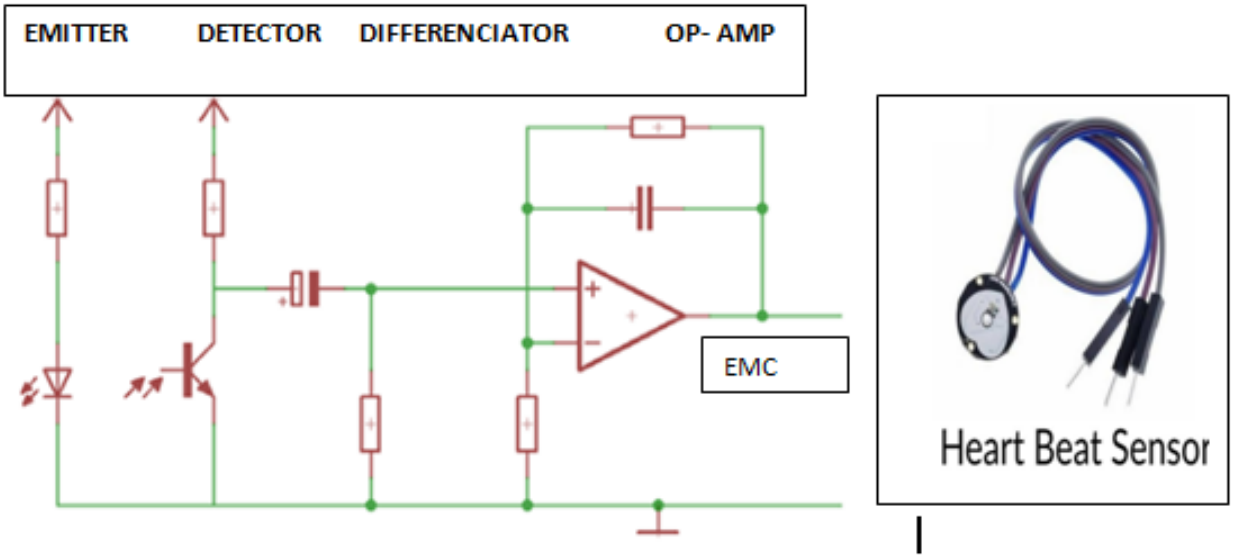

Figure 8 Heart Beat circuit Diagram and sensor model

The signals are DC in nature related to the tissues and the blood volume at the same time,AC component synchronous with the heartbeat system and caused by pulsatile changes in arterial blood volume may be superimposed on the DC signal. It is essential to remove or isolate AC components from this circuit is

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essential for a better performance. The final output will be fed to an Op-Amp to filter and support to ADC available in the Embedded Micro Controller to calculate the BPM using software loaded .BPM(Beats per minute) = 60*f, where f is the pulse frequency. Heart rate or heart beat is the critical parameter for morbidly obese person and must be maintained well within the limit for wellness of the patient. In most cases these values will not be in control for the person with health disability apart from morbid obesity, a separate medical method have to be imposed to recover them without much workout.

SPO2

It's a measurement of how much oxygen of a person blood is carrying as a percentage of the maximum it could carry, for a good and healthy person 96 – 99% will be the value of spo2.Oxygen saturation is an important , essential element in the management and understanding of patient care system. For morbidly obese or general persons the Oxygen is closely regulated within the body because hypoxemia can lead to many acute adverse effects on individual organ systems. These include the brain, heart, and kidneys and other functions rapidly.

Obesity or morbid obesity is a powerful independent contributor of a low and very low SPO2,which affects more clinical trials in most of the cases. The table below (Table 2)shows various conditions, age and SPO2 level

Conditions	By Age	SpO2 percentage
Normal	**Adults & Children**	**95% to 100%**
Normal	>70 years old	about 95%
Brain is affected	Adults & Children	80% to 85%
Cyanosis	Adults & Children	Below 67%

Table 2. Various levels of SPO2

The below mentioned arrangements (7c) are the most common clinical practice and a real time model available in the commercial market. The same method can also be used for obese person also to measure and monitor SPO2.

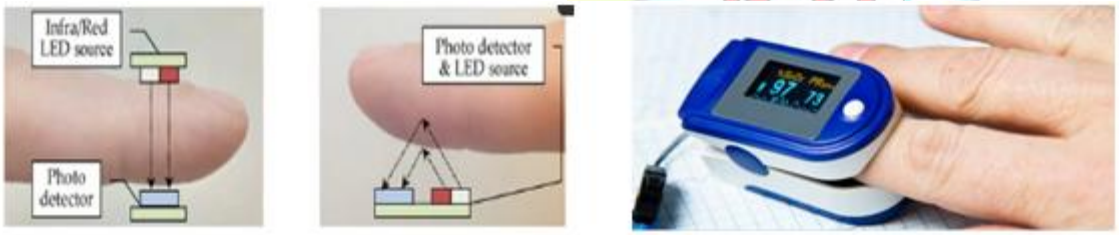

Figure 7c SPO2 and Heartbeat Sensor Positioning and sensor model

BODY TIGHTNESS MEASUREMENT

Muscle stiffness is a kind of sensation of pain or stiffness of the muscles. Obese persons experience muscle stiffness after intense exercise practices or inactivity. Musculoskeletal pain always associated with morbid obesity with BMI above 35.0 kg/m^2, however, information on factors associated with pain in adults with obesity and severe obesity is limited. However, evidence between musculoskeletal pain in individuals with obesity and associations with sociodemographic, anthropometric, lifestyle, and clinical variables are scarce, especially in individuals with severe obesity. A table below (Table 3) clearly indicates muscle tightness of morbidly obese persons and percentage of organ affects with four level analysis, the survey taken by agencies of United States . Muscle stiffness can be measured using Force Sensible Resistor (FSR) kept at chest level as mentioned in the (figure 8) below image. The FSR is a Piezo Resistive Sensing technology, whose resistance changes in accordance with the pressure applied to it. It is a passive transducer, it needs a constant excitation voltage to convert force in to voltage for analog signal related to the force of stiffness of muscles.

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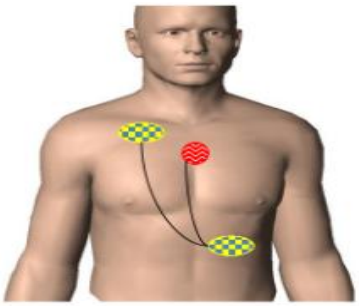

Figure 8 FSR Sensor Positioning Body Tightness sensing

8 a Image of FSR sensor

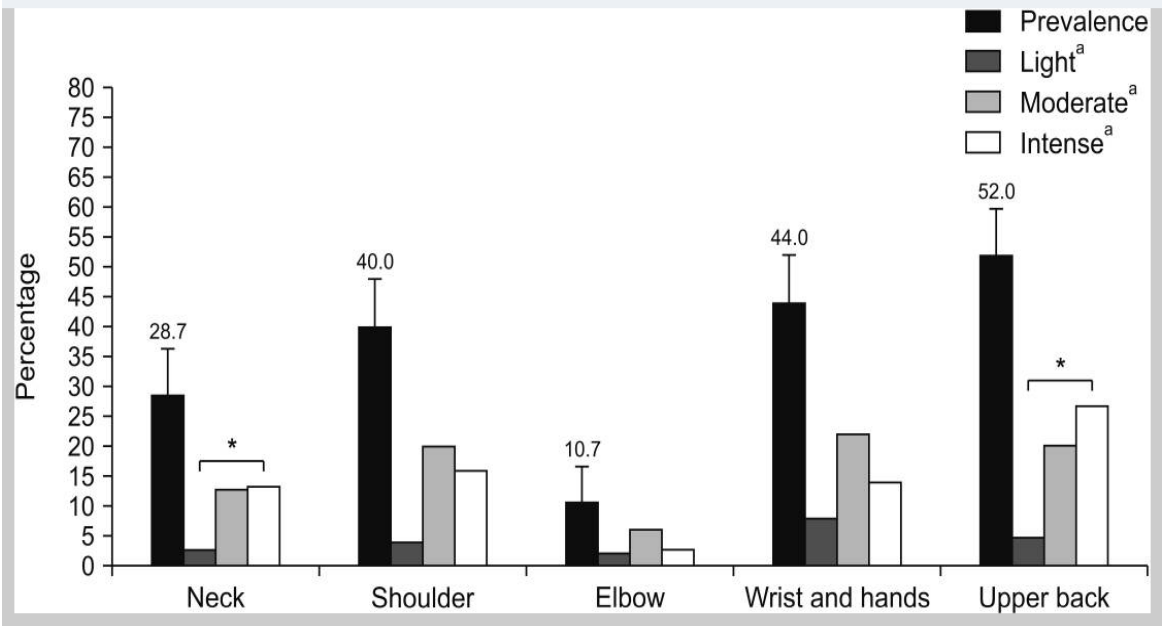

Table 3. Muscle stiffness levels of various organs at a four level methode

All the analog data corresponds to the variables acquired from the sensors are processed and then fed to our Embedded Micro Controller PIC16F877A. The EMC is a 8 bit with 10 bit ADC built-in, the work of the Embedded micro controller in this research is to accept all analog variables simultaneously, converts them in to equal discrete variables (Digital), then converts them in to serial using USART built in and again supported to a RS232 convertor chip for real-time IoT interface to fulfill the exact requirement as we discussed earlier with the support of ESP 32 IoT module as mentioned in the figure10. The below mentioned circuit diagram (Figure 9) consists of a power supply, reset circuit, clock circuit ,RS232 interfaceand concern I/O connectivity facility.

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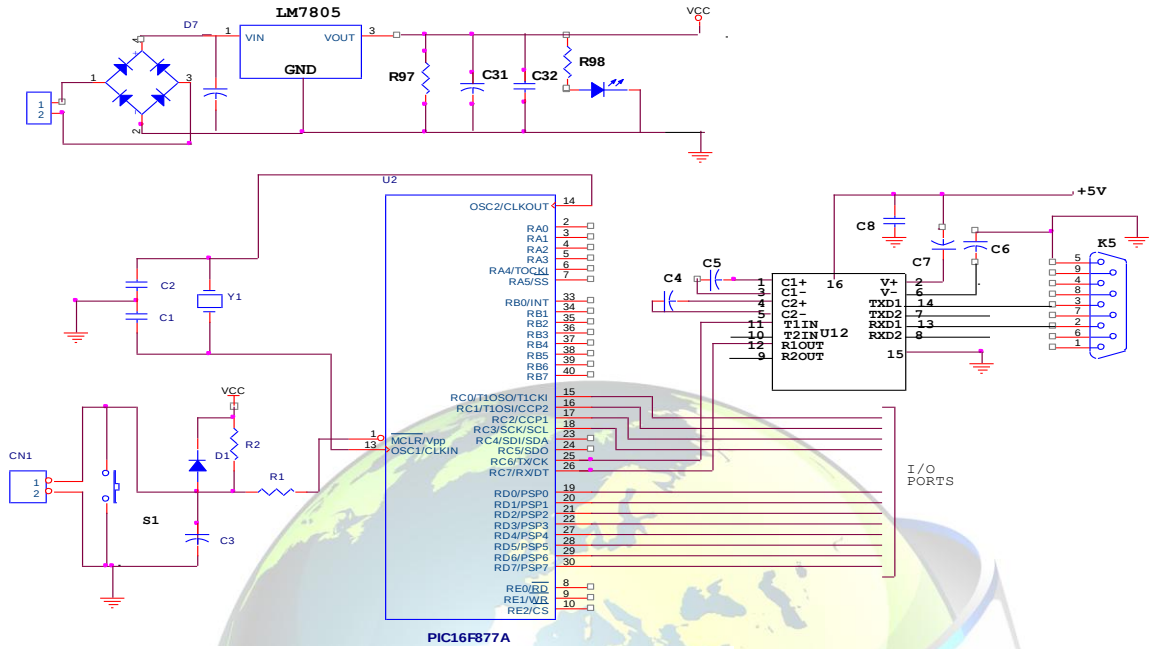

Figure 9 Embedded controller circuit Diagram with RS232 Interface

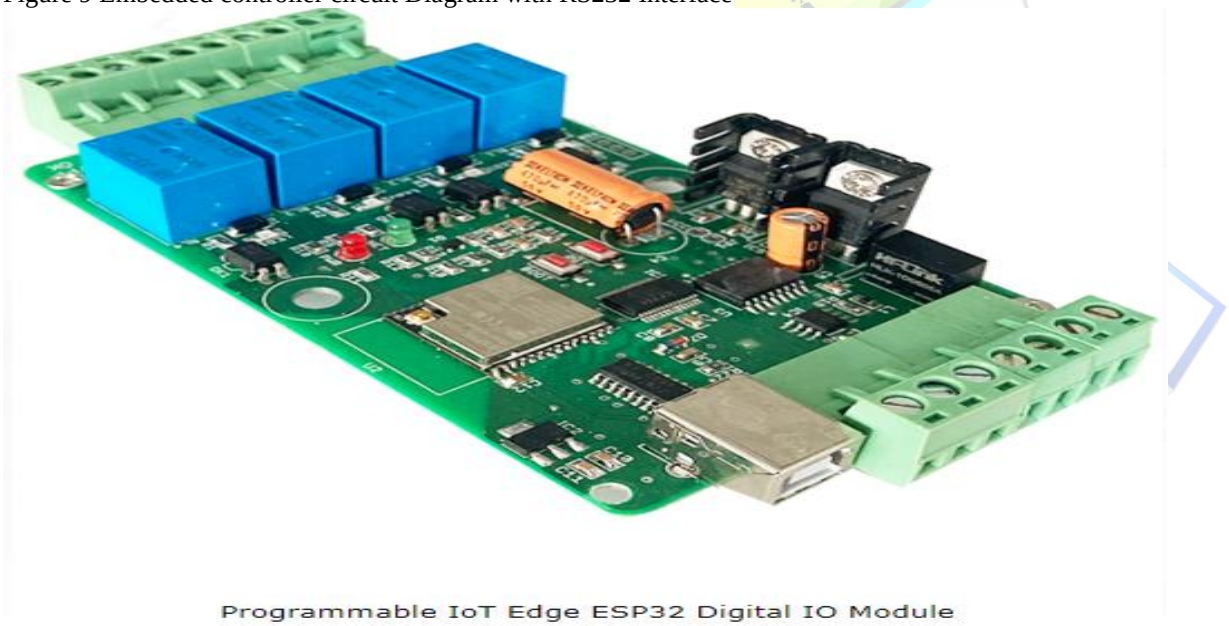

Figure 10 RS232 based ESP32 IoT interface board

The real time hardware model developed for this research is show in the picture (figure 11), and computer results taken in a real-time way also shown on the figure 11 a meets the expected standard of obese management as we discussed earlier.

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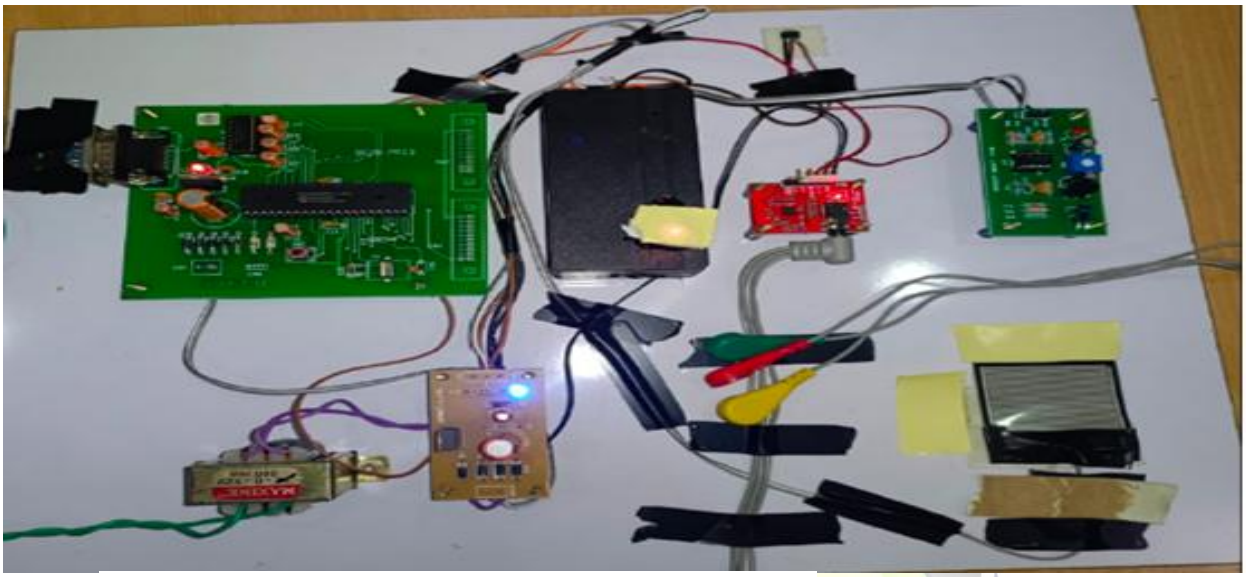

Figure 11 Prototype Model Build to Evaluate the Proposed concept

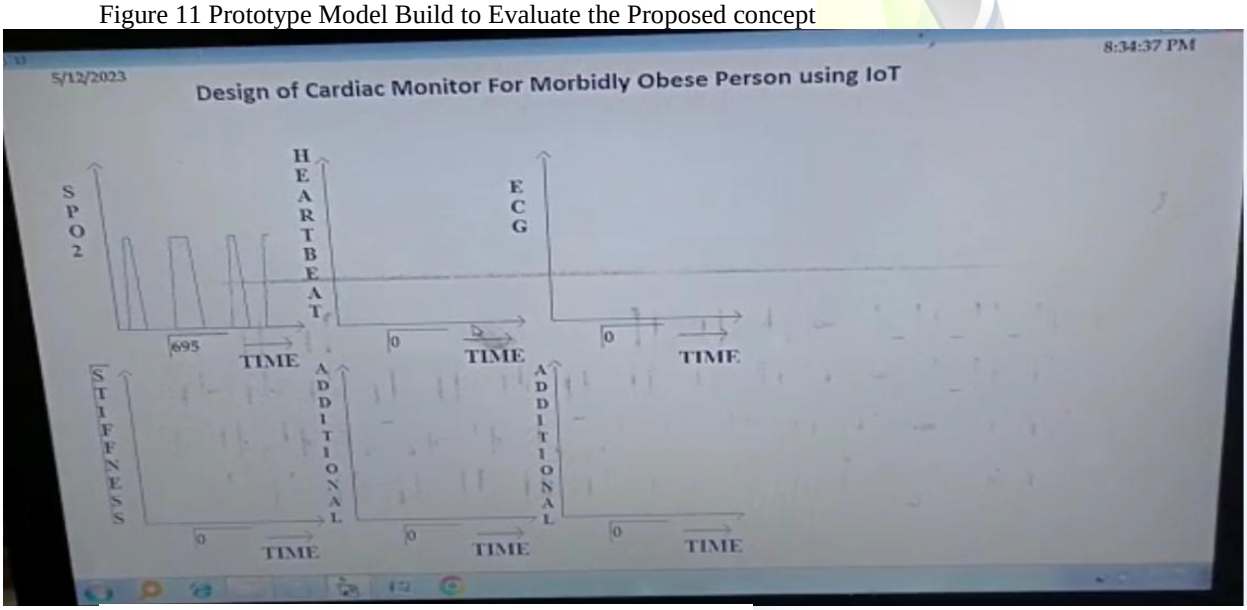

Figure 11 a Prototype Model output screen Proposed concept

IV. CONCLUSION

The development of a cardiac monitor specifically designed formorbidly obese individuals is a significant step towards addressing therising problem of obesity-related cardiovascular diseases has beensuccessfully implemented. The monitor integrates multiple sensors,including an ECG sensor, SPO2 sensor, heart rate sensor, and forcesensing resistor, along with a microcontroller for accurate analysis ofvital data. By continuously monitoring ECG, blood oxygenconcentration, heart rate, and breathing patterns during exercise, the monitor provides comprehensive information for preventing potentialcardiovascular complications. It allows for early detection ofirregularities, strain on the cardiovascular system, and compromised lung function, enabling timely interventions and a safer exercise experience.Ultimately, the project aims to improve the overall well-being and qualityof life for morbidly obese individuals facing cardiovascular challenges.

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