PROBLEM STATEMENT

Reports reveal that, in Ghana, **12% of female deaths (ages 15-49) in the past five years** resulted from pregnancy complications, with **62% attributed to late or inadequate medical intervention**. Barriers such as distance, transportation costs, and time constraints prevent pregnant women from undergoing regular antenatal care, thereby increasing maternal risks.

GOAL OF THE SYSTEM

1. Monitor the health of pregnant women throughout their pregnancy to ensure that medical officers receive continuous updates on their vital signs.
2. Predict potential pregnancy complications early on, alerting medical staff when there are signs of developing issues so that they can intervene before the situation becomes critical.

HARDWARE FUNCTIONAL REQUIREMENTS

1. The vitals of a pregnant woman must be transferred from the wearable device to the central hub for pregnancy predictions.
2. The central hub must send vitals to the mobile app for doctors to view pregnancy predictions.
3. The mobile app must push vitals and pregnancy data to the cloud for storage.
4. The wearable device must collect body temperature in real time.
5. The wearable device must measure heart rate in real time.
6. The wearable device must measure oxygen saturation in real time.
7. The wearable device must consume minimal power to remain active for extended periods.
8. Health data must be encrypted to prevent security breaches.
9. Only positive predictions of pregnancy complications must be sent from the central hub to the pregnant woman’s dashboard.
10. Vitals from the wearable device must be sent to the mobile app, allowing the pregnant woman to track her vitals over time.
11. Sensors must be small enough to be wearable.
12. Sensors must be portable.
13. Sensors must be non-invasive.
14. The system must be cost-effective.

SPECIFICATIONS

1. Vitals of pregnant woman must be transferred **every 10 seconds** from the wearable device to the central hub at a data rate of **1-2 Mbps**.
2. Prediction of pregnancy complications must be sent to the mobile app from the central hub **every 30 seconds** at a rate of **50 Mbps - 1 Gbps**.

3. Text messages containing predictions indicating a **medium or high probability** of pregnancy complications must be sent to the mobile app with **low latency** (especially in emergencies).
4. Vitals of pregnant woman must be transmitted **over a maximum distance of 15 km** to the central hub, ensuring pregnancy complication predictions can still be made regardless of the pregnant woman's location.

   *(I used the distance between Oyarifa and Legon as a case study)

5. Vitals of pregnant women and pregnancy complication predictions must be sent from the mobile app to the cloud server **every hour**, provided there is internet connectivity.
6. The body temperature sensor must record temperatures between **35°C** and **40°C**.
7. The heart rate sensor must capture pregnancy-related values starting from between **70 bpm and 120bpm**.

   (My team and I will firm up these values of point 6 and 7 after our meeting with the medics on Friday)

8. The system must not exceed **$70** in cost.
9. The system must be **battery-powered**, lasting **at least a week without charging**.
10. All pregnancy complication predictions must be stored on the central hub.

Resources:
https://www.linkedin.com/advice/0/what-some-tips-writing-technical-specifications-cowac
https://www.aalpha.net/blog/how-to-write-a-design-specification/
Example: https://wiki.laptop.org/mediawiki/images/d/d4/CL2_Hdwe_Design_Spec.pdf
https://electronics.stackexchange.com/questions/153296/how-do-you-document-your-hardware-design-decisions
https://www.linkedin.com/pulse/functional-design-specification-suppliers-response-urs-dra%C5%A1kovcy/
Module 01: Requirements Engineering, Part 03: Specification ISearchInfoShoppingTap to unmute2xIf playback doesn't begin shortly, try restarting your device.•example systems that are very similar soyou know what kind of requirements thereare and you can define them in a certainway for example embedded systems youUp nextLiveUpcomingCancelPlay NowShareInclude playlistAn error occurred while retrieving sharing information. Please try again later.Watch laterShareCopy link

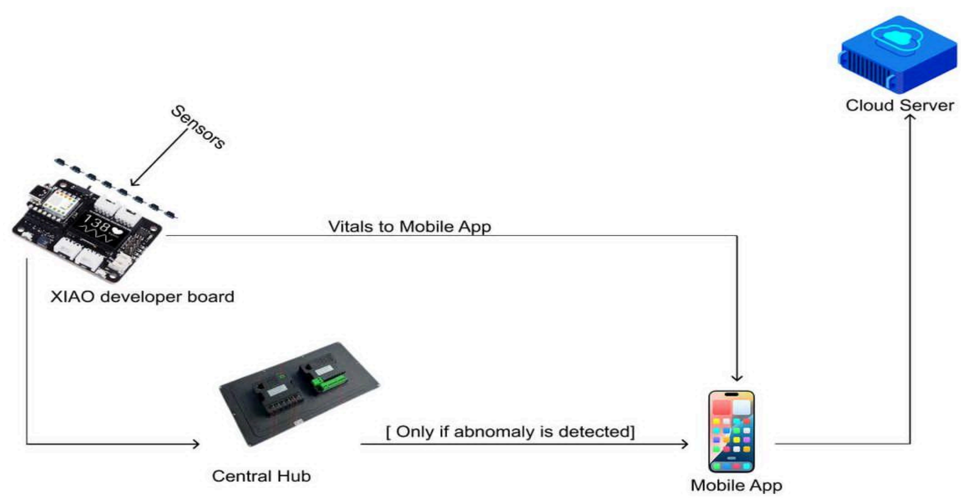
Design specification: Engineering Design ProcessSearchInfoShoppingTap to unmute2xIf playback doesn't begin shortly, try restarting your device.•from the product that we want to buildso that could be related to athleticsUp nextLiveUpcomingCancelPlay NowShareInclude playlistAn error occurred while retrieving sharing information. Please try again later.Watch laterShareCopy link

What we should avoid in Functional Design Specifications?

- Vague or ambiguous statements,
- Each function should have a unique reference,
- Specification of functionality should not be duplicated,
- Each function defined should be testable. This is particularly important for Automation Control System to validate because Factory and Site Acceptance Testing is carried out against the FDS/URS.
- FDS should be understood by both the purchaser's representatives and suppliers,
- Jargon should be avoided.

https://www.linkedin.com/pulse/hardware-design-specification-erik-dra%C5%A1kovcy/

HARDWARE SYSTEM DIAGRAM



SYSTEM OPERATIONAL FLOW DIAGRAM

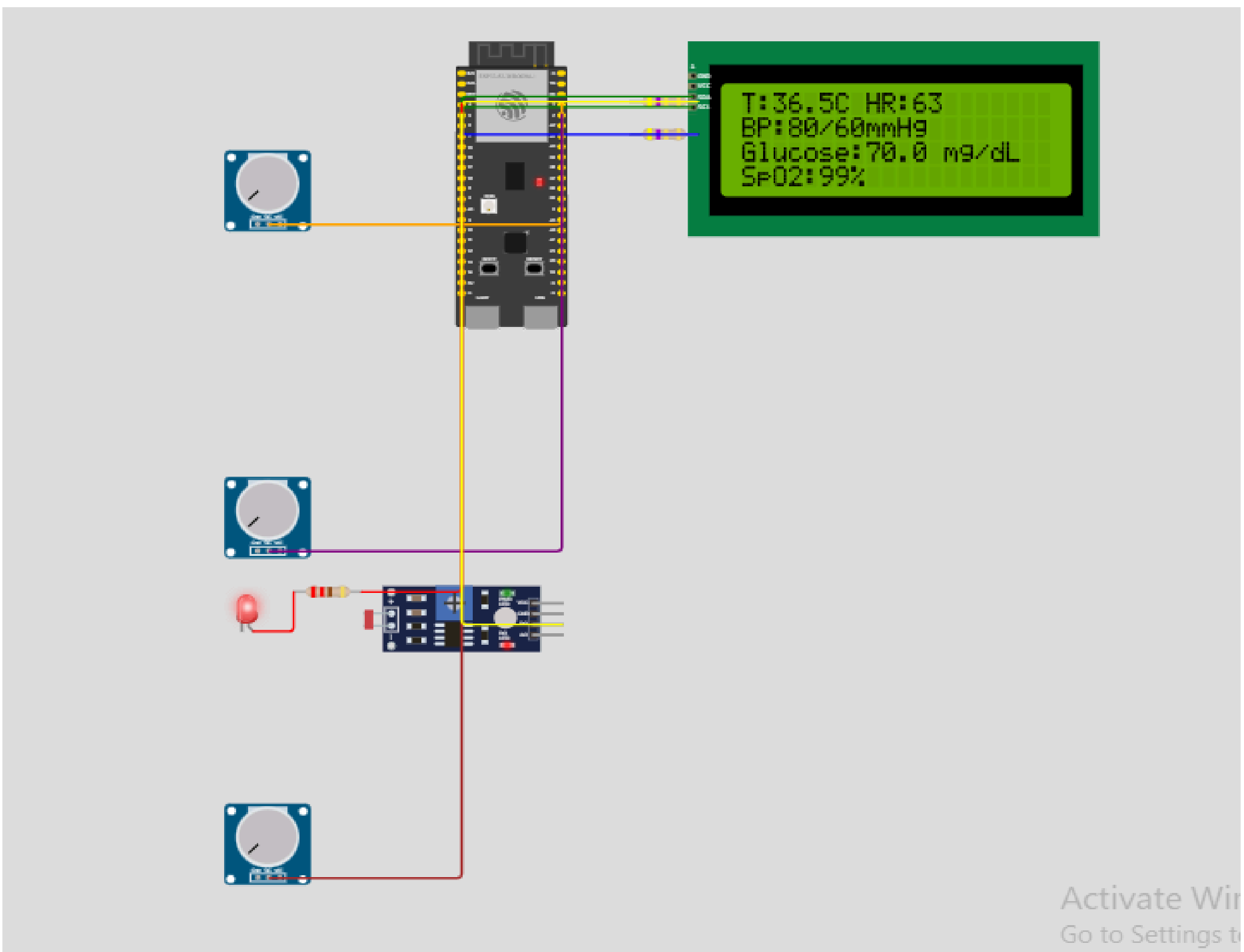
https://lucid.app/lucidchart/2a05bf68-fc19-46b0-934e-de0e81663163/edit?viewport_loc=-192%2C-140%2C4404%2C2048%2C0_0&invitationId=inv_be04de1b-f061-49e0-b554-a52378cd5b90

COMPONENT SELECTION

1.Body Temperature Measurement - TMP117 Sensor
2.Heart Rate and Oxygen Saturation Measurement - MAX30102 Sensor
3.Blood Pressure Measurement - Blood Pressure Monitor CK-101
4.Blood Glucose Measurement - Red light IR Sensor
https://youtu.be/2YSc3q21rJQ?si=zRL2tYpbl1H8dk0i - This is an example

- All these will communicate with the Xiao ESP32S3 developer board using I2C Protocol hence support for I2C is the primary reason for selecting these sensors.
- Lora Modules will be placed on the Xiao ESP32S3 developer to send vitals captured to the Central Hub for pregnancy predictions

SIMULATION OF WEARABLE DEVICE



COMPONENTS USED FOR SIMULATION

1.TMP117 Sensor - Body Temperature

2.MAX30102 Sensor - Heart Rate And Oxygen Saturation

3.Two Potentiometers - Systolic and Diastolic Blood Pressure

4.Red IR LED,IR Receiver and Potentiometer - Blood Glucose Non-invasive Monitor

5.TWO LEDs(20x4 and 16x02)

6.Esp32-s3-devkitc-1 Board

7.Xiao-esp32-c3 Board

8. 4.7k Ohm Resistors

GENERAL NOTES

1.Use Case Definition

Title:

Development Of Integrated Wearable Device For Remote Monitoring Of Pregnant Women In Ghana

Actors:
Pregnant Woman,Family Relative and Medical Doctor

Goal:
Monitor vital signs such as **Body Temperature,Blood Pressure,Blood Glucose level,Oxygen Saturation and Heart Rate** for abnormal levels and predict the likelihood of pregnancy complications such as Preeclampsia,Gestational diabetes and Anemia regularly from the onset of pregnancy

Steps:

1. Pregnant woman wears the wearable device to capture the above mentioned vitals
2. Vitals recorded from wearable device are sent to microcontroller with AI model for pregnancy complication prediction
3. Pregnancy Complication prediction is made on microcontroller device and sent to mobile app

4. Pregnant Woman and Family Relative is able to view vitals recorded and Doctor is able to view pregnancy complication prediction on mobile app

Outcome: Vitals of pregnant women regularly monitored and constant prediction of possibility of a pregnancy complication all throughout pregnancy.

2.Choosing Core Components

A. Microcontroller: Esp32-s3-devkitc-1 Board for wearable device and Xiao-esp32-c3 Board for pregnancy complication prediction
B.
C.
D.
E. SENSORS:
-TMP117 Sensor - Body Temperature
- MAX30102 Sensor - Heart Rate And Oxygen Saturation
- Red light IR sensor - Blood Glucose level
- ********* - Blood Pressure

D.Communication Module - WIFI

E.Breadboard for prototype and ensure system works after which a PCB design will come in

F.Others:
- 3D Casing for wearable device
- Flash memory to store data
- PlatformIO for programming MCU
- Mobile app to visualize data

COMPONENT SPECIFICATIONS

Body Temperature Measurement

(A) TMP117 Temperature Sensor – *Texas Instruments*

- **Voltage Range:** 1.7 V to 5.5 V
- **Power Consumption:**
  - Active: Typically 3.5 μA (low-power operation)
  - Shutdown: 150 nA

- **Conversion Rate:** 1-Hz (1 temperature reading per second)
- **Operating Temperature Range:** –55 °C to 150 °C
- **Accuracy:**
  - ±0.1 °C (max) from –20 °C to 50 °C
  - ±0.15 °C (max) from –40 °C to 70 °C
  - ±0.2 °C (max) from –40 °C to 100 °C
  - ±0.25 °C (max) from –55 °C to 125 °C
  - ±0.3 °C (max) from –55 °C to 150 °C
- **Resolution:** 16-bit → 0.0078 °C per LSB
  - Example:
    - ADC = 0 → 0 °C
    - ADC = 1 → 0.0078 °C
    - ADC = 1000 → 7.8 °C
- **Thermal Response Time:** ~0.39 to 0.72 seconds (depends on mounting and environment)
- **Size:**
  - WSON: 2.00 mm × 2.00 mm
  - DSBGA: 1.53 mm × 1.00 mm
- **Weight:** Minimal (few milligrams)
- **Communication Protocol:** I²C
- **Applications:** Wearables, industrial sensing, medical devices

- **Cost:** [$2.15 – $7.68 USD] (depending on model and quantity)

This range covers all variants:

- **$2.15** (lowest) → TMP117MAIDRVR
- **$7.68** (highest) → TMP117AIDRVT Digi-Reel®

- **Datasheet & Product Page:**
🔗 TMP117 by Texas Instruments

(B) MAX30205 Temperature Sensor – *Analog Devices (Maxim Integrated)*

- **Temperature Range:** 0 °C to +50 °C
- **Accuracy:** ±0.1 °C (medical-grade)
- **Power Consumption:**
  - Active: 600 µA (typical)
  - Shutdown: 0.1 µA
- **Supply Voltage:** 2.7 V to 3.3 V
- **Response Time:** Fast (optimized for real-time body temperature monitoring)
- **Package Size:** 8-pin SOIC (4.9 mm × 3.9 mm)
- **Communication Protocol:** I²C
- **Applications:** Wearables, health monitors, medical devices
- **Cost :** $11.69
- **Datasheet & Product Page:**
🔗 MAX30205 by Analog Devices

(C) ADT7420 Temperature Sensor – *Analog Devices*

- **Temperature Range:** –40 °C to +150 °C

- **Accuracy:** ±0.1 °C (medical-grade)
- **Power Consumption:**
    - Active: 210 μA
    - Shutdown: 2 μA
- **Supply Voltage:** 2.7 V to 5.5 V
- **Communication Protocols:** I²C or SPI
- **Package Size:** 16-lead LFCSP (3 mm × 3 mm)
- **Applications:** Wearables, industrial equipment, healthcare devices
- **Cost:**$9.87
- **Datasheet & Product Page:**
  🔗 ADT7420 by Analog Devices

Parameter	TMP117 (TI)	MAX30205 (Analog Devices)	ADT7420 (Analog Devices)	Why TMP117 Wins
Temperature Range (°C)	−55 to +150	0 to +50	−40 to +150	TMP117 has the widest range, suitable for more extreme conditions
Accuracy (°C)	±0.1 (−20 to 50), ±0.3 (−55 to 150)	±0.1 (only 0–50)	±0.1	TMP117 maintains accuracy across broader ranges
Power Consumption	3.5 µA (active), 150 nA (shutdown)	600 µA (active), 0.1 µA (shutdown)	210 µA (active), 2 µA (shutdown)	TMP117 is ultra-low power — excellent for battery-powered wearables
Resolution	16-bit → 0.0078 °C	13-bit → ~0.0039 °C	16-bit → 0.0078 °C	TMP117 provides high resolution for precise sensing
Response Time	0.39–0.72 s	Fast (not quantified)	Not specified	TMP117 gives a known fast response, useful in dynamic body temperature tracking
Voltage Range (V)	1.7 to 5.5	2.7 to 3.3	2.7 to 5.5	TMP117 works across a broader voltage range — more flexibility in system design
Communication	I²C	I²C	I²C / SPI	All support I²C, but TMP117 simplifies integration with most MCUs
Size	2×2 mm (WSON), 1.53×1.00 mm (DSBGA)	4.9×3.9 mm (SOIC)	3×3 mm (LFCSP)	TMP117 has the smallest package — ideal for compact wearables
Medical-Grade	Yes (±0.1 °C in human body range)	Yes	Yes	All are medical-grade, but TMP117 offers lowest power + compactness
Cost	Affordable (depending on distributor)	Slightly higher due to medical optimization	Varies (similar range)	Competitive pricing for performance and efficiency

Key Advantages of TMP117

- Ultra-low power consumption : extends battery life in wearables
- Tiny size : Fits in compact designs like smart patches
- Medical-grade accuracy : ±0.1°C in body temperature range
- Cost-effective

Heart Rate and Oxygen Saturation Sensors

(A) MAX30102 Sensor

- **Functionality:** Measures Heart Rate (PPG) and Oxygen Saturation (SpO_2)

- **Power Consumption:**

    - Active: 1.6 mA (typical)
    - Shutdown: 0.7 μA
- **Communication Protocol:** I²C
- **Supply Voltage:**
    - VDD: 1.8V
    - LED Driver: 3.3V to 5.5V
- **Operating Temperature Range:** –40°C to +85°C
- **Size:** 5.6 mm × 3.3 mm × 1.55 mm
- **Continuous Power Dissipation:**
    - 440 mW @ TA = +70°C
- **Additional Features:**
    - Integrated red and infrared LEDs
    - Ambient light cancellation
    - Compact package suitable for space-constrained designs
- **Compatibility:** Works with ESP32 via I²C
- **Applications:** Wearables, fitness bands, health monitors
- **Cost :** $12.99

Advantages

- Compact size — ideal for wearables
- Low power consumption
- ESP32 compatibility
- Reliable performance in ambient light environments

🔗 [MAX30102 Datasheet]

(B) SparkFun Pulse Oximeter (MAX32664C Integrated)

- **Functionality:** Measures Heart Rate and SpO_2
- **Power Consumption:**
  - Operating: ~0.7 mA
- **Communication Protocol:** I^2C
- **Supply Voltage:** 1.8V to 3.3V
- **Size:** 12.7 mm × 10.2 mm (module size)
- **Applications:** Ideal for wearable prototyping
- **Cost:**$52.52
- **Additional Features:**
  - Pre-calibrated sensor
  - Supports ESP32
  - Designed for fast development cycles

Advantages

- Simplified integration
- Pre-calibrated — saves time during setup
- Optimized for ESP32 and prototyping

🔗 [SparkFun Pulse Oximeter Product Page]

(C) MAX30112 Sensor

- **Supply Voltage:**
  - Single 1.8V supply

- Separate LED supply: 3.1V to 5.25V

- **Operating Temperature Range:** –40°C to +85°C
- **Communication Protocol:** I²C

- **Size:** 2.8 mm × 2.0 mm

    - 6×4 ball array, 0.4 mm pitch (WLP package)

- **Shutdown Current:** 1.4 μA

- **Continuous Power Dissipation:**

    - 440 mW @ TA = +70°C (derate 5.5 mW/°C above 70°C)

- **Applications:** Advanced health monitoring wearables
- **Cost :**$6.80

🔗 [MAX30112 Datasheet]()

BLOOD PRESSURE AND BLOOD GLUCOSE MEASUREMENT

(A)AS7263 Near Infrared (NIR) Spectral Sensor

- **Functionality:** Measures near-infrared reflectance for spectroscopy

- **Detected Wavelengths:** 610 nm, 680 nm, 730nm, 760nm, 810nm, and 860nm (each with 20 nm full-width half-maximum)

- **Analog-to-Digital Converter (ADC):** 16-bit digital output

- **Illumination:**

    - Built-in NIR LED

    - External LED pins for custom illumination

- **Communication Interfaces:**

    - I²C (Address: 0x49, hardware-defined)

    - UART with AT command support

- **Operating Voltage:** 2.7V to 3.6V
- **Connectors:** 2x Qwiic connectors for easy I²C integration
- **Multiplexing Support:** Use a Qwiic Mux to operate multiple sensors on the same bus
- **Power Supply Type:** Qwiic-enabled (uses 1 mm pitch 4-pin JST)
- **Applications:** Material classification, wearable NIR sensing, agricultural analysis, biomedical monitoring
- **Cost:** $33.59
- **Platform Support:** Compatible with Arduino,ESP32 (SparkFun provides Arduino libraries, and since the ESP32 works with the Arduino framework, the sensor integrates easily) and MicroPython

* Yes, the **MAX30102** and **MAX30112** are in the **same family** of integrated biosensor devices developed by **Analog Devices (formerly Maxim Integrated)**, and they share a similar purpose — monitoring **optical signals for heart rate and SpO_2 (blood oxygen)** measurements.

* Communication mode of all sensors to the MCU is I²C

<u>WHY I²C MODE OF COMMUNICATION</u>

1. Compact Design = Fewer Wires = Smaller Wearable

- Wearables must be **small**, **lightweight**, and **tidy** inside.
- I²C uses **just two shared wires (SDA + SCL)** for all sensors — no need for separate lines per sensor.
- This simplifies your PCB design and **frees up space for a battery, BLE antenna, or casing**.

2. Ultra-Low Power = Longer Battery Life

- I²C-based medical sensors like **TMP117, MAX30102, ADT7420, and AS7263** are optimized for low-power operation.
- The **ESP32 can sleep** while sensors retain state, and then resume communication quickly.

- Less power used = **more time between recharges**, which is **essential for wearables**.

3. Supports Multiple Sensors Simultaneously — on One Bus

- All your sensors (heart rate, SpO_2, temperature, NIR) **communicate through the same 2 lines**.
- As long as each has a unique I^2C address, they **work concurrently** without needing extra pins.
- This avoids wiring mess and keeps your firmware clean.

4. Code Efficiency and Reuse (ESP32 + Libraries)

- ESP32 has **native I^2C support** with existing, reliable libraries for almost all sensor modules you're using.
- No need to juggle multiple protocols — you write **clean, modular code** with consistent read/write functions.
- Faster development, fewer bugs, and easier updates later.

5. Ready for Expansion (Scalable Design)

- In the future, if you add sensors for motion (accelerometer), hydration, or pressure, most of them also speak I^2C.
- You won't need to redesign your PCB — **just plug and expand**, even with a mux if needed.

MICROCONTROLLERS

FOR SMARTWATCH,

(1) ESP32-S3-DevKitC-1 – Microcontroller for Wearable Device

Key Specifications

- **Microcontroller**: ESP32-S3-WROOM-1/1U/2
- **CPU**: Dual-core 32-bit Xtensa® LX7, up to 240 MHz
- **Wireless Connectivity**: Wi-Fi 802.11 b/g/n (2.4 GHz), Bluetooth® 5 (LE)
- **Memory**:
  - Flash: 8 MB Quad SPI
  - PSRAM: Up to 8 MB (depending on the module variant)
- **GPIO**: 22 digital I/O pins
- **Analog Inputs**: 6 ADC channels
- **PWM Outputs**: 6 channels
- **Interfaces**: I²C, SPI, UART, USB OTG, ADC, DAC
- **Operating Voltage**: 3.3 V
- **Power Supply**: 5 V input via USB Type-C or 5V pin
- **Onboard Voltage Regulator**: 5 V to 3.3 V Low Dropout (LDO) regulator
- **Current Supply**: Provides up to 800 mA from the 3.3 V rail

Power Regulation

- The onboard **5 V to 3.3 V LDO regulator** efficiently converts a 5 V supply (e.g., USB) into a stable 3.3 V output.

- This ensures safe power delivery to the microcontroller and all connected sensors—ideal for wearable device design.
- Enables flexible power input using standard 5 V USB or Li-Ion battery modules.

Documentation & Resources

- 🔗 **ESP32-S3-DevKitC-1 User Guide** (Espressif)
- 📄 **ESP32-S3-DevKitC-1 Datasheet (PDF)** via Mouser
- 🛒 **Product Page (DigiKey)**

(2)SiFli SF32LB52x Bluetooth MCU – Key Features and

1. CPU and Memory

- **High Performance Processor (HCPU)**
  - Arm Cortex-M33 STAR-MC1 core @ up to 240 MHz
  - Performance: 370 DMIPS, 984 EEMBC CoreMark
  - 512 KB SRAM
- **Ultra Low-Power Processor (LCPU)**
  - Arm Cortex-M33 STAR-MC1 core @ up to 24 MHz
  - 64 KB SRAM

2. Storage and Memory Interfaces

- NOR Flash up to 96 MHz (SiP)
- OPI-PSRAM up to 144 MHz (SiP)

- MPI (QSPI) for external NOR, NAND, and OPI-PSRAM
- SD/SDIO with support for:
  - SD3.0
  - SDIO3.0
  - eMMC

3. Graphics and Display

- **GPU: ePicaso 2.0**
  - 2D/2.5D rendering
  - Hardware-accelerated rotation, scaling, mirroring
  - Max resolution: 512×512
- **Decompression**
  - Lossless Decompression Accelerator (eZIP 2.0)
- **LCD Controller**
  - Interfaces: 8080, SPI, Dual-SPI, Quad-SPI
  - 1 layer + 1 background layer alpha blending
  - Independent Always-On Display support

4. Audio

- **DAC:**
  - 24-bit, 8k–48kHz

- SNR/Dynamic Range: 109 dB
- Noise Floor: 3.7 μVrms

- **ADC:**
  - 24-bit, 8k–48kHz
  - SNR/Dynamic Range: 99 dB
- **Interfaces:**
  - 1x I2S
  - 1x PDM

5. Wireless

- **Bluetooth 5.3 – Dual Mode**
  - BLE Audio Support
  - Sensitivity:
    - -100 dBm (BLE / 1 Mbps)
    - -96.3 dBm (BR)
    - -95.5 dBm (EDR2)
  - Tx Power:
    - Up to 13 dBm (EDR2/3)
    - Up to 19 dBm (BR/BLE)
  - Power Consumption:
    - Rx Peak Current (BR): 2.4 mA @ 3.8V

        - BLE Connected: ~50 µA

6. Peripherals

- Up to 45 GPIOs
- 3x UART, 4x I2C, 2x SPI
- USB 2.0 Full Speed
- Peripheral Task Controller (PTC)

7. Analog

- 12-bit General Purpose SAR ADC (8 channels)
- Integrated Temperature Sensor (monitoring the internal temperature of the chip itself i.e detect if the MCU is overheating due to high workload or environmental conditions)

8. DMA

- **General DMA:** Efficient data transfer between internal memory and peripherals
- **extDMA:** Efficient data transfer between internal and external memory

9. Timers

- 2x 16-bit GPTIM
- 2x 32-bit BTIM
- 1x 32-bit ATIM
- 2x 24-bit LPTIM
- 1x RTC

- 2x 24-bit WDT
- 1x IWDT

10. Security

- AES, HASH, CRC hardware accelerators
- True Random Number Generator (TRNG)
- PSA Certified Level 1

11. Power Management

- High-efficiency buck and low-power LDO
- 2x external 3.3V LDOs (150 mA max each)
- Sleep current: 2 μA
- Integrated 560 mA lithium battery linear charger (4.2V–4.45V)
- VBAT voltage range: 3.2V–4.7V
- VBUS voltage range: 4.6V–5.5V

12. Package

- QFN68L
- 44 GPIOs
- Dimensions: 7 × 7 × 0.85 mm

The SF32LB52x features 4 I²C interfaces, enabling communication with various I²C-compatible devices such as sensors, displays, and memory modules.

LINKS

https://www.sifli.com/usercategory/product/614973/#677018

Why It's Ideal for Smartwatches

- **Custom-made for smartwatches**
  - Used in products by Redmi, Oppo, Noise, etc.
- **Optimized Resources**
  - 512KB SRAM + 16MB PSRAM
  - Dedicated MIP peripheral eliminates need for FPGA
- **Low Power Consumption**
  - ~50 μA with BLE connected
- **Cost-effective**
  - Priced around **$2**

(3)STM32F207/217 Microcontroller Specifications

CPU and Memory

- **CPU Core: Arm Cortex-M3 32-bit RISC processor**
- **Core Frequency: Up to 120 MHz**
- **Performance:**
  - **150 DMIPS / 398 CoreMark from Flash**
  - **Uses ART Accelerator™ for zero-wait-state Flash execution**
- **Embedded Memory:**
  - **Flash Memory: From 256 KB to 1 MB**

- SRAM: Up to 128 KB
- Embedded Boot ROM with In-System Programming (ISP) support
- Embedded JTAG and SWD for debug and trace

Storage and Memory Interfaces

- Flexible Static Memory Controller (FSMC):
  - Supports SRAM, PSRAM, NOR Flash, NAND Flash
  - Also supports CompactFlash interface
- External memory interfaces ideal for LCD controllers or external Flash/RAM expansion
- Embedded Flash:
  - Supports dual-bank Flash operation (read-while-write)
- SRAM:
  - Integrated tightly coupled SRAM (TCSRAM) with fast access
- Boot Mode:
  - Selectable boot from Flash, system memory, or SRAM

Power Efficiency

- Fabricated on 90 nm CMOS process
- Dynamic voltage scaling
- Ultra-low power: 175 µA/MHz at 120 MHz while executing from Flash
- Power modes: Sleep, Stop, and Standby with fast wake-up

Rich Connectivity & Interfaces

- **2x USB OTG:**
  - **One Full-Speed (FS)**
  - **One High-Speed (HS) with dedicated PHY**
- **Ethernet MAC 10/100:**
  - **With IEEE 1588 v2 Precision Time Protocol (PTP)**
- **8- to 14-bit parallel camera interface**
- **6x USARTs (up to 7.5 Mbit/s)**
- **3x SPI (up to 30 Mbit/s)**
- **3x I²C**
- **2x CAN 2.0B**
- **1x SDIO interface**

Audio Features

- **2x I²S (half-duplex) with support for audio formats (PCM, I²S standard)**
- **Dedicated PLL for audio clocking (precision sampling)**

Analog Features

- **3x 12-bit ADCs:**
  - **Up to 2 MSPS individually**
  - **6 MSPS in interleaved triple-mode**
- **2x 12-bit DACs**

- **Temperature Sensor integrated for thermal monitoring**
- **Analog True Random Number Generator (TRNG)**

Timers

- **Up to 17 timers:**
    - **General-purpose, advanced-control, basic, and watchdog timers**
    - **16-bit and 32-bit timers for complex time-based control applications**

Security

- **STM32F217 only: Crypto/Hash Processor for hardware-accelerated:**
    - **AES (128/192/256-bit)**
    - **Triple DES**
    - **Hashing (MD5, SHA-1)**

Packaging

- **Available in 100 to 176-pin packages**
- **Smallest package size: 10 x 10 mm**
- **Supports high-density pin configurations for I/O-rich designs**

FOR AI MODEL,

(1)Seeed Studio XIAO ESP32C3

- **Processor: ESP32-C3 32-bit RISC-V single-core processor running at 160 MHz**
- **Memory: 400KB SRAM and 4MB of onboard Flash memory**
- **Wireless Connectivity: WiFi (IEEE 802.11 b/g/n) and Bluetooth 5 (BLE)**
- **Form Factor: Ultra-small size (21 x 17.8mm), single-sided components**
- **Power: Supports 3.7V lithium battery with built-in charging capabilities**
- **GPIO: 11 digital I/O pins with PWM support**
- **Analog: 4 analog input pins (ADC)**
- **Interfaces: I2C, UART (2x), SPI**
- **Special Features: External RF antenna included for better wireless performance**
- **Security: Hardware acceleration for AES-128/256, Hash, RSA, HMAC**
- **Buttons: Reset button and bootloader mode button onboard**
- **Power Consumption: Deep sleep power consumption of approximately 43μA**
- **Development Support: Compatible with Arduino IDE and MicroPython**
- **TinyML Capability: Sufficient processing power and memory for lightweight ML applications**
- **Grove Compatibility: Compatible with Grove Shield for Seeeduino XIAO**
- **Wake-up Support: Supports GPIO wake-up from deep sleep (pins D0-D3)**
- **Operating Modes: Supports Station mode, SoftAP mode, SoftAP + Station mode for WiFi**

(2)STM32H723ZG Microcontroller

General Overview

- **Core: 32-bit Arm® Cortex®-M7 with double-precision floating-point unit (DP-FPU)**

- **Operating Frequency: Up to 550 MHz**

- **Performance: 1177 DMIPS / 2.14 DMIPS/MHz (Dhrystone 2.1)**

- **Instruction Set: DSP instructions supported**

- **Memory Protection: Memory Protection Unit (MPU)**

- **Cache: 32 KB instruction cache and 32 KB data cache Zephyr Project Documentation+9Datasheet4U+9Arrow+9Zephyr Project Documentation+7STMicroelectronics+7STMicroelectronics+7Datasheet4U+2STMicroelectronics+2STMicroelectronics+2AllDatasheet+4STMicroelectronics+4STMicroelectro** nics+4

Memory

- Flash Memory: 1 MB with Error Correction Code (ECC)
- SRAM: Total of 564 KB, comprising:
  - 128 KB Data Tightly Coupled Memory (DTCM) RAM
  - 432 KB System RAM (up to 256 KB can be remapped to Instruction TCM)
  - 4 KB Backup SRAM (retained in lowest-power modes) STMicroelectronics+3STMicroelectronics+3STMicroelectronics+3STMicroelectronics+1STMicroelectronics+1

External Memory Interfaces

- Flexible Memory Controller: Supports SRAM, PSRAM, SDRAM/LPSDR SDRAM, NOR, and NAND memories with up to 16-bit data bus
- Octo-SPI Interfaces: 2x, supporting Execute-in-Place (XiP)
- SD/SDIO/MMC Interfaces: 2x STMicroelectronics

Connectivity

- Ethernet: 1x 10/100 Mbps Ethernet MAC compliant with IEEE 802.3-2002
- USB: 1x USB OTG Full-Speed/High-Speed
- CAN: 3x Flexible Data-rate CAN (FD-CAN)
- UART/USART: Up to 4x
- SPI: Up to 6x
- I²C: Up to 4x
- I²S: Up to 3x

- SAI: 2x
- SPDIF_RX: 4x
- HDMI-CEC: 1x
- Camera Interface: 1x
- GPIOs: Up to 114, with external interrupt capability Zephyr Project DocumentationSTMicroelectronics+2Datasheet4U+2AllDatasheet+2Evelta+2STMicroelectronics+2Evelta+2

Analog Features

- ADC: 3x 16-bit ADCs with up to 36 channels, achieving up to 3.6 MSPS in 16-bit mode and 7.2 MSPS in interleaved mode
- DAC: 2x 12-bit DACs
- Comparators: 2x
- Operational Amplifiers: 2x with 8 MHz Gain Bandwidth Product Zephyr Project Documentation+1STMicroelectronics+1

Timers and Watchdogs

- Timers: Up to 17 timers, including:
  - 2x 32-bit timers
  - 12x 16-bit timers
  - High-resolution timer with 2.1 ns resolution
- Watchdogs: Independent and Window Watchdog timers Zephyr Project Documentation

Graphics and Display

- **Chrom-ART Accelerator: Hardware graphical accelerator for enhanced GUI performance**
- **LCD-TFT Controller: Supports resolutions up to XGA (1024x768)**
- **JPEG Codec: Hardware JPEG codec for image processing STMicroelectronicsZephyr Project Documentation**

Security Features

- **Random Number Generator (RNG): Hardware true random number generator**
- **Memory Protection: Memory Protection Unit (MPU)**
- **Error Correction: ECC for all memories Zephyr Project Documentation+1STMicroelectronics+1STMicroelectronics+1Amazon+1**

Power Supply and Management

- **Operating Voltage: 1.62 V to 3.6 V**
- **Power Modes: Sleep, Stop, and Standby modes**
- **Backup Domain: VBAT supply for RTC and 32x32-bit backup registers**
- **Internal Regulators: Embedded LDO regulator**
- **Oscillators:**
    - **Internal: 64 MHz HSI, 48 MHz HSI48, 4 MHz CSI, 32 kHz LSI**
    - **External: 4-50 MHz HSE, 32.768 kHz LSE Mouser+3STMicroelectronics+3Zephyr Project Documentation+3**

Packaging and Temperature Range

- **Package: 144-pin LQFP (20x20 mm)**
- **Operating Temperature: -40°C to +85°C** [DigiKey+1STMicroelectronics+1]

Development Board

- **Nucleo-H723ZG: Development board featuring the STM32H723ZG MCU, compatible with Arduino, ST Zio, and Morpho connectors**

(3) ESP32-S3-DevKitC-1 (ESP32-S3 MCU Chip)

Core

- **Dual-core Xtensa® 32-bit LX7 processors**
- **Up to 240 MHz clock frequency**
- **Vector instructions for acceleration of neural networks and signal processing**
- **512 KB SRAM (Tightly-Coupled Memory - TCM)**
- **Embedded ROM: 384 KB**
- **Embedded Cache: 256 KB**

Memory

- **External Flash: Up to 32 MB (Quad or Octal SPI)**
- **External PSRAM: Up to 8 MB (Quad or Octal SPI)**
- **Instruction & Data Cache support**

Connectivity

- **Wi-Fi 802.11 b/g/n (2.4 GHz), up to 150 Mbps**
- **Bluetooth 5 (LE)**
    - **Long Range**

    - **Advertising Extensions**
    - **2 Mbps PHY**
- **USB 1.1 OTG with PHY (native, full-speed)**

Security

- **Hardware Encryption: AES-128/256, SHA-2, RSA, HMAC, Digital Signature**
- **Secure Boot & Flash Encryption**
- **JTAG disable, eFuse support**

AI Acceleration

- **Vector instructions for neural network and signal processing**
- **Designed for Edge AI applications**

Peripherals

- **GPIOs: Up to 45 GPIOs**
- **ADC: 2 × 12-bit SAR ADCs, up to 20 channels**
- **DAC: 2 × 8-bit DAC**
- **Touch sensors: 14 capacitive touch channels**
- **PWM: LED PWM (8 channels)**
- **Temperature Sensor: Built-in**
- **Hall Sensor: Not included (unlike ESP32)**

Communication Interfaces

- **SPI: 4 × SPI**
- **I2C: 2 × I2C**
- **UART: 3 × UART**
- **I2S: 2 × I2S**
- **CAN: 1 × TWAI (CAN bus)**
- **RMT: 4 × RMT channels (Remote Control)**
- **SD/MMC: SDIO 2.0 host/slave**
- **JTAG: Yes, for debugging**

Power Management

- **Operating Voltage: 1.8V or 3.3V, depending on module**
- **Low-power modes: Deep Sleep (~10 μA), Light Sleep**

Package Options

- **WROOM modules with:**
  - **PCB antenna or u.FL antenna connector**
  - **Memory configurations: 8MB/16MB/32MB Flash, 2MB/8MB PSRAM**

Operating Conditions

- **Temperature range: -40°C to +105°C**
- **ESD protection: ±2 kV HBM (typical)**

NB: All the sensors use I2C mode of communication with ESP32

Why Machine Learning Model on the MCU

Why This Makes the Most Sense for Your Use Case:

1. Real-Time, Life-Critical Monitoring

- **Fall detection and fetal kick detection must respond instantly — any delay due to internet issues could risk lives.**
- **MCU processing avoids network delays and guarantees real-time responsiveness.**

2. Works in Remote or Poor-Connectivity Areas

- **You specifically mentioned this system targets rural areas with low doctor-to-patient ratios — internet access may be unreliable or unavailable.**
- **On-device ML allows continuous operation even when offline.**

3. Lower Power and Cost

- **Devices worn by patients (wearables) need to be battery-efficient. MCU-based solutions consume far less power than streaming data to the cloud regularly.**
- **Also avoids recurring cloud/server costs, which could scale if many users are connected.**

4. Privacy and Compliance

- **Health data is sensitive. Keeping it on-device avoids legal and ethical challenges with transmitting patient vitals over networks.**

5.Wider Distance Reach

ANEMIA PREDICTION

(I) PAPER ONE - MODEL DEVELOPMENT FOR ANEMIA PREDICTION IN PREGNANCY

1. Demographic Characteristics

- Age (<35 or ≥35)
- Education (High school or not specified further)

2. Nutritional Status

- MUAC (<23.5 or ≥23.5)
- BMI (<18.5, 18.5–24.9, ≥25)
- Iron supplement during pregnancy (Yes / No)

3. Disease History (Medical Conditions)

These are binary (Yes/No) features indicating if the participant had the condition:

- Acute Respiratory Infection
- Diarrhea
- Pneumonia
- Malaria
- Tuberculosis
- Hepatitis
- Cancer
- Diabetic Mellitus
- Hyperthyroid
- Hypertension
- Rheumatic
- Stroke

4. Food Consumption Patterns

For each food type, the frequency is categorized as: Daily / Weekly / Monthly

- Sweet food
- Salty food
- Cholesterol-rich food
- Grilled food
- Meat
- Spicy food

5. Smoking Habit

- Yes / Rarely / None

Dependent Variable (Target Feature)

- Anemia status (Yes / No) — this is what the model is trying to predict.

(2)PAPER TWO - Leveraging machine learning models for anemia severity detection among pregnant women following ANC: Ethiopian context

FEATURES : 'Age', 'Region', 'Residence', 'ANC visit', 'Source of water', 'Toilet Type', 'Religion', 'Household Member', 'Frequency of Reading newspaper', 'Frequency of listening to TV', 'Duration of pregnancy', 'Birth History', 'Current pregnancy Wanted', 'Termination History', 'BMI', 'Mosquito Net', 'Marital status', 'H_education', 'H_occupation', 'Anemia'.

Anemia affects approximately 41.8% of all pregnancies worldwide, with Africa having the highest prevalence at 61.3% - References:

2. 2021 GBD, Collaborators A. Prevalence, years lived with disability, and trends in anaemia burden by severity and cause, 1990–2021: findings from the Global Burden of Disease Study 2021, The Lancet Haematology, Jul. 2023, https://doi.org/10.1016/s2352-3026(23)00160-6

3. Mohamed Mussa A, et al. Prevalence of anemia and associated factors among pregnant women at Hargeisa Group Hospital, Somaliland. BMC Pregnancy Childbirth. May 2024;24(1). https://doi.org/10.1186/s12884-024-06 539-3.

4. Ahmed RH, et al. Anemia among pregnant women in internally displaced camps in Mogadishu, Somalia: a cross-sectional study on prevalence, severity and associated risk factors. BMC Pregnancy Childbirth. Dec. 2021;21(1). https://doi.org/10.1186/s12884-021-04269-4

NOTES:

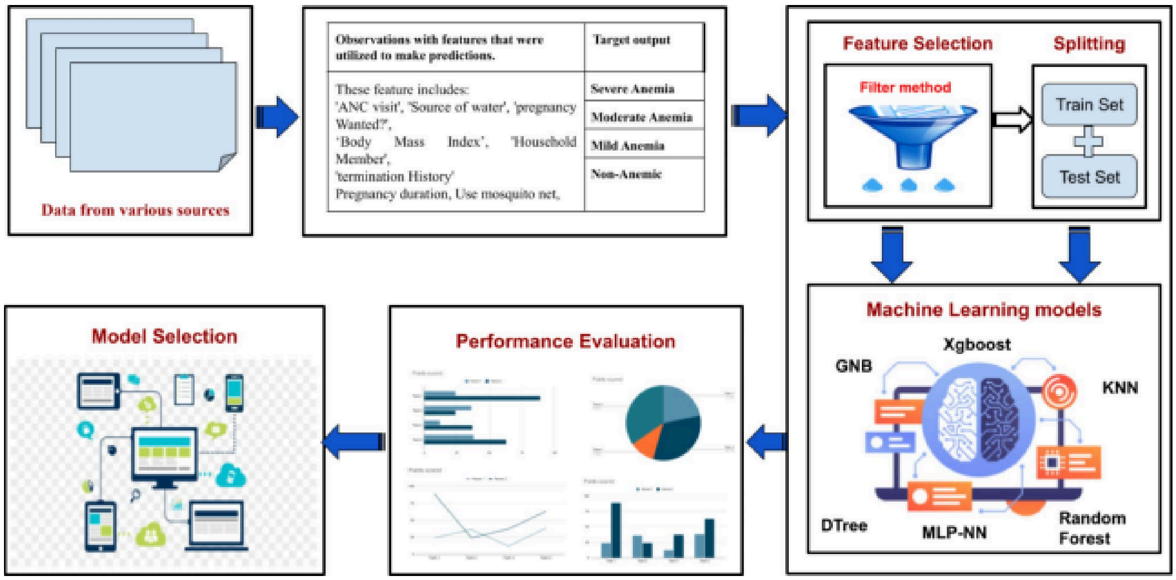
1. For continuous variables, we employed mean imputation, and for categorical variables, we replaced missing values with the mode to maintain data integrity and avoid bias

2. To address this, we incorporated cross-validation techniques in our model training pro - cess. This included k-fold cross-validation, which allows for a more reliable estimate of model performance by dividing the dataset into multiple subsets, ensuring that each instance is used for both training and validation across different iterations. This approach enhances the generalizability of our findings and assures that our mod - els perform well when applied to unseen data.

GENERAL : WHY ML?

To effectively address these challenges, leveraging machine learning (ML) presents significant opportunities. ML algorithms can analyse complex datasets to identify patterns that may not be evident through traditional methods, enhancing predictive accuracy. This approach allows for personalized healthcare solutions, optimizing resource allocation in low resource settings, and empowering healthcare providers with data-driven insights.

The distinct characteristics of each model played a crucial role in our analysis. For instance, the Multi-Layer Perceptron Neural Network (MLP-NN) is adept at capturing com - plex nonlinear relationships within the data [26], while the probabilistic nature of Gaussian Naive Bayes [27] offers a different perspective. The KNN classifier employs a distance-based approach [28], and the Decision Tree follows a rule-based methodology [29]. Additionally, we incorporated ensemble learning through Random For - est and the gradient boosting technique of XGBoost [30]. This diversity allowed us to compare the models from different perspectives in our study, and we categorized these distinct models into the following specific classes.



ANEMIA MACHINE LEARNING STEPS AND NOTES

WHY Mutual Information is done *before* training the model — it's part of the data preprocessing phase.

Importance

1.Speeds up training.

2.Reduces overfitting (the model doesn’t learn noise).

3.Improves accuracy by focusing on the most predictive features.

give code to do Mutual Information is done before training the model — it's part of the data preprocessing phase..............import pandas as pd

df = pd.read_csv("pregnant_women_anemia_dataset.csv")

 # List all columns (features)

print("📌 Columns in the dataset:")For each model, it performs:

- 🔍 **Grid Search (`GridSearchCV`)**
- 🎯 **Random Search (`RandomizedSearchCV`)**
- 📈 **Bayesian Optimization (`BayesSearchCV`)**

print(df.columns.tolist())....give code to do thus

QUESTIONS FOR MEDIC

1.Can there be a scenario where a person vomits and does not have nausea OR the person does not vomit but has nausea?

2.What point in time or how often does a medic want to receive updates of details on the symptoms of preeclampsia?Should it be daily,weekly or biweekly or based on as and when a pregnant woman feels like it?

3.Questions on our questionnaire- Are they good,what needs to be changed and added or removed?

- Can he help us administer the questionnaire to the pregnant women

4.Number of antenatal visits in relation to weeks of pregnancy(i.e minimum total of 14 antenatal vits)

- 1 to 28 weeks - One Visit per month
- 28 to 36 weeks - Two Visits per month
- 36 to 42 weeks - 1 visit per week

5.How often would you as a medic want to receive predictions of preeclampsia, anemia from the questionnaire(influencing how often she fills the form)?

6.For the data to be input manually, what is your proposed frequency of measurement and input from the urine dipstick?

GDM(Gestational Diabetes Mellitus) CONFUSION

1.Not a Direct Diagnosis, but a Risk Alert of the biomarker values that are indicating possibility of GDM

PARAMETERS TAKEN

1. Lipid Profile Biomarkers

- LDL (Low-Density Lipoprotein)

  - Why it matters: High LDL correlates with insulin resistance and cardiovascular risk in GDM.

- HDL (High-Density Lipoprotein)

  - Why it matters: Low HDL is associated with impaired glucose metabolism.

- Triglycerides

  - Why it matters: Elevated triglycerides are a hallmark of GDM-related dyslipidemia.

- Total Cholesterol

2. Glycemic Control Biomarkers

A. HbA1c (Glycated Hemoglobin)

  - Why it matters: Reflects average blood glucose over 2–3 months; ≥5.7% suggests prediabetes.

- OGTT Glucose Values

  - Fasting Glucose

    - Why it matters: Fasting ≥5.1 mmol/L (WHO criteria) indicates GDM risk.

  - 1-Hour Post-Load Glucose

    - Why it matters: Values ≥10.0 mmol/L signal glucose intolerance.

    - 2-Hour Post-Load Glucose

    - Why it matters: Values ≥8.5 mmol/L (WHO) or ≥7.8 mmol/L (NICE) diagnose GDM.

B. Clinical Utility:

   - Early prediction of HbA1c and fasting glucose could flag women needing immediate lifestyle interventions.

   - Triglycerides + HDL may help identify metabolic syndrome components before GDM onset.