LAUTECH Journal of Engineering and Technology 19 (2) 2025: 251-258
10.36108/laujet/5202.91.0262

Wireless Body Fat Measurement Machine with a Smartphone Interface

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Article Info

Article history:

Received: Apr 11, 2025
Revised: May 19, 2025
Accepted: May 29, 2025

Keywords:

Obesity,
Bioelectrical impedance,
Sensor,
Body-fat-composition

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ABSTRACT

Scientific literature and the World Health Organization (WHO) predict that in the year 2025, there will be about 2.3 billion adults globally who are overweight and 700 million who will be obese. This persistent metabolic disease has not been effectively addressed due to the use of inappropriate methods for measuring body fat and the unique characteristics of human physical and cellular structure. To ameliorate this condition, a new mechanism for weight measurement is proposed. The proposed mechanism operates with a minute alternating current (bioelectrical impedance technique) of 0.2– 0.8 mA via a two-lead finger. The device was designed with five components: 5 5-Volt Li-Po battery, a HC-05 Bluetooth module, a Dry electrode sensor, a Galvanic skin response sensor, and a programmable microcontroller (Arduino Shield) that is programmed to compute the voltage value for the body fat composition. The study was conducted within the University of Nigeria, Nsukka community, with adolescents aged 5 – 19 years for both genders and adults aged 20 – 38 years. The results revealed that as age (in years) and weight (in kg) increase, body fat percentage tends to increase. Weight in (kg) is a key parameter in the BMI method and was considered in the study, with consistent results as shown in the tables. To use the bioelectrical impedance technique, the approximated internal body resistance of 300 Ω – 1 kΩ, age (in years), and weight (in kg) are necessary to obtain a precise body fat percentage

INTRODUCTION

Adipose tissue, primarily visceral white adipose tissue, along with persistent mild inflammation, oxidative stress, insulin blockage, and hyperactive insulinemia, are the hallmarks of obesity, a complex, long-lasting metabolic illness (Abeso, 2021). According to the Body Mass Index, there are four categories for body weight or size: underweight (0 -18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25 – 29.9 kg/m²), and obesity (30 – 34.9 kg/m²). Obesity has also been classified using the waist-hip ratio and the waist circumference method, with values of < 90 centimeters for men and < 70 centimeters for women (Duclos, 2016).

Obesity is a complex medical problem caused by a poor diet, sedentary lifestyles, gender, and genetic factors (Abeso, 2021). When nutritional energy consumption exceeds energy outflow, an energy imbalance results, leading to an increase in the number of obese cases. Triglycerides, which are present in adipose tissue, grow in size or quantity and are then given additional energy once more, leading to weight growth (Chooi et al., 2019).

Nearly one-third of the world's population is classified as overweight or obese, and the number

of overweight and obese people has doubled since 1980 (Chooi et al., 2019). Regardless of topography, civilization, or literacy, records have improved for both sexes and at all ages, particularly adolescents (Chooi et al., 2019). According to recent data, obesity and overweight are the most prevalent dietary diseases of the century and the most modern health conditions, posing a persistent public health concern (Dhurandhar et al, 2022). Scientific literature and the World Health Organization (WHO) predict that in the year 2025, there will be about 2.3 billion adults globally who are overweight and 700 million who will be obese.

Obesity is known as a foremost public health challenge, since it affects nearly all biological functions of the body and adds to the rise of other comorbidities, such as cardiovascular diseases, diabetes, dyslipidemia, anxiety, depression, various types of cancer, sleep disorders, apnea and changes in hormonal and reproductive functions (Munawar et al., 2017). Because the Body Mass Index (BMI) is a mathematical estimate of weight-to-height computation, it has not been able to produce the necessary results to minimise obesity and other health risks linked with it. This is explained by the unusual composition of human fat, which is composed of 7% minerals in bone, 20% metabolic tissue, and 73% fat-free mass (Ernest, 2018). Bulkiness, the financial cost of body mass index (BMI) machines, and inaccessibility of bioelectrical impedance analysis (BIA) machines are some of the challenges that limit the increase in overweight or obesity.

This study aims to apply the bioelectrical impedance technique to classify body fat composition as normal weight, underweight, overweight, or obese, as referenced in the World Health Organization (WHO) index of body fat, and recommends having recommends having better, cheaper, and more accessible measurement methods to curtail overweight or obesity. Figure 1 is the design and development process for the hardware device.

MATERIAL AND METHODOLOGY

GSR Sensor and HC-05 Bluetooth device were connected to the Arduino shield board to assemble the gadget (all parts were bought from SICHIRAY, China). A 5V Li-Po power source with an ON/OFF control switch is attached to the Arduino shield board's barrel jack. The GND, TX, and 3.5V pins of the Arduino shield board are linked to the GND, VCC, and OUT of the GSR sensor. The HC-05 Bluetooth's TXD and RXD pins are linked to the A0 and A1 pins. The Arduino shield's G and VIN pins are linked to the Bluetooth's GND and VCC. A 5V Li-Po battery supplies an AC of 50 KHZ to Arduino Atmega328 16-MHz, which supplies a current of 0.2-0.8mA to the GSR sensor to create a sympathetic nervous movement of the skin for the current to have direct contact with the body fat. Two dry electrodes with gloves are stuck into two chosen fingers for five minutes as programmed by the Arduino IDE. The measured current from the human body is fed back to the Arduino Atmega328 16-MHz, which is converted to an output voltage. Thirty-eight persons were used for the study. Figure 1 is the procedure for hardware design. The components were selected to suit modern measurement methods for easy data storage and friendly usage.

To carry out a measurement, the parameters considered are: Age (in Years), Weight (in kg), and Voltage (in Volts), imputed into equations (1) and (2) for ideal body fat percentage:

$$\text{Female} = (0.1871 \times \text{Weight}) + 0.5800 \times \text{Age}) - (0.920 \times \text{Voltage}) \quad (1)$$

$$\text{Male} = (0.0923 \times \text{Weight}) + (0.01605 \times \text{Age}) - (0.0263 \times \text{Voltage}) \quad (2)$$

The female and male parameters of equations (1) and (2) represent ideal body fat percentage. The internal resistance of the human body of 300Ω was used for the computation.

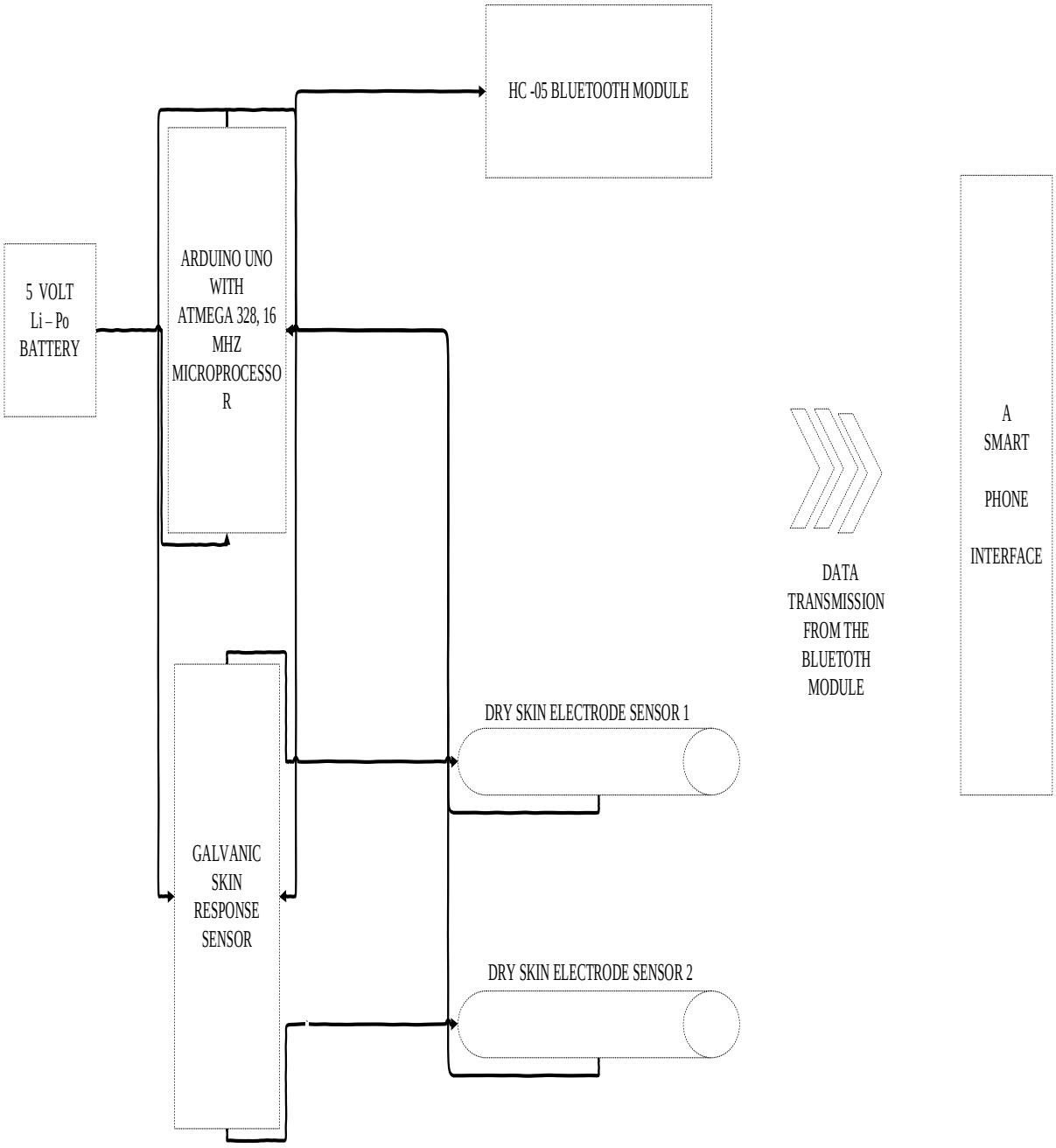

Figure 1. Block Diagram for the development of the body fat measurement machine with a Smartphone Interface

RESULTS

The variation in the body fat percentage for both genders for children aged 5 -19 years and adults of both genders aged 20 – 38 years is in Tables 2, 3, 4, and 5. The values are referenced with the WHO (World Health Organization) classifications of body mass as normal weight, underweight, overweight, and obese using the traditional BMI (Body Mass Index) as presented in Table 1.

DISCUSSIONS

Electrically charged ions are transported or conducted by the human body's cells. These bodily cells are crucial for figuring out a person's body fat percentage and confirming if they are overweight or obese. Because it is a function of height (in m^2) to weight (in kg), the commonly used body mass index (BMI) approach does work with this process.

Figure 2. Measurements of body fat with two-choice finger and a Smartphone Interface

Table 1: Classifications of BMI using weight in (kg) and height in (m^2) for the traditional BMI technique

Classification	**BMI (kilogram/m^2)**
Underweight	0 -18.5
Normal weight	18.5 - 24.9
Overweight	25 - 29.9
Obesity class 1	30 - 34.9
Obesity class 2	35 – 39.9
Extreme Obesity class 3	> 40

Table 2: Body fat percentage for females aged 5 - 19 years

Age (in Years)	Weight (in Kg)	Body Fat (%)	Categories
5	19	6.42	Underweight
6	21	7.37	Underweight
7	23	8.32	Underweight
8	25	9.28	Underweight
9	28	10.42	Underweight

10	31	11.56	Underweight
11	35	12.89	Underweight
12	40	14.41	Underweight
13	45	15.92	Underweight
14	51	17.64	Underweight
15	57	19.32	Healthy
16	62	20.84	Healthy
17	65	21.98	Healthy
18	69	23.31	Healthy
19	73	24.61	Healthy

Table 3: Body fat percentage for males aged 5 - 19 years

Age (in Years)	Weight (in Kg)	Body Fat %	Categories
5	16	2.27	Underweight
6	19	2.71	Underweight
7	21	3.05	Underweight
8	24	3.48	Underweight
9	26	3.84	Underweight
10	29	4.28	Underweight
11	32	4.27	Underweight
12	36	5.25	Underweight
13	40	5.23	Underweight
14	45	6.39	Underweight
15	49	6.93	Underweight
16	52	6.92	Underweight
17	53	7.61	Underweight
18	54	7.86	Underweight
19	56	8.20	Underweight

Table 4: Body fat percentage for women aged 20 - 48 years

Age (in Years)	Weight (in Kg)	Body Fat (%)	Categories
20	75	25.59	Healthy
21	77	26.55	Overweight
22	79	27.49	Overweight
23	81	28.46	Overweight
24	83	29.42	Overweight
25	85	30.37	Obese
26	87	31.33	Obese

27	89	32.27	Obese
28	91	33.23	Obese
29	93	34.18	Obese
30	94	34.95	Obese
31	95	35.72	Obese
32	97	36.69	Obese
33	99	37.62	Obese
34	101	38.58	Obese
35	103	39.53	Obese
36	105	40.45	Morbid Obese
37	107	41.44	Morbid Obese
38	109	42.40	Morbid Obese

Table 5: Body fat percentage for men aged 20 - 48 years

Age (in Years)	Weight (in Kg)	Body Fat (%)	Categories
20	56	8.36	Underweight
21	57	8.62	Underweight
22	58	8.87	Underweight
23	60	9.21	Underweight
24	61	9.47	Underweight
25	62	9.74	Underweight
26	63	9.72	Underweight
27	64	10.23	Underweight
28	65	10.48	Underweight
29	66	10.73	Underweight
30	67	10.74	Underweight
31	68	11.24	Underweight
32	69	11.49	Underweight
33	70	11.74	Underweight
34	71	12.00	Underweight
35	72	12.25	Underweight
36	73	12.50	Underweight
37	75	12.85	Underweight
38	75	13.01	Underweight

The bio-impedance analysis methods take into account the human skin's resistance to contact at the hand or foot. The results are inconsistent because, at a certain age, the skin and muscle fat tend to oppose the passage of the alternating current (bioelectrical impedance technique). With

the two approaches outlined, the device built for this study took into account the aforementioned constraints, and the results validate the actual health status of an individual when dealing with obesity and related health issues. To assess body fat composition, you need to know your weight (in kilograms), age (in years), and the approximate internal body resistance (between 300 and 1kΩ).

LIMITATIONS

If a better Bluetooth module is created to connect with smartphones and other smart electronic devices, the Arduino Shield device microcontroller can be made to communicate data from a single test. During a single test, the Galvanic Skin Response sensors can be configured with electrical devices to provide a display feedback of the minute's current flow into the human cell. The study was impacted by the limited data collection because a more thorough comparison analysis across various regions would have been possible with additional data. Lack of funding also had an impact on the study because other health sector stakeholders, such as institutions, religious leaders, and community leaders, could have helped raise awareness and mobilise the public.

CONCLUSIONS

Obesity, mobility impairment, cardiometabolic problems, and psychological suffering are all linked, indicating the need for an integrated, global approach to healthcare. To evaluate body fat composition, the current study looks at the need for a uniform body fat measurement technique that provides direct contact with the central body fat. This study has also established that as people grow, their body fat composition increases, so in assessing overweight or obesity, age is vital to achieve a valid value of body fat percentage.

AUTHOR'S CONTRIBUTIONS

Kingsley Celestine Omeke: Research Conceptualization and Design.

Columbus Tobechukwu Eze: Research Execution - experiments, data collection, fieldwork

Ugwu Gladys Ndidiamaka: Data Analysis

Ojo Omeiza David: Manuscript Drafting, Interpretation, and Discussion of Results

DECLARATIONS

Ethical approval: FPSRA/UNN/24/00130

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study and the institution's management.

Competing interests: Not applicable

Funding: This research received no external funding

Data availability statement: The original data presented in this study are included in the article.

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