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Design and Construction of Children's Basal Metabolic Rate Measuring Equipment Based on an Android Application for Height Parameter

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Abstract

This study aims to design and develop a Basal Metabolic Rate (BMR) measurement tool based on an Android application with a focus on children, utilizing the HC-SR04 ultrasonic sensor as the main component. This device utilizes the ultrasonic sensor to measure height automatically with high accuracy. The height measurement process is carried out automatically by the ultrasonic sensor, and the resulting measurement data is then integrated with the Android application. Within the application, users can input other necessary data to calculate the child's BMR, such as age and weight. The collected data is then processed by a pre-designed algorithm to directly generate an estimation of the child's BMR. The Android application serves as a user interface that facilitates interaction and monitoring of measurement results. Testing is conducted to validate the accuracy of the device and application and to ensure the availability of accurate information for users. Thus, the results of this research are expected to provide a significant contribution to monitoring and optimizing children's health through practical and efficient BMR monitoring.[1]

Keywords

Measurement tool for children's Basal Metabolic Rate (BMR), HC-SR04 Ultrasonic Sensor, Android Application.

Specifications table

Hardware name	<i>Children's Basal Metabolism (BMR) Measurement Based on Android Application (Height)</i>
Subject area	• <i>Electronics and Microcontroller system</i> • <i>Diagnostic</i>
Hardware type	• Measuring physical properties and in-lab sensors • Field measurements and sensors • Electrical engineering and computer science • Mechanical engineering and materials science
Closest commercial analog	<i>This device measures the height of a toddler who is located in a standing position at the mark of the device</i>
Open source license	CC BY-SA 4.0
Cost of hardware	80,48 US\$
Source file repository	DOI 10.17605/OSF.IO/RSHCV
OSHWA certification UID	-

1. Hardware in context

Lucky Kurniawan developed the "MEDCA" device, a BMI (Body Mass Index) and BMR (Basal Metabolic Rate) measuring tool with a coin acceptor as a usage requirement. In his research discussion, the researcher suggested that the mechanical parts of the device should be made from higher quality standard materials to prevent movement during weighing, and recommended the use of Bluetooth communication for height measurement to reduce the number of cables needed, thus making the design tidier [4].

In 2019, Fictor Marulitua Hutasoit, Sumarno, Fitri Anggraini, Indra Gunawan, and Ika Okta Kirana, in their study titled "Automation of Height Measurement at Bane Pematangsiantar Health Center Using Arduino Uno-based Ultrasonic Sensor," concluded that using an Arduino Uno ATmega 328P connected to an HC-SR04 sensor can establish an interface between the system and other subsystems, creating an integrated system. After testing the Arduino-based automatic measurement tool, it was concluded that the device successfully operated according to conditions detected by the HC-SR04 sensor, displaying results on an LCD. This automatic height measurement tool is expected to be developed further by adding electronic components that can automatically determine weight and incorporating a database form so that measurement data can be stored, resulting in a single device that measures both height and weight and includes a database for storing the measurement results [5].

The research by Akbar W and Rachmat H, titled "Design and Development of an Integrated Electronic Body Mass and Height Measurement System for Toddler Nutrition Evaluation," concluded that the integrated electronic body mass and height measurement device for toddler nutrition evaluation using a strain gauge sensor and ultrasonic transducer has a good linearity level. From three tests, the body mass linearity was found to be $R^2 = 0.9998$, and the body length linearity was $R^2 = 0.9999$. The precision level of the device was also quite good, with a precision of 0.15 kg for body mass and 0.12 cm for body length. Although not zero, these values are close to the device's accuracy specifications. However, the accuracy of the body length measurement was poor, with an error of 4.85 cm, which is significantly higher than the designed system's accuracy specification of 1 cm. This error was mainly due to the ultrasonic transducer's suboptimal performance inside the measurement box. To address this issue, system improvements in the measurement program and the construction of the sliding lever system in the measurement box are needed [6].

Priambodo's 2019 study titled "Design and Development of a Bluetooth Low Energy (BLE) Based BMI Measurement Tool Displayed on a Smartphone" suggested that the PVC pipe material used for the support stand could be replaced with a sturdier material, such as metal, for better durability [7].

The research by Lisa Choirunnanda, Triana Rahmawati, and Lamidi from the Department of Electromedical Technology at Poltekkes Kemenkes Surabaya, titled "Height Measurement Tool for Nutritional Status Testing in Toddlers Using Anthropometry Method," noted that most previous devices were designed specifically for measuring the weight and height of infants. The device they developed differs from previous tools in that it is specifically designed to measure both the weight and height of toddlers, as well as assess their nutritional status. The measurement results displayed on Delphi matched the values produced by the device. The nutritional status assessment results, displayed as z-scores on Delphi, were the same as those calculated manually, indicating that the nutritional status assessment program is accurate. Therefore, it can display the nutritional status corresponding to the measured weight and height of toddlers [8].

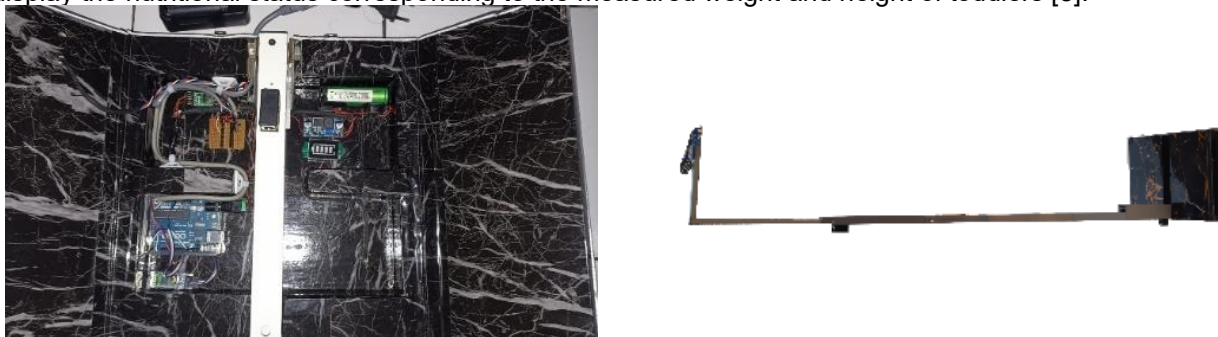


Fig.1. The proposed hardware of the Children's Basal Metabolism (BMR) Measurement Based on Android Application (Height)

Based on the developments in BMI calculation tools mentioned above, further advancements can be made in terms of portability and the use of Android applications. It is hoped that the literature review above will support the development of a BMI measurement tool for children aged 2 to 5 years as an early detection tool for stunting, featuring a portable design and Android application-based interface.

2. Hardware description

The formed system is a toddler's height measurement captured by an HC-SR04 sensor using the principle of ultrasonic wave reflection. The sensor consists of two main parts: a transmitter that emits waves and is reflected by objects in front of

it, then the reflected waves are captured back by the receiver. The sensor data is then sent to an Arduino Uno, where the Arduino Uno calculates the time it takes for the sensor to capture back the wave and then calculates and produces the height value. After obtaining the height data, it is sent to an Android application via the HC-05 Bluetooth module.

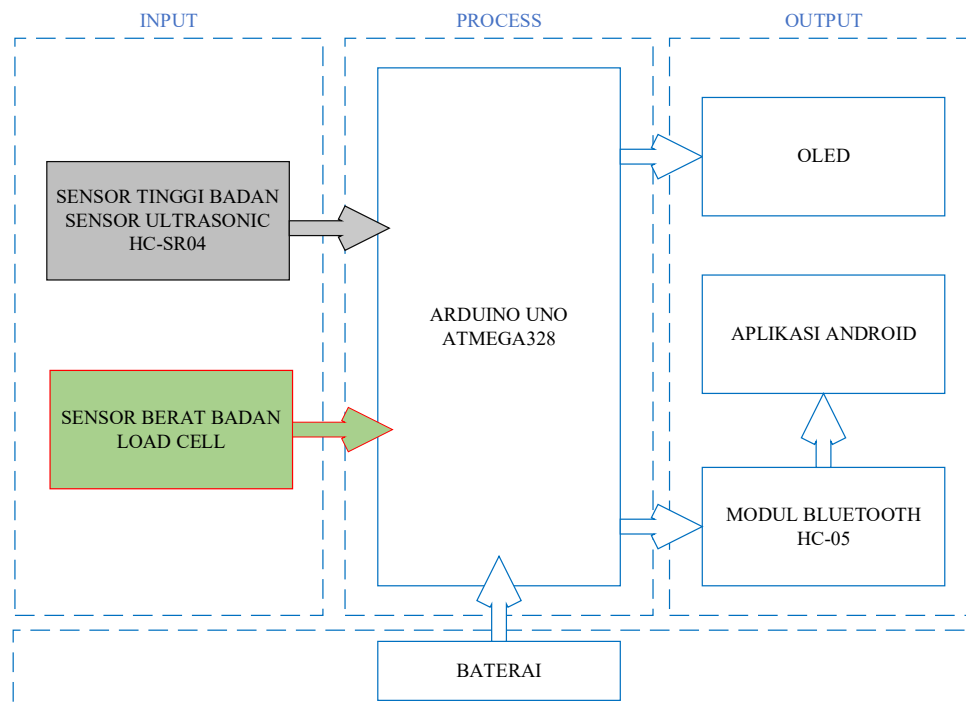


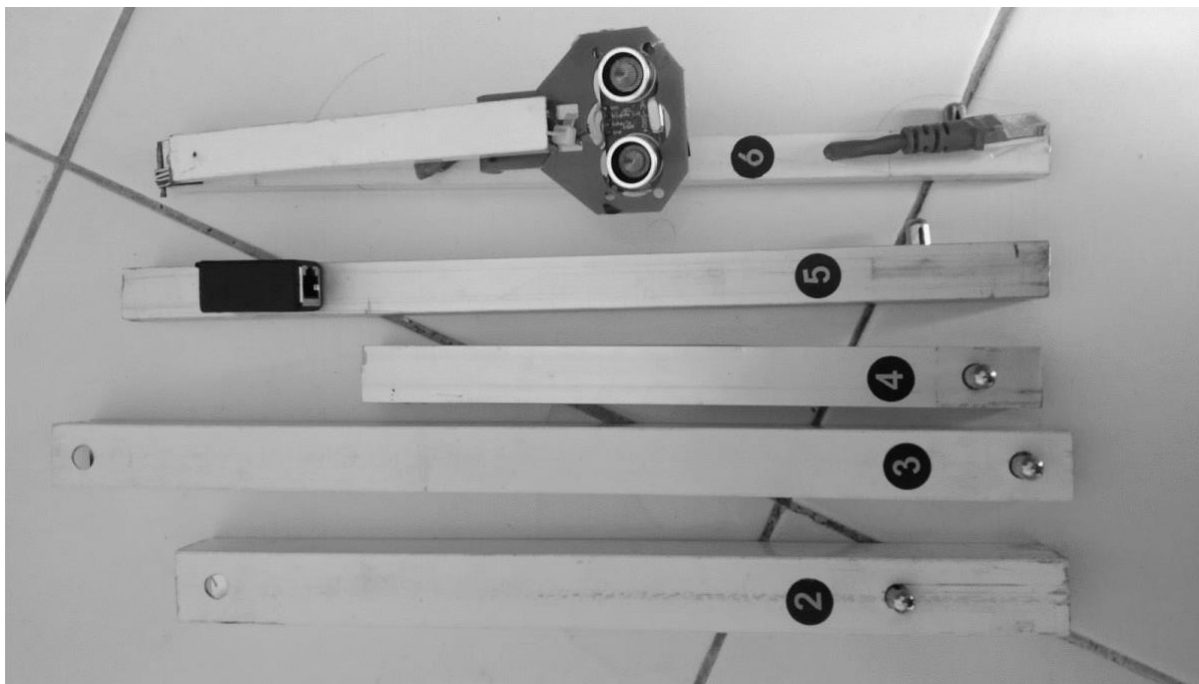
Fig. 2. The diagram block of the Hand exoskeleton model with bilateral rehabilitation mode

In FIGURE 1 show the diagram of the system. The Android-based BMR calculator is one of the tools that assist in displaying estimated RDA values for children aged 2 – 5 years old. This system consists of several blocks, including:

1. Ultrasonic Sensor HC-SR04: This sensor is used to measure the height of the child during measurement.
2. Age Setting: This setting is done in the Android application menu.
3. Gender Setting: This setting is done in the Android application menu.
4. Arduino Uno Atmega328: As the main control in running the BMR calculation program.
5. Bluetooth Module: as the data transmission sender for the child's height to the Android application.
6. Battery: serves as the voltage supply to the entire block circuit.
7. Android Application: is the display used as an interface in displaying the results of the child's BMR measurement.

2.1. HC-SR04 hardware

In the mechanical diagram above, the design of a BMR measuring device for children 2 to 5 years old based on an Android application is depicted. The image above provides an illustration of the changes that can occur in the mechanics of measuring height. Initially the tool was just a box, then the height sensor pole was pulled up. This mechanical plan prioritizes portable purposes to make it easier for users or medical personnel to carry it.



(a) parts of the height measuring pole



(b) Mast height after assembly

Fig. 3. Design Children's Basal Metabolism (BMR) Measurement Based on Android Application (Height)

2.2. Hardware Circuit

The HC-SR04 ultrasonic sensor circuit above has the advantage of being easy to use, readily available in the market, and reasonably priced. The Echo pin serves as the receiver pin for the ultrasonic waves created by the transducer and is connected to pin 9 of the Arduino. Meanwhile, the Trigger pin is responsible for activating the transducer to send ultrasonic signals. The OLED display is used to show the height measurement results. Before the data is sent to the application, we can also view the data on the OLED display. As for the Bluetooth circuit above, it functions to transmit the height measurement readings, where the data will be sent to the application via an Android smartphone..

Table 1
Summary of Arduino Uno Atmega328 Specification

Items	Specification
Mikrokontroler	ATmega 328
Operating Voltage	5 V
Input Voltage	7– 12 V
Input Voltage Limit	6 – 20 V
Number of digital I/O	14 digital pin (6 of them provide PWM output)
Number of Analog input pins	6 pin
DC current per I/O pin	40mA
DC current for the pin is 3.3 V	50mA
Memori Flash	32 KB (ATmega 328) about 0.5 KB used by the bootloader
SRAM	2 KB (ATmega 328)
EPROM	1 KB (ATmega 328)
Clock Speed	16 MHz

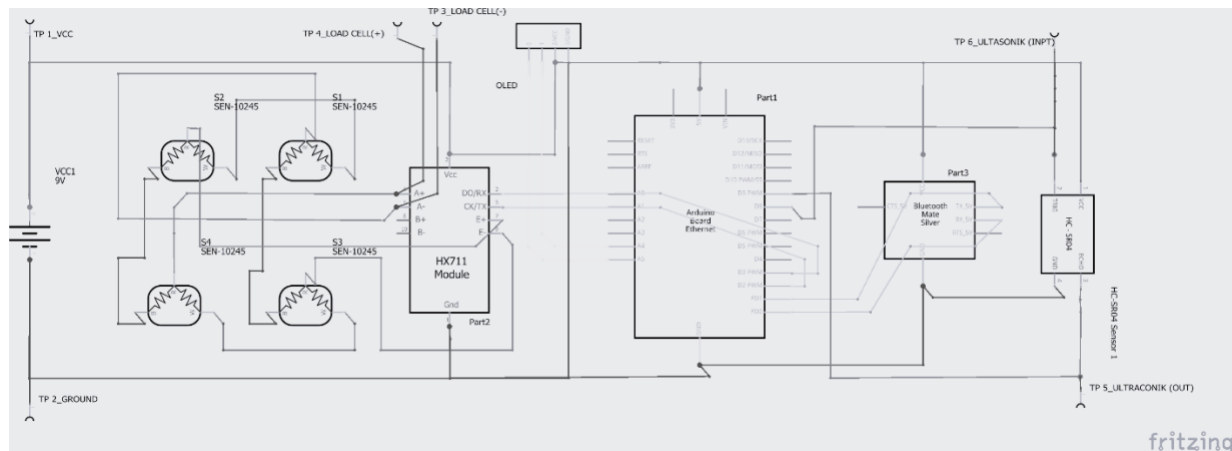


Fig. 5. Hardware circuit

2.3. Firmware

The software is divided into 2 parts, namely the Android application and Arduino Ide. **Figure 7** explains the flow diagram of a BMR measuring tool for children aged 2 – 5 years based on an Android application. When the tool is activated, on the Arduino blog, Arduino will initialize the sensors it has, namely the height and serial sensors. The height sensor will measure the height of children aged 2 to 5 years. Next, the height value will be sent to the Android application via the HC-05 module. **Figure 8** is a continuation of the height measurement results that have been sent from Arduino using Bluetooth. Next, after the application is opened, it will first be connected to the BMR calculating device using Bluetooth. The connected Bluetooth system will direct the user to enter the child's age and gender parameters. After the data, age and gender are obtained, the application will calculate the BMR results, carbohydrate, fat and protein levels and then display them.

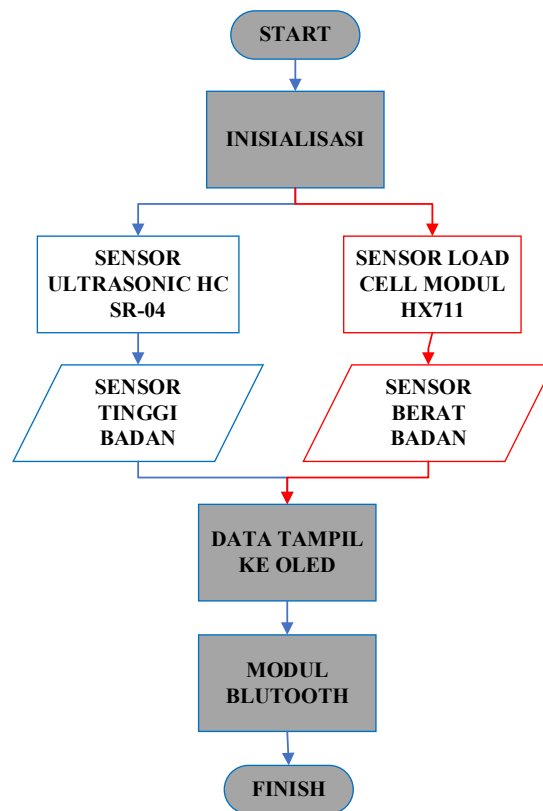
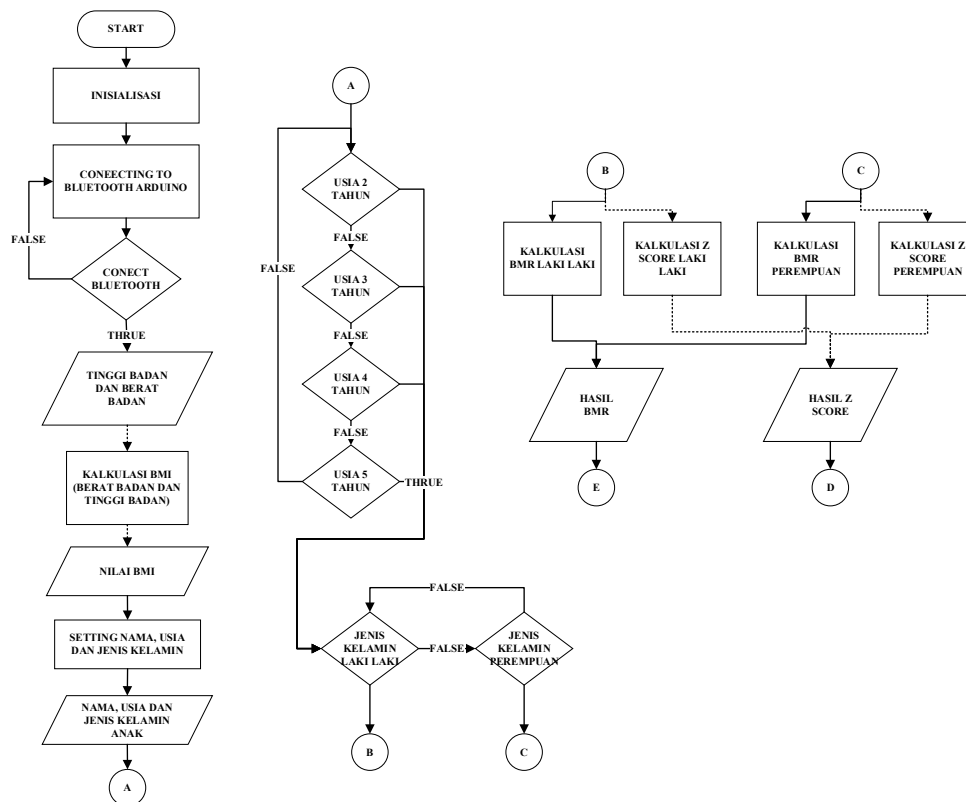


Fig. 7. Coding flowchart of hardware in arduino



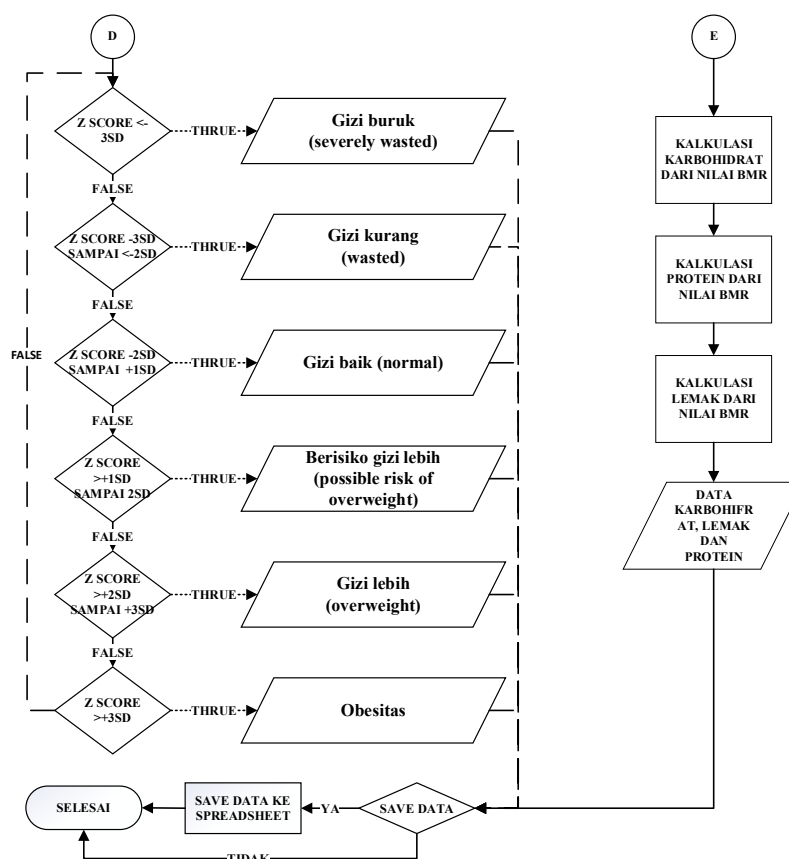


Fig. 8. Flowchart of Application

2.4. The advantages of this tool

Basal Metabolic Rate (BMR) or Basal Metabolic Rate (AMB) is the minimum energy requirement needed for vital body processes. Vital body processes include maintaining muscle tone, circulatory system, respiration, cell metabolism, and maintaining body temperature [3]. The energy needs of healthy toddlers are influenced by basal metabolism, growth rate, and energy expenditure used for activities. Energy from intake must still be considered as a control over the toddler's weight, while maintaining normal nutritional status. Distribution of macronutrient needs for children aged 1-3 years, namely 45% to 65% carbohydrates, 30%-40% fat, and 5%-20% protein. At the age of 4-5 years, the percentage of carbohydrate needs is still the same as the needs of children aged 1-3 years, namely 45-65%, but the fat requirement is slightly reduced, namely 25-35%, and the protein requirement is increased by 10-30%. (Krause and Mahan, 2021) [1]. Based on the explanation above, our device offers several advantages. It is portable and easy to carry around. The device is user-friendly because it comes with a guide within the app. Additionally, this counting device has a spreadsheet database to maintain children's calculation data. Most importantly, the connection between the device and the app uses Bluetooth, so it won't be an issue for areas with poor internet connectivity.

2.5. Cost

There are many types of stadiometers equipped with scales that are now available at affordable prices. However, many lack the complete features needed for use with toddlers, such as automatic BMR calculation and database functionality. Therefore, we have created this device specifically for monitoring toddlers during their growth and development process. This device is also portable, easy to carry around with a bag, and simple to use..



(a)



(b)

Fig. 9. (a) Stadiometer SAGA , (b) ONEHEALTH DIGITAL HEIGHT & WEIGHT SCALE ONEHEALTH

2.6. Summary

- (a) Based on the results of the discussion and the aims of the module created by the author, it can be concluded that:
- (b) 1) For overall performance, this tool uses several modules including Arduino UNO, HC-05, HC-SR04, and 5 volt DC voltage for the power supply voltage.
- (c) 2) The Arduino Uno microcontroller is programmed using the Arduino IDE which contains a program in the form of a section for initializing the HC-SR04 sensor pin, Oled pin then in the void setup and void loop sections there is a program for reading the HC-SR04 sensor and sending data to the application using the Bluetooth HC module - 05.
- (d) 3) The results of the accuracy of measuring the body length of toddlers have a good average reading value in reading body height. Then, in applying this sensor, the farther the object is from the sensor, the longer the reflection time will be.
- (e) 4) The design of the data distribution system from sensor readings to the Android application was successful and perfect, there was no difference in values, only a difference in readings of around $\frac{1}{2}$ second due to the delay in sending from the device to the application.
- (f) 5) In the process of testing the function of the tool, appropriate results were obtained where the application was able to detect the name, age and gender input from the application. Then the application also works well in receiving data from the device via Bluetooth.

3. Design files summary

3.1. Design file

This section explains the design files produced, including both the hardware design (schematics and printed circuit board (PCB)) and the firmware for operating the BMR measuring device and its application, as shown in Table 3.

Table 3
Design file summary of Toodler BMR calculator

Design file name	File type	Open source license	Location of the file
Aplication	.aia	CC BY-SA 4.0	DOI 10.17605/OSF.IO/RSHCV
Aplication	.apk	CC BY-SA 4.0	DOI 10.17605/OSF.IO/RSHCV
Firmware device	.ino	CC BY-SA 4.0	DOI 10.17605/OSF.IO/RSHCV
Blok board	.png	CC BY-SA 4.0	DOI 10.17605/OSF.IO/RSHCV
skematic	.pdf	CC BY-SA 4.0	DOI 10.17605/OSF.IO/RSHCV

3.2. Schematic and Board

The schematic file consists of the main device for measuring height, equipped with a Bluetooth module. This circuit includes an HC-SR04 sensor, OLED, and Bluetooth module, all directly connected to an Arduino ATmega 328 with a power supply from a rechargeable 18560 battery.

3.3. Firmware

firmware pengukur tinggi badan di buat di aplikasi arduino ide 1.8.19 dan untuk aplikasi android untuk perangkat lunak di buat menggunakan WEB MIT apps inventor.

4. Bill of materials summary

Table 4

Bill of materials of Toodler BMR calculator

Designator	Component	Number	Cost per unit (USD)	Total cost (USD)	Source of materials	Material type
	Arduino Uno Atmega 328	1	27,01	27,01	https://www.tokopedia.com/beetrona/arduino-uno-r3-original-made-in-italy-arduino-original	Semi-conductor
	HC-SR-04 ultrasonic sensor	1	3,41	3,41	https://www.tokopedia.com/salwapedia458/hc-sr04p-ultrasonic-mulai-modul-mulai-modul-sensor-3-5-5v-tegangan	
	Oled interfeace	1	3,17	3,17	https://shopee.co.id/product/2178321/294405238?gsht=DKw0uyfn1N5Bug6z	
	HC-05 Bluetooth Modul	1	4,02	4,02	https://www.tokopedia.com/fghggffuyt/modul-bluetooth-hc-05	
	Baterai Lithium 18560	1	2,38	2,38	https://www.tokopedia.com/maiden-indonesia/baterai-18650-vc7-3500mah-vc7-vc7-1pcs-e63df	
	Harware Scale (custom)	1	12,20	12,20	wood workshop in surabaya	

	Holo stainless teleskopik	2	7,68	15,37	https://www.tokopedia.com/bengkel-pak-agus/pipa-stainless-kotak-hollow-4x4-cm-p-100cm-hollow-stenlis-40x40mm-201	
	charger	1	1,89	1,89	https://www.lazada.co.id/products/alat-cas-batrai-lithium-charger-baterai-universal-untuk-tipe-18650163402665014500-dll-i986216895-s1480418602.html?from_gmc=1&fl_tag=1	
	RJ45 LAN cable can be rolled	1	0,91	0,91	https://shopee.co.id/product/2178321/6566760531?d_id=84b1f&uls_trackid=501jaip40061&utm_content=35cU9hNef6ohXsfxsCWRnAisw2JK	
	Conector Female female RJ45 LAN	1	0,79	0,79	https://www.tokopedia.com/kinza563/promooo-konektor-barel-rj45-coupler-cat-5-6-7-connector-barrel-lan	
	Waterpass	1	2,44	2,44	https://www.blibli.com/p/waterpass-kotak-mini-15-x-40-mm/is--IBG-70004-01048-00001?pickupPointCode=PP-3380196&srsId=AfmBOopAm9GU--luvwIUsY3vSsP4UENTitTgqONwsNg8LYaPQPovhs0CrKwE	
	Bag	1	6,89	6,89	https://www.blibli.com/p/tas-pakaian-kotak-tas-travelbag-tas-midik-tas-koper-mudik-tas-murah/is--HEA-70215-98813-00001?pickupPointCode=PP-3510631&srsId=AfmBOooZdKM4HVljWcw4KylRSmauY1soZUk-61Z_eIaMFnNjKCrGF68lQh8	

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5. Build instructions

5.1. Hardware Design

The mechanical design of the height measuring device uses stainless steel hollow rods of different sizes, allowing them to be nested like telescopic poles. For the weight measuring mechanism, durable hardwood is used and custom-shaped as shown in **Figure 10**.

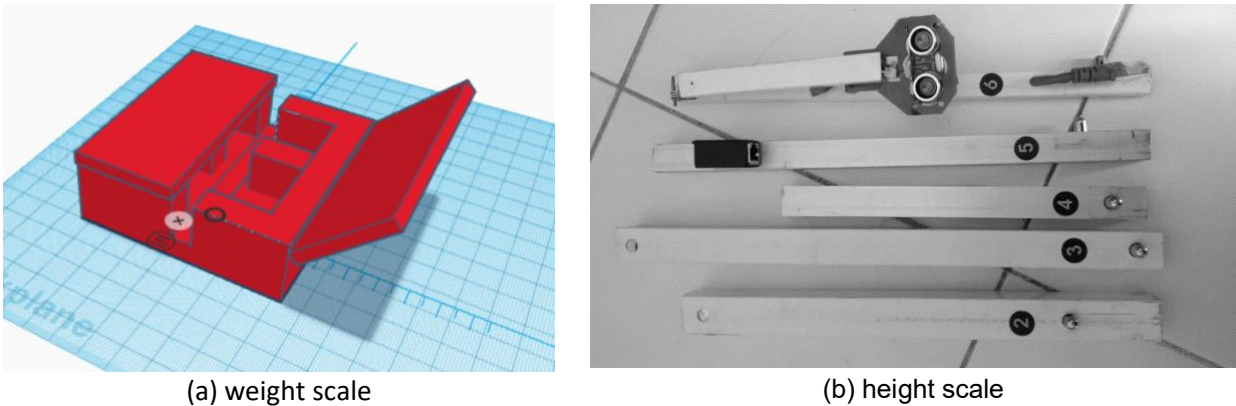


Fig. 10. Device

5.2. Firmware Design

The firmware is designed using the Arduino IDE 1.8.19 application. In this case, when the program runs, the system will display values on the serial monitor, and the Bluetooth module will receive and read the values on the monitor, which will then be sent to the application. Figure 11 (a) shows the listing that functions to send data to Bluetooth, and Figure 11 (b) shows the display when the monitor is shown.

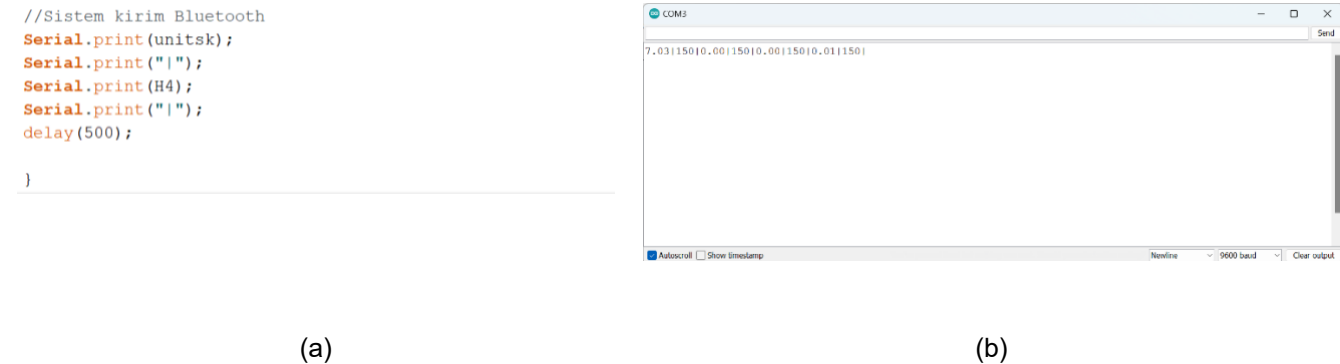


Fig. 11 (a) Running Arduino code to obtain the MAC address, (b) placing the MAC address on master program code.

5.3. Hardware Circuit

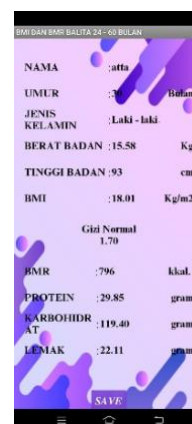
Once the program has been uploaded, the device is ready to operate. First, turn on the device, then connect the application to the device using Bluetooth. The device is now ready for use. After that, the toddler can stand for measurement.



(a) Subject



(b) Interfade Oled



(c) Aplication

Fig. 12. Circuit hardware build instruction

Figure 12(a) illustrates the use of the device, where a toddler stands on the device for measurement. Figure 12(b) shows the display on the device's OLED screen, which presents the height and weight measurements. The Arduino then sends this data to the Android application to calculate the child's BMR. The BMR calculator interface in the application can be seen in Figure 12(c).

6. Operation instructions

Instructions for using the device are as follows: first, assemble the separate telescopic rods into one unit. The rods are numbered, making assembly easy and foolproof. After setting up the height measurement mechanics, connect the height measurement wiring by linking the HC-SR04 sensor to the main board using the provided connector and coiled cable. Once all the mechanical components are in place, you can turn on the device by pressing the switch located inside the weight measurement mechanism box. After the device is powered on, connect the Android application to the device using Bluetooth connectivity. A complete application guide is available in the app menu. Once connected, the device is ready to use for measurement.

7. Validation and characterization

When measuring the comparison, the author compares the value with the measured misar. Comparison of measuring values was made from 50 cm to 140 cm and sensor reading results were obtained as in the table below

Table 7

the mean and standard deviation of height measurements with measured objects

Benda terukur	50	60	70	80	90	100	110	120	130	140
1	51	61	71	81	91	101	111	120	131	140
2	50	60	71	81	91	100	110	121	130	141
3	51	61	70	80	90	101	111	121	131	141
Rata-rata	50.6	60.6	70.6	80.6	90.6	100.6	110.6	120.6	130.6	140.6
SD	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27



(a)



(b)



(c)

Fig. 13. measuring objects using a ruler (a) reading results on oled (b) read results on application c).

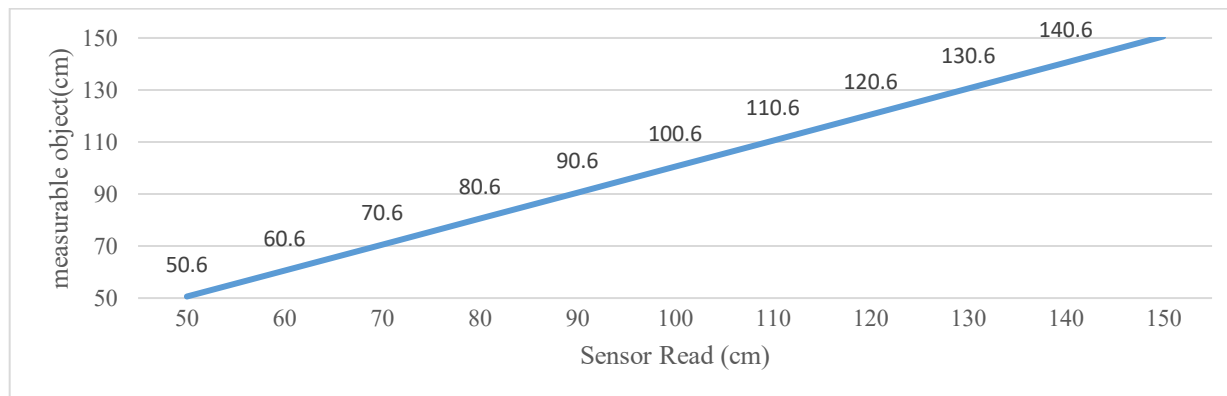


Fig. 14. linearity of sensor readings

8. Conclusion

The purpose of this study is to create a portable, user-friendly tool for calculating the Basal Metabolic Rate (BMR) of toddlers aged 1 to 5 years old, equipped with a simple database. This research demonstrates that the height sensor used, namely the HC-SR04, can be utilized to measure toddlers' height and is suitable for use. All data calculation systems are conducted within an Android application program, where the application is developed using the MIT App Inventor platform.

Ethics statements

Credit author statement

Toro Lego Pratama: Conceptualization, Methodology, and Software. **Andjar Pudji:** Data collection and measurement. **Muhammad Ridha Mak'ruf:** Design and Validation.

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Declaration of interests

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The authors declare that there is no conflict of interest.

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