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Growth Monitoring System Using Infant Length to Determine Nutritional Status in Children Aged 0-12 Months.

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ABSTRACT This research addresses the pressing issue of monitoring the growth and nutritional status of infants aged 0-12 months, a critical period for health and development. Inadequate growth monitoring can lead to undetected nutritional deficiencies and long-term health consequences. To tackle this problem, the study developed an innovative Growth Monitoring System that utilizes length, weight, and head circumference as key indicators of nutritional status. The system integrates advanced technology, including an ESP-32 microcontroller, load cell sensors for weight measurement, ultrasonic sensors for height measurement, and infrared sensors for head circumference measurement. The methodology involved collecting data from 30 respondents, where the system automatically recorded measurements and generated growth curves displayed on a web-based platform. The accuracy of the measurements was evaluated, revealing significant variability in error rates. Specifically, the highest error in head circumference measurement was recorded at 25.38%, while the weight measurement exhibited a lower error rate of -20.47%. These results highlight the challenges in achieving precise measurements but also demonstrate the system's capability to provide essential data for assessing infant growth. In conclusion, the developed Growth Monitoring System represents a significant advancement in child health monitoring, offering a reliable and efficient method for tracking the growth of infants. Despite the observed measurement errors, the system's automated data collection and analysis capabilities provide valuable insights into nutritional status. The research emphasizes the potential for broader implementation of such systems in pediatric clinics and national health programs, ultimately contributing to improved health outcomes for infants. By enhancing the accuracy and accessibility of growth monitoring, this research paves the way for more effective interventions in early childhood nutrition and health.

INDEX TERMS Body Length, Weight, Head Circumference, Website Builder

I. INTRODUCTION

One out of every four children worldwide experiences stunting. [1]. In some developing countries, the figure is even higher, with one in three children affected. This fact indicates that their physical growth and brain development are hindered due to inadequate nutrition. Malnutrition is a leading cause of approximately 2.6 million deaths annually, which accounts for one-third of total child deaths. [2] [3]. Stunting refers to the failure of growth that occurs as a result of prolonged accumulation of nutritional deficiencies, beginning from pregnancy to 24 months of age [4] [5].

This situation worsens due to the inability to catch up on delayed growth needed to achieve the expected growth. Stunting, or impaired growth, is the term used to refer to a

person's height being below what is expected for their age. This assessment is done by measuring the Z-Score of Height-for-Age (HAZ). If someone has a Z-Score of Height-for-Age less than -2 standard deviations (SD), they are considered to be experiencing stunting. The occurrence of stunting is caused by inadequate nutritional intake, both in terms of quality and quantity, as well as high levels of disease or a combination of both. Usually, this condition is often observed in countries with unstable economic situations. [6] [7]. Based on the Indonesian Nutrition Status Survey (SSGI) conducted by the Ministry of Health, the prevalence of stunting in Indonesian toddlers reached 21.6% in 2022. This figure saw a decrease of 2.8 percentage points compared to the previous year. The East Nusa Tenggara Province (NTT)

had the highest prevalence of stunting in toddlers at 35.3%, experiencing a decrease of 2.3 percentage points from 2021, when it was previously at 37.8%. Next, the West Sulawesi Province ranked second with a prevalence of stunting in toddlers at 35%. This was followed by the West Papua and West Nusa Tenggara Provinces, with respective prevalences of stunting in toddlers at 34.6% and 32.7%. It is observed that there are 18 provinces with prevalence rates of stunting in toddlers exceeding the national average. Meanwhile, 16 provinces have prevalence rates of stunting in toddlers below the national average. On the other hand, Bali Province recorded the lowest prevalence of stunting at the national level, at only 8%. This figure is significantly below the national average for stunting in 2022 [8][9].

Research related to stunting supports government efforts by monitoring child development through the analysis of height, weight, and BMI data. One relevant study is the research conducted by Avinash S. Vaidya and his colleagues [10]. The study titled "CGMS – An Automated Solution to Monitor Child's Growth" in 2014 discusses the accuracy limits in five height measurements, where the accuracy limit is 2 mm. Their experimental results indicate that measurement errors of about +/- 5 mm would not have a significant impact when BMI is used as a growth parameter. If measurement errors are caused by constant factors, techniques like regression can be applied to address these errors and reduce the risk of false negative results. The findings of this research have the potential to rapidly and affordably identify malnourished children in developing countries. In other words, this research focuses on the development of automated solutions for monitoring child growth using measurement tools such as height, weight, and body mass index (BMI).

This research demonstrates that when measurements have slight errors, analysis techniques like regression can help correct and reduce the likelihood of false negative results, providing an efficient and affordable way to identify children with malnutrition in the context of developing countries. Friska Oktaviana et al. wrote the journal article "Early Detection of the Risk of Stunting in Pregnant Women and Its Recommendations" (2020), which utilized forward chaining techniques to detect stunting with an accuracy rate of 89%. However, there is currently no detailed and comprehensive information available on the results of this research, such as socio-economic factors, educational backgrounds, and a more in-depth analysis [11]. Vilda Ana Veria. S in research "Mobile Health Nutrition Book Design to Prevent Stunting at Childreen. Heping Qian, dkk "A Self – Service Scheme of Infant Scale for Height and Weight "(July, 2019) In this study, parents can easily measure the height and weight of their baby and automatically record and generate a growth curve through their mobile phones. The generated tool has high precision, good stability, and convenient use, presenting reliable raw data. However, it is not mentioned how much accuracy it achieves, and there are still many other measurement parameters not included in this study [12].

Bayu Wahyudi et al., "Analysis of Baby Weight and Length Data using Arduino-based Baby Length and Weight Measurement Tools" (2021). This research employs the ARDUINO UNO microcontroller for processing data from an ultrasonic sensor to measure baby length and a load cell sensor to measure baby weight. The data is then displayed in Microsoft Excel with parameters leading towards a healthy growth chart (KMS). Additionally, the data is also shown on a 16x2 LCD as an alternative option for measurement without inputting data into the KMS. According to a comparison and analysis between the tool created by the authors and existing tools, the percentage results indicate a comparison of 0% to 3.5% for length measurements and 0.1% to 1.5% for weight measurements. Based on the obtained results, the tool created by the authors demonstrates normal conditions [13].

The aim of this research is to develop a Growth Monitoring System capable of accurately measuring the length, weight, and head circumference of infants and analyzing this data to assess their nutritional status. The system aims to provide an efficient and accurate approach in monitoring the health and growth of infants aged 0-12 months. Additionally, this research seeks to integrate technology for automated measurement and analysis, enabling the identification of abnormal growth patterns and facilitating timely corrective actions. The generated graphs will be presented through a website builder, displaying data on length, weight, and head circumference. The research also aims to evaluate the accuracy of measurements, with the largest observed error value in head circumference measurement at 25.38%, and the smallest error value in weight measurement at -20.47%.

This research provides diverse and significant contributions to the development of child growth monitoring. First, the study produces an innovative Growth Monitoring System capable of accurately measuring a child's length, weight, and head circumference. However, it goes beyond that by analyzing the collected data to evaluate the nutritional status of these children. Second, through the use of technology, this research enables an automated process of measurement and analysis, ultimately saving time and reducing the risk of human error in the process. Third, by focusing on length, weight, and head circumference as key indicators, this research offers an efficient approach to assessing the nutritional status of infants aged 0-12 months. This approach can detect abnormal growth patterns earlier and provide better guidance for timely corrective actions. Fourth, the utilization of comprehensive anthropometric data from a population of infants aged 0-12 months contributes to the development of a more accurate growth model. This model helps compare individual growth to the general growth trends of the population, providing valuable context in the assessment. Fifth, through visualized graphs presented via a website, this research raises awareness among parents

and medical professionals about a child's development. Finally, this research identifies error rates in anthropometric measurements, offering potential for improvement in measurement methods and data accuracy in the future. Overall, this research has a positive impact in driving the development of more advanced growth monitoring systems and provides significant benefits to the health and growth of early-age children.

II. MATERIALS AND METHODS

This research was conducted at a public health center in the city of Semarang. The data collection process involved 30 respondents within the age range of 0 to 12 months. Data collection was carried out calmly with the respondents. The recorded data will be sent via a website builder where the measurements of body length, weight, and head circumference for infants aged 0 to 12 months are stored. The module can also display the information on an LCD TFT screen. Meanwhile, the data collected on the website builder will be processed in Excel format. This research utilized a load cell sensor to detect weight, which is then connected to an HX711 module [14] [15] The load cell is utilized to obtain output values, and a Li-Po battery [16] is used as the power source. The microcontroller employed in this research is the ESP-32 [17]. The device's display utilizes an ILI9341 TFT LCD [18].
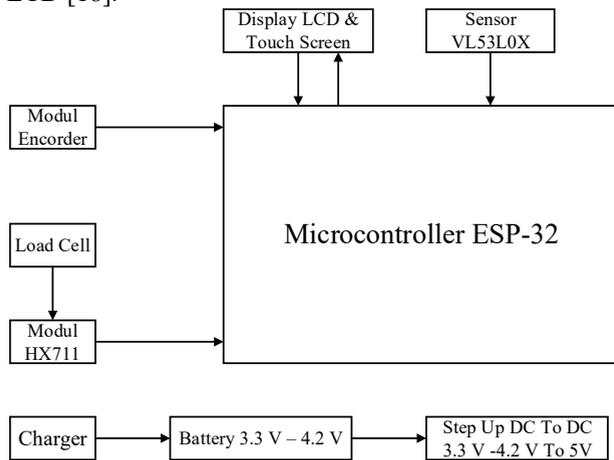

FIGURE 1. Block Diagram of Growth Monitoring System Using Baby's Body Length and Weight to Determine Nutritional Status in Children Aged 0 – 12 Months

The explanation for this block diagram is that the encoder module will be processed by the ESP-32 microcontroller, and then the load cell with the HX711 module [15]. The load cell sensor will detect pressure, indicating the weight of an object. The output from this load cell sensor will be received and processed by the ESP-32 microcontroller. The LCD display is used for menu selection, which will be processed by the microcontroller. The VL53L0X sensor is employed to detect distance, and this data will be processed by the microcontroller as well. The output from the ESP-32 will then be transmitted to the website builder.
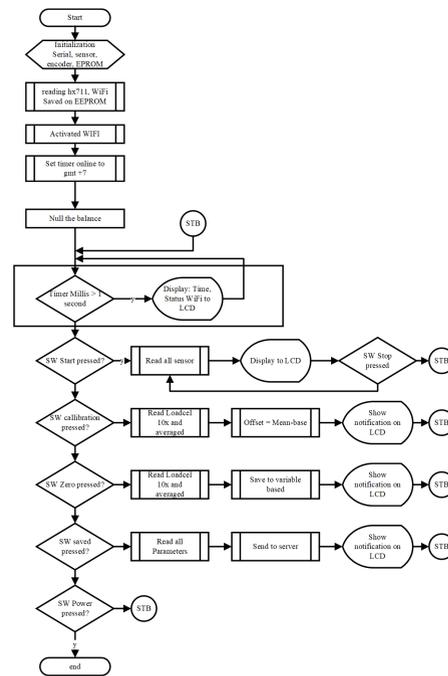

FIGURE 2. Program Flow Diagram

When **Figure 2** The design of this Growth Monitoring System involves placing the weight measurement sensor on a measurement board that serves as support when the subject is being measured. Meanwhile, the height measurement sensor is positioned at the top of the head, perpendicular to the reflector plate of the height sensor. The user interface consists of a display and keypad for inputting the gender, height, and weight data of the infant being measured.

A.   DATA ANALYSIS

The average is a number obtained by dividing the sum of the data values by the number of data points in the set. This formula will be used when data is collected 30 times to find the average value of the recorded Z-Scores. The formula for the average value is present in the eq (1) :

$$\overline{x} = \frac{x1+x2...+xn}{n} \tag{1}$$

Here, x represents the average for n measurements, x1 denotes the first measurement, x2 denotes the second measurement, and xn represents the nth measurement.

The %error indicates the system's error. A lower Error Value is the average difference from each data. Error can indicate a deviation between the standard and the design or model. The formula for error is shown in the eq (2).

$$\%ERROR = \frac{(x_n-x)}{x_n} \times 100\% \tag{2}$$

III. RESEARCH RESULT

In this study, testing of the module was conducted with 30 respondents. FIGURE **3** shows the results of the design of this research module:
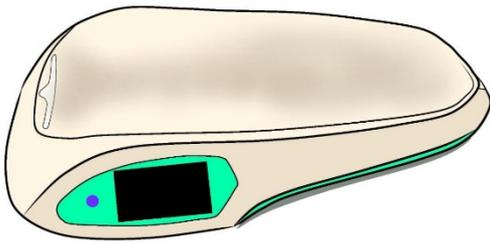
FIGURE 3. Tool Mechanical Diagram

This design consists of several modules, including the ESP-32 as the microcontroller, a Load Cell for measuring the weight of the respondents, and the HX711 module as an amplifier for the load cell readings. The encoder module is a device that generates output signals based on physical movement or changes in position. The VL530X sensor, often referred to as a Time-of-Flight (ToF) sensor, is a device used for measuring distance by calculating the time taken for reflected light to return from an object. This sensor is commonly used for distance detection and position measurement.

The ESP-32 module functions as the microcontroller controller, responsible for executing various control tasks, processing data, and reading output values from sensors. When the device is powered on, it can be set up with WIFI to display the data results through the monitoring website builder. The first step in filling out this website builder is to input the respondent's name, age, and gender. If the respondent is already on the device, the values for height, weight, and head circumference will be automatically generated and displayed on the website builder. **FIGURE 4.**
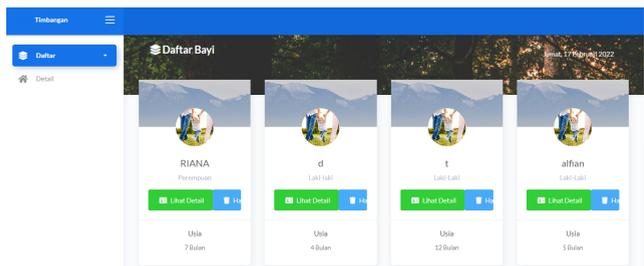

FIGURE 4. Display Results on Website Builder

Testing of this device was conducted to ascertain the accuracy of the readings. Below are the results of collecting data ten times with the module.

TABLE 1
Data Collection Results

No.	Respondent To-	Body Length	Weight	Head Circumference
1.	Respondent 1	77.7	4.2	35.1
2.	Respondent 2	46	1.9	48.9
3.	Respondent3	46	7.3	42.7
4.	Respondent4	53.8	2.3	55.6
5.	Respondent5	46	2.3	47.1
6.	Respondent 6	46	2.3	46.8
7.	Respondent 7	48	3.7	48.2
8.	Respondent 8	67.8	2.2	35.1
9.	Respondent 9	45	3.7	48.2
10.	Respondent 10	67	3.5	32.4

From the result **TABLE 1** diatas terlihat hasil pengumpulan data sebanyak 10 kali. In table 4.1 is the result of the selected measurements of 10 respondents' data by measuring body length, weight and head circumference.

In **TABLE 2** the results of the measurement values for respondents 1 to 10:

TABLE 2
Measurement results

No.	Information (Measurement)	Average	Error	STDV
1.	Body Length	54.33	18.10 %	2.77
2.	Weight	3.34	-20.47 %	0.26
3.	Head Circumference	44.01	25.38 %	2.97

This is the result of calculations from data from respondents 1 to 10. The largest error value during measurement was in measuring head circumference at 25.38% and the smallest error was in measuring body weight with a value of -20.47

TABLE 3
Measurement results on standards

Data	2 Kg	3 Kg	4 Kg	5 Kg	6 Kg	7 Kg	8 Kg	9 Kg	10 Kg
1	2.1	3.1	4.0	5.0	6.0	7.0	8.0	9.2	10.0
2	2.0	3.0	4.0	5.1	6.1	7.0	8.0	9.2	10.2
3	2.0	3.0	4.0	5.1	6.1	7.0	8.1	9.2	10.1
4	2.0	3.0	4.0	5.1	6.1	7.0	8.0	9.2	10.1
5	2.0	3.0	4.0	5.0	6.2	7.0	8.0	9.0	10.0

In TABLE 3 is the result of measurements and tests using weights weighing from 2 kg to 10 kg. Measurements were carried out 5 times repeatedly.

TABLE 4
The calculation results

Output (Kg)	Average	Error (%)
2 Kg	2.02	-94
3 Kg	3.02	-94.3
4 Kg	4	-96
5 Kg	5.06	-96.2
6 Kg	6.1	-95.6
7 Kg	7	-93
8 Kg	8.02	-92.2
9 Kg	9.16	-90.3
10 Kg	10.08	-90.8

In TABLE 4 is the value of the measurement results in testing the module against the standard, where measurements are carried out 5 times in a row which results in accuracy. The table above contains the mean or average of each measurement value, there is also an error value, the smallest error value is -90.3% at a weight measurement value of 9 Kg and the largest error value is -96.2% at a weight measurement value of 5 Kg .
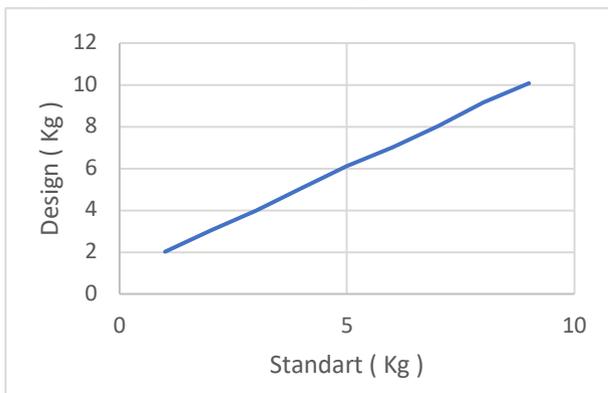

FIGURE 5. Test weight measurement

In FIGURE 5 is a test point graph that starts with measuring weights weighing 2 kg to 10 kg.

FIGURE 6. Combination measurement for length and weight

In FIGURE 6 The obtained values are from the output generated by the device. Respondent 1 has a length of 77.7 cm, a weight of 4.2 kg, and a head circumference of 35.1 cm. Based on the nutritional status results, Respondent 1 is classified as malnourished based on the Z-score value.

FIGURE 6. Combination measurement for length and weight

In FIGURE 6, The obtained values are from the output generated by the device. Respondent 3 has a length of 46 cm, a weight of 7.3 kg, and a head circumference of 42.7 cm. Based on the nutritional status results, Respondent 3 is classified as obese based on the Z-score value.

IV. DISCUSSION

The results of the discussion in this research reveal several significant findings and implications regarding the development of the Growth Monitoring System and the assessment of nutritional status in infants aged 0-12 months. Firstly, the research findings affirm that the developed Growth Monitoring System has a significant capability in accurately measuring the length, weight, and head circumference of infants. This finding underscores that the system can serve as a reliable tool in gathering crucial data for overall child growth monitoring. Furthermore, the data analysis conducted in this research is capable of providing in-depth insights regarding the nutritional status of children.

By analyzing the collected anthropometric data, the system can offer a more comprehensive assessment of the child's growth and nutritional condition. This brings clear benefits for parents and healthcare professionals in identifying potential growth or nutritional issues that require prompt attention. During the discussion, it was also revealed that the use of technology for automated analysis has helped reduce the time and effort needed to process data. This has the potential to provide significant benefits in situations where a quick response is required, such as detecting significant growth changes or health issues in children. In this context, it's important to note that the measurement results indicate a certain level of error in some aspects of the measurements, particularly in head circumference measurements. Nevertheless, these results offer valuable insights into the potential technical improvements in measurements to reduce errors in the future. Overall, the discussion results in this research provide strong support for the contribution of the Growth Monitoring System in providing crucial data for monitoring the health and growth of children. The implications generated from this research encourage the implementation of similar systems on a broader scale to support more effective and efficient child health monitoring efforts.

IV. CONCLUSION

Overall, this research has produced a Growth Monitoring System that utilizes the length and weight of infants as tools to assess nutritional status in children aged 0-12 months. The system comprises key components, including a microcontroller circuit involving the ESP-32, a load cell sensor, an HX711 module, an ILI9341 TFT LCD, an optocoupler encoder S51, and a VL53L0X sensor. Arduino programming is used to detect changes in the device, store data on the website builder, and serve as a monitoring tool. Measurement results from respondents 1 to 10 indicate that the highest error value occurred in head circumference measurement at 25.38%, while the lowest error occurred in weight measurement at -20.47%. The measurement process involves preparing the device, placing it in a stable position, and then the respondent can initiate the measurement by pressing the ON button. After the measurement is complete, the data value is saved on the website builder. Thus, this research has successfully developed a growth monitoring system that uses length and weight as indicators to evaluate the nutritional status of children aged 0-12 months. In addition to achieving the provided results, this research opens up potential for future development and steps that can make a significant contribution in the field of child growth and health monitoring. First, the development of growth models can be enhanced to consider broader variables, including genetic, environmental, and nutritional factors, which can provide a more accurate representation of the dynamics of child growth. Second, measurement technology needs to be improved to reduce errors, with exploration of more accurate sensors and more precise calibration methods

to enhance the validity of measurement results. Third, the development of integrated mobile applications can make it easier for parents and healthcare professionals to monitor child growth in real-time and provide advice based on monitoring results. Fourth, in-depth studies on nutritional factors, including nutrient intake and dietary patterns, will provide a more comprehensive understanding of the relationship between nutrition and growth. Fifth, the positive results of this research encourage the possibility of implementing similar systems on a larger scale, such as in pediatric clinics or national growth monitoring programs, to provide broader benefits in national child health monitoring efforts. By delving deeper into these directions, this research could play a role in advancing effective and efficient child growth monitoring in the future.

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