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DEVELOPMENT OF A SMART SCALE FOR DAILY FLUID INTAKE AND TOTAL BODY FLUID MONITORING IN THE ELDERLY

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ABSTRACT This research aims to design and build a weighing scale equipped with features for monitoring daily fluid needs and total body fluid in the elderly. This device is specifically designed to help the elderly monitor their fluid intake independently to prevent dehydration and improve their quality of life. The system uses an Arduino Mega 2560 R3 microcontroller, with a 3.5-inch TFT touchscreen display, and a weight measurement range of 30–100 kg and height of 120–180 cm. The research method used is design and development with stages of planning, creation, testing, and data analysis. The accuracy testing shows that the device is capable of measuring body weight with a satisfactory level of accuracy, as well as calculating daily fluid needs based on the Holiday-Segar formula and total body fluid based on the Watson formula. The analysis results on the device show that it functions well, with the weight sensor accuracy from the comparison with the weighing scale being 99.97%, the distance sensor accuracy from the comparison with the measuring tape being 99.67%, and the accuracy of the Holiday-Segar formula calculation being 99.81% and the Watson formula for men being 99.94% and for women being 99.86%. From the research results, it can be shown that this tool is effective as an aid for monitoring the health of the elderly, providing accurate and practical information, and supporting efforts to prevent dehydration among the elderly in the community.

INDEX TERMS Elderly, Holiday-Segar, Watson, Scale

I. INTRODUCTION

The elderly population in Indonesia continues to increase in line with rising life expectancy. Older adults are particularly vulnerable to various health problems, one of which is dehydration. Dehydration in the elderly can lead to serious complications such as impaired kidney function, confusion, and reduced mobility, ultimately resulting in a decreased quality of life [1]. Water plays a crucial role in maintaining body homeostasis, including regulating temperature, supporting digestion, transporting nutrients, and eliminating metabolic waste. Approximately 60% of an adult's body weight consists of water distributed within cells, blood, and interstitial fluids [2].

With advancing age, daily fluid requirements in the elderly become more critical due to physiological changes such as a diminished sense of thirst, reduced kidney function, and alterations in body composition that decrease total body water. The use of multiple medications (polypharmacy) also increases the risk of dehydration in elderly individuals [3]. These changes affect various aspects of life, including overall health [4]. To prevent dehydration, international geriatric organizations recommend a daily fluid intake of 1.5–2 liters. However, studies indicate that many elderly individuals fail to meet this recommendation, largely due to physical and cognitive limitations, as well as difficulties in recognizing early signs of dehydration [5], [6].

Existing fluid monitoring and weighing devices are generally not specifically designed for the elderly, thus limiting their effectiveness. Previous studies have developed various instruments, such as a weighing scale with daily fluid requirement display for children and adults using a load cell sensor [7], as well as an automatic height and weight measurement device based on the Broca method using Arduino UNO, load cell sensor, and HC-SR04 sensor [8]. Nevertheless, these studies did not specifically address the needs of elderly users.

This study focuses on the design and development of a weighing scale equipped with features for monitoring daily fluid requirements and total body water specifically for the elderly. Body weight is measured using a load cell sensor, while height is measured using an HC-SR04 ultrasonic sensor. Daily

fluid requirements are calculated using the Holliday-Segar formula, while total body water is estimated using the Watson formula. The device is designed with a body weight measurement range of 30–100 kg and a height range of 120–180 cm. This study does not cover other clinical aspects beyond anthropometric measurements and fluid requirement calculations. Furthermore, the respondents involved were elderly individuals aged 60–80 years[9] who met the inclusion criteria to avoid potential measurement risks, such as those with heart or kidney diseases where excessive fluid intake could worsen their condition [10], [11].
Based on these considerations, the objective of this research is to design and develop a weighing scale with integrated monitoring of daily fluid requirements and total body water for elderly individuals. This device is expected to assist the elderly in maintaining fluid balance more easily and accurately, thereby preventing dehydration and improving their quality of life.

II. RESEARCH METHODS

This study employed a design and development approach. The system was designed using an Arduino Mega 2560 R3 as the main controller [12], a load cell sensor for body weight measurement [13], an HC-SR04 ultrasonic sensor for height measurement [14], and a TFT touchscreen for data input and output [15]. The research procedure consisted of several stages, including system design (hardware and software), prototype development through sensor and display integration with the microcontroller, and testing and validation. Validation was performed by comparing the device's measurements with standard instruments such as calibration weights and measuring tapes to evaluate accuracy. The Holliday-Segar formula was used to calculate daily fluid requirements, while the Watson formula was applied to calculate total body fluid [16]. Data analysis was carried out by calculating percentage error to assess measurement accuracy and the reliability of formula implementation in the developed system.
Daily fluid requirements were calculated using the Holliday-Segar formula, which estimates fluid needs based on body weight[17], with 100 ml\/kg for the first 10 kg,50 ml\/kg for the next 10 kg,20 m\/kg for each kg above 20 kg.

Total body fluid was calculated using the Watson formula, with different equations for males and females, incorporating body weight, height, and age [17]:
For males in eq. (1) and female in eq. (2)

$$TBW\ (L) = 2.447 - (0.09516 \times Age) + (0.1074 \times Height) + (0.3362 \times Weight) \quad (1)$$

$$TBW\ (\text{L}) = -2.097 + (0.1069 \times \text{Height in cm}) + (0.2466 \times \text{Weight in kg}) \quad (2)$$

A. BLOCK DIAGRAM

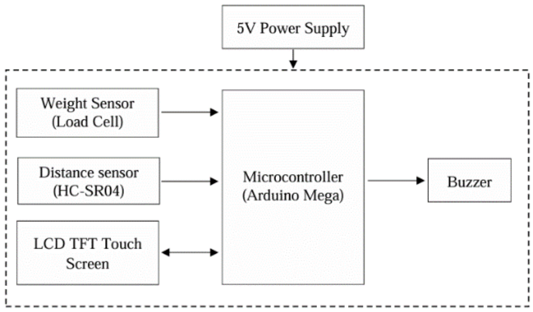

FIGURE 1. Block diagram of the weighing scale system for monitoring daily fluid requirements and total body fluid in the elderly.

The block diagram in Fig. 1 illustrates that the device operates with a 5-volt power supply. When the switch is turned ON, the Arduino Mega controls the entire system and displays the initial interface on the screen. The user selects gender and age on the display, after which the load cell sensor measures body weight and the HC-SR04 sensor measures body height. The acquired data are processed by the microcontroller to calculate and display the daily fluid requirements and total body fluid. The system is also equipped with a buzzer as a functional indicator [18].

B. FLOWCHART

The flowchart in Fig. 2 describes the system workflow from initialization to result display. The process begins when the device is powered on and initialization is completed. The user is then prompted to select gender and age, which are displayed on the LCD screen. Subsequently, body weight measurement is performed using the load cell sensor. If no measurement is obtained, the system remains in the measurement stage until valid data are acquired. Once body weight is successfully measured and displayed, the system continues with height measurement using the HC-SR04 ultrasonic sensor. Similarly, the height result is displayed on the LCD once measurement is complete. Gender, age, body weight, and body height data are then processed by the microcontroller to calculate daily fluid requirements using the Holliday-Segar formula and total body fluid using the Watson formula. The calculation results are displayed on the LCD. Finally, the user is given the option to perform another measurement or terminate the process.

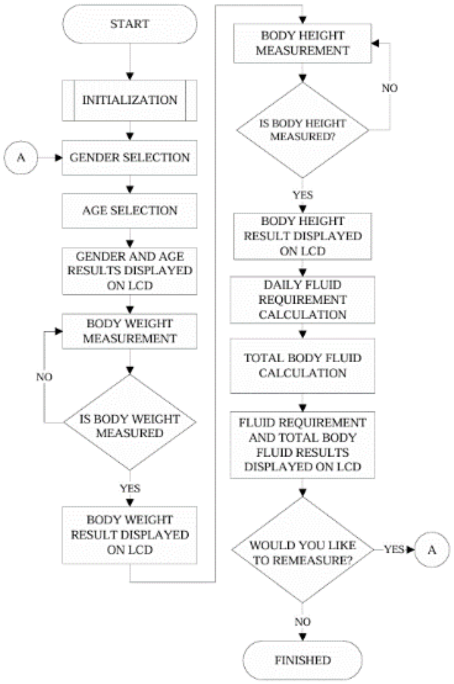

FIGURE 2. **Flowchart of the weighing scale system for monitoring daily fluid requirements and total body fluid in the elderly.**

C. SCHEMATIC DESIGN

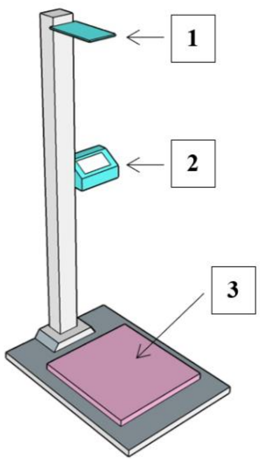

FIGURE 3. **Schematic design of the device for monitoring daily fluid requirements and total body fluid in the elderly.**

Fig. 3 presents the schematic design of the device used to measure daily fluid requirements and total body fluid in the elderly. The system consists of three main components. First, the HC-SR04 ultrasonic sensor functions as the input for height measurement. Second, the TFT touchscreen LCD serves as the user interface for entering gender and age data, as well as for processing and displaying measurement results. Third, the load cell sensor is used to measure body weight. The integration of these three components enables the system to calculate daily fluid requirements based on the Holliday-Segar formula and total body fluid using the Watson formula, with the results displayed directly on the screen.

III. RESULT AND DISCUSSION

A. PHYSICAL APPEARANCE OF THE DEVICE

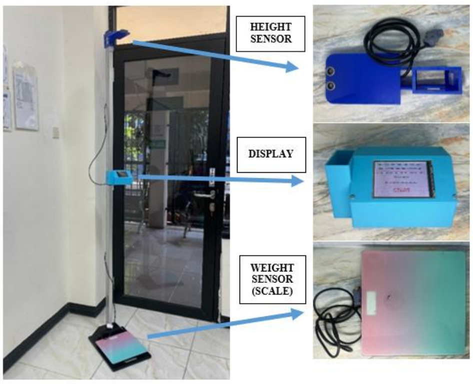

FIGURE 4. **Physical prototype of the weighing system with daily fluid requirement and total body water monitoring for elderly users. The device integrates a load cell sensor embedded in the scale platform for body weight measurement, an HC-SR04 ultrasonic sensor mounted on the pole for body height measurement, and a TFT LCD display for data input and output. The modular design ensures ease of use and accessibility for elderly users.**

The developed device is a digital weighing scale equipped with a height measurement stand and a TFT touchscreen LCD as the user interface. A load cell sensor is installed at the base of the scale to detect body weight, while an HC-SR04 ultrasonic sensor is placed on the stand to measure body height. The TFT LCD screen displays input menus for gender and age, as well as the measurement results of body weight, height, daily fluid requirements, and total body fluid. The physical design was created to be user-friendly for the elderly, featuring a simple interface, interactive buttons, and a sufficiently large display size as shown in fig. 4 ..

B. STANDART OPERATING PROCEDURE

The operating procedure of the device is described as follows:

1) The device is charged using a USB type-C cable.
2) The system is activated via the On/Off switch until the initial display appears on the screen.
3) The measurement process is initiated by pressing the *Start* button.
4) Gender data are entered by pressing “P” for male or “W” for female.
5) Age data are input using the “+” button to increase or the “–” button to decrease the value.

6) The user stands on the scale, allowing the system to measure body weight with the load cell sensor and body height with the HC-SR04 ultrasonic sensor.
7) Gender, age, weight, and height data are displayed on the screen, and the user presses the *Next* button to proceed.
8) The microcontroller calculates daily fluid requirements using the Holliday-Segar formula and total body fluid using the Watson formula. The results are displayed on the screen.
9) Upon completion, the user may press the *Back* button to return to the main menu or perform another measurement.
10) The system is turned off using the On/Off switch.
11) The device is stored in a safe place after use.

C. TESTING AND DATA ANALYSIS

This section presents the measurement data obtained from the device in accordance with the specified design. Data analysis was carried out by calculating the mean value, correction value, percentage of error, and percentage of accuracy. Through this method, the mathematical accuracy of the device in performing measurements and computations can be determined.

1) Body Weight Measurement

TABLE I
ANALYSIS OF WEIGHT MEASUREMENT DATA

Calibration Weight (kg)	Average (kg)	Error Value	Error %	Accuracy
30	30.02	0.02	0.00067	99.93 %
40	40.01	0.01	0.00025	99.98 %
50	49.99	0.01	0.00022	99.98 %
60	60.02	0.02	0.00033	99.97 %
70	70.01	0.01	0.00014	99.99 %
80	80.02	0.02	0.00025	99.98 %
90	90.02	0.02	0.00022	99.98 %
100	99.98	0.02	0.0002	99.98 %
Average Accuracy:				99.97 %

Testing of the weight sensor was performed by comparing the measurement results with standard calibration weights ranging from 30–100 kg. The results displayed on the TFT screen were compared with the standard values as shown in Table 1. . The load cell sensor achieved an average accuracy of 99.97%, indicating its high reliability in measuring body weight for elderly users.

2) Body Height Measurement

Height sensor testing was conducted by comparing the HC-SR04 ultrasonic sensor with standard measurements taken using a 300 cm measuring tape. The results on Table 2 displayed on the TFT screen showed an average accuracy of 99.67%, confirming the sensor's high performance in height measurement.

TABLE 2
ANALYSIS OF HEIGHT MEASUREMENT DATA

Measuring Tape (cm)	Average (cm)	Error Value	Error %	Accuracy
120	120.6	0.6	0.00500	99.50%
130	130.7	0.7	0.00538	99.46%
140	140.5	0.5	0.00355	99.65%
150	150.5	0.5	0.00333	99.67%
160	160.5	0.5	0.00309	99.69%
170	170.4	0.4	0.00235	99.76%
180	180.1	0.1	0.00056	99.94%
120	120.6	0.6	0.00500	99.50%
Average Accuracy:				99.67 %

3) Daily Fluid Requirement Calculation (Holliday-Segar)

This test employed the Holliday-Segar formula, where data collection was conducted by comparing the theoretical calculations of elderly daily fluid requirements with the results generated and displayed by the device as shown in Table 3. . The unit of measurement for this formula is expressed in liters. The testing was carried out at Panti Sosial Tresna Werdha Budi Mulia 3, involving 16 elderly respondents with body weight ranging from 35.4 to 79.9 kg. Each respondent underwent five measurement repetitions, and the results were analyzed to determine the accuracy of the device's calculations compared to manual computation.

TABLE 3
ANALYSIS OF DAILY FLUID REQUIREMENT DATA IN THE ELDERLY USING FORMULA 1

Theoretical Value (L/day)	Average (L/day)	Error Value	Error %	Accuracy
2.07	2.07	0.002	0.00097	99.90%
2.36	2.36	0.002	0.00085	99.92%
2.70	2.70	0.004	0.00148	99.85%
2.33	2.33	0.002	0.00086	99.91%
2.49	2.49	0.002	0.00080	99.92%
1.84	1.84	0.004	0.00218	99.78%
1.98	1.98	0.004	0.00202	99.80%
1.81	1.81	0.004	0.00221	99.78%
2.26	2.26	0.004	0.00177	99.82%
2.17	2.19	0.020	0.00923	99.08%
2.12	2.12	0.002	0.00094	99.91%
2.09	2.08	0.002	0.00096	99.90%
1.96	1.96	0.004	0.00204	99.80%
2.29	2.29	0.002	0.00087	99.91%
2.30	2.30	0.002	0.00087	99.91%
2.01	2.01	0.004	0.00199	99.80%
Average Accuracy:				99.81 %

Daily fluid requirement calculations were validated by comparing system results with manual calculations using the Holliday-Segar formula. The testing produced an average accuracy of 99.81%, indicating that the system performs fluid requirement calculations very reliably and close to manual results.

4) Total Body Fluid Calculation (Watson – Male)

In the Watson formula test for elderly males, data collection was performed by comparing theoretical calculations with the results computed and displayed by the device. The measurement unit of this formula is expressed in liters per day. The test was conducted at Panti Sosial Tresna Werdha Budi Mulia 3, involving 8 elderly male respondents aged 66–90 years, with body weights ranging from 35.4 to 79.9 kg and heights between 153 and 165 cm. Each respondent underwent five measurement repetitions, and the results were analyzed to determine the accuracy of the system in calculating total body fluid using the Watson formula.

TABLE 4
ANALYSIS OF TOTAL BODY WATER DATA IN ELDERLY MALES USING FORMULA 2

Theoretical Value (L)	Average (L)	Error Value	Error %	Accuracy
30.22	30.21	0.01	0.00044	99.96%
34.51	34.50	0.01	0.00040	99.96%
40.99	41.00	0.01	0.00018	99.98%
33.42	33.48	0.06	0.00178	99.82%
36.35	36.33	0.02	0.00057	99.94%
23.34	23.33	0.02	0.00065	99.94%
27.64	27.63	0.01	0.00037	99.96%
24.66	24.65	0.01	0.00040	99.96%
Average Accuracy:				99.94 %

Testing was carried out using data on body weight, height, and age of male subjects. The system's results were compared with manual calculations based on the Watson formula. From the data showed at Table 4, the device achieved an accuracy of 99.94%, demonstrating excellent implementation of the Watson formula for male subjects.

5) Total Body Fluid Calculation (Watson – Female)

In the Watson formula test for elderly females, data collection was carried out by comparing theoretical calculations with the results computed and displayed by the device. The measurement unit of this formula is expressed in liters per day. The test was conducted at Panti Sosial Tresna Werdha Budi Mulia 3, involving 8 elderly female respondents with body weights ranging from 43.1 to 60.2 kg and heights between 138 and 154 cm. Each respondent underwent five measurement repetitions, and the results were analyzed to determine the accuracy of the system in calculating total body fluid using the Watson formula.

Testing for female subjects was conducted using the same method, comparing system calculations with manual results. The device achieved an accuracy of 99.86%, confirming that the Watson formula for females is also implemented with high precision and reliability.

TABLE 5
ANALYSIS OF TOTAL BODY WATER DATA IN ELDERLY FEMALES USING FORMULA 3

Theoretical Value (L)	Average (L)	Error Value	Error %	Accuracy
27.01	27.02	0.01	0.00040	99.96%
27.51	27.71	0.20	0.00722	99.28%
26.54	26.53	0.01	0.00035	99.97%
25.67	25.64	0.03	0.00116	99.88%
23.82	23.81	0.00	0.00017	99.98%
28.61	28.59	0.02	0.00058	99.94%
28.25	28.23	0.02	0.00067	99.93%
25.10	25.09	0.01	0.00043	99.96%
Average Accuracy:				99.86%

IV. CONCLUSION.

Based on the testing and analysis conducted, it can be concluded that a weighing scale equipped with features for monitoring daily fluid requirements and total body fluid using weight and distance sensors has been successfully designed. The test results show that the load cell sensor was able to measure body weight with an accuracy of 99.97% compared to standard calibration weights ranging from 30–100 kg. The HC-SR04 ultrasonic sensor for height measurement also demonstrated high accuracy, achieving 99.67% compared to measurements taken with a 300 cm measuring tape. Daily fluid requirement calculations using the Holliday-Segar formula achieved an accuracy of 99.81%, while total body fluid calculations using the Watson formula reached 99.94% for males and 99.86% for females. Therefore, this device has been proven to provide highly accurate measurement and calculation results, making it suitable for use as a monitoring tool for fluid requirements in the elderly.

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