Waist-To-Height Ratio (WHtR) Assessment Device

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Abstract— **Many diseases are associated with excess abdominal fat like cardiovascular diseases. Monitoring and controlling abdominal fat is one of the many factors that can change the status of a person's health. Awareness of the waist-to-height ratio can be a guide to adjusting to a person's lifestyle and maintaining a normal waist-to-height ratio (WHtR) value. This study developed the WHtR assessment device that automatically calculates the WHtR value, displays the health status, and suggests the ideal waist circumference. The device is composed of a microcontroller that interconnects the other components of the device. A touchscreen liquid crystal display component was used as an input and output unit at the same time. The several tests that were conducted revealed accurate WHtR value calculation. The device is effective in assessing the health status of all age groups. The ideal waist circumference from the device was compared to manual computation and found that the success rate was one hundred percent (100%).**

Keywords— *waist-to height-ratio; microcontroller; liquid crystal display*

I. INTRODUCTION

Abdominal excess fat is a significant and independent risk factor for the disease. Research supports the measurement of waist circumference to assess the risks associated with obesity or excess weight. Studies have shown that WHtR is a stronger cardiovascular risk and mortality predictor [1]. The most commonly used criterion for assessing the frequency of overweight has been the body mass index. BMI can be used to screen for categories of weight that may cause health problems but is not a diagnosis of an individual's body fatness or health. BMI critics find it most disturbing that the measurement does not take full account of abdominal fat, also known as visceral adipose tissue (VAT), which gathers around the internal organs as people gain excess weight and is more dangerous than regular subcutaneous fat as it acts differently in the body [2].

Meanwhile, studies have found that the waist-height ratio is a good indicator of the risk of heart attack, stroke, or death, but the risk of diabetes has not been confirmed. The ratio of waist to height has a function to measure body fat distribution. Higher waist-height ratio values indicate a higher risk of cardiovascular diseases related to obesity because they are correlated with abdominal obesity. To examine the relationship between the ratio of waist to height (WtHR) and body fat, it is widely accepted that being overweight, historically defined as having a body mass index greater than twenty-five kilograms per square meter, is a major risk factor for a wide range of chronic diseases and injuries, including cardiovascular disease, type II diabetes, and certain site-specific cancers, including colorectal and breast cancer [3-4].

Though there are a lot of websites that have WHtR calculators, there is still no hand-held device without an internet connection that calculates the waist-to-height ratio of individuals. For this reason, this study developed a hand-held device that calculates WHtR, assesses the health status based on WHtR value, and suggests an ideal waist circumference for the user.

II. METHODS

A. Design and Specification

Fig. 1 shows the overall arrangement of components of the waist-to-height ratio assessment device. The block diagram is composed of a microcontroller by Arduino, a touchscreen LCD by Nextion, and a power supply unit. The touchscreen LCD served as the input and output unit of the device while the microcontroller served as the processing unity of the device. The power supply unit was responsible for giving the proper voltage input for the device to function.
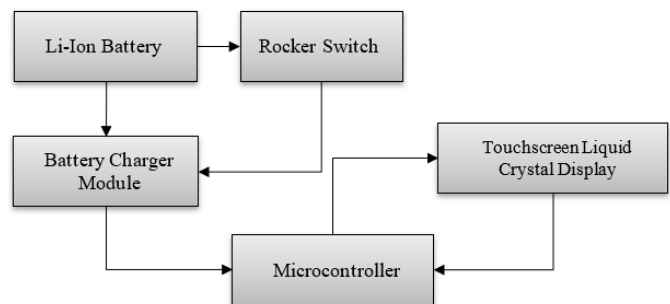

Fig. 1. The block diagram of the device.

Fig. 2 is the schematic diagram of the waist-to-height ratio assessment device. The 3.2" Nextion LCD serves as the input and output device of the system. The TX and RX of the Nextion LCD are connected to the D11 and D10 of the Arduino, respectively while the 5V and the GND of the Nextion LCD are connected also to the 5V and GND pins of the Arduino. The two 3.7V 18650 lithium-ion batteries are connected to the battery charger protection module. The input and the output of the battery charger protection module are connected to the DC power jack and Arduino Uno microcontroller, respectively. The DC power jack is used to charge the battery with a 7.4V charger.
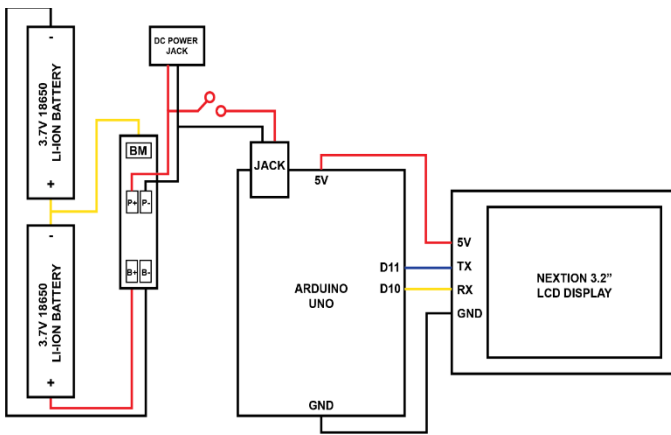
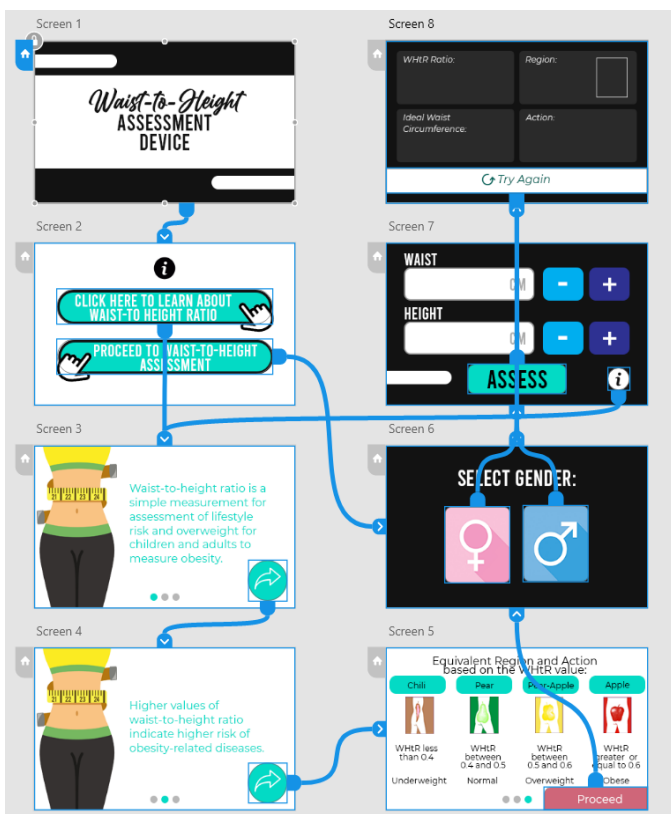Fig. 2.   The schematic diagram of the device.

Fig. 3.   The wireframe of screens in the device.

Fig. 3 shows the wireframe of the screens or the layout of the screens that will be shown in the LCD. It displays the functional elements in the screen like the pages and buttons. Screen 1 is the loading screen of the device. After loading the contents of the assessment device, Screen 2 will be shown. On Screen 2, the user needs to select from the two choices. The first choice is "Click here to learn about waist-to-height ratio". If this choice is selected, Screen 3 will be shown. Screen 3 gives information about the waist-to-height ratio to the user. Additional information is shown on Screen 4 and Screen 5 when the next graphical button is pressed. From Screen 5, the proceed button can be clicked to proceed to the waist-to-height

ration assessment screen that starts at Screen 6. Screen 6 is immediately shown if the second choice from Screen 2 is selected. The second choice is to "Proceed to waist-to-height assessment". Screen 6 is where the user will select the gender. The pink background image represents "female" and the blue background image represents "male". After selecting the gender, Screen 7 will be shown where the user inputs the waist and height in centimeters using the plus (+) and minus (-) buttons. When the waist and height are entered, the user can press the "Assess" button to proceed to Screen 8 where the waist-to-height ratio, body shape region, ideal waist, and proposed action are shown. From Screen 7, the user can also click the information button to proceed to Screen 3.
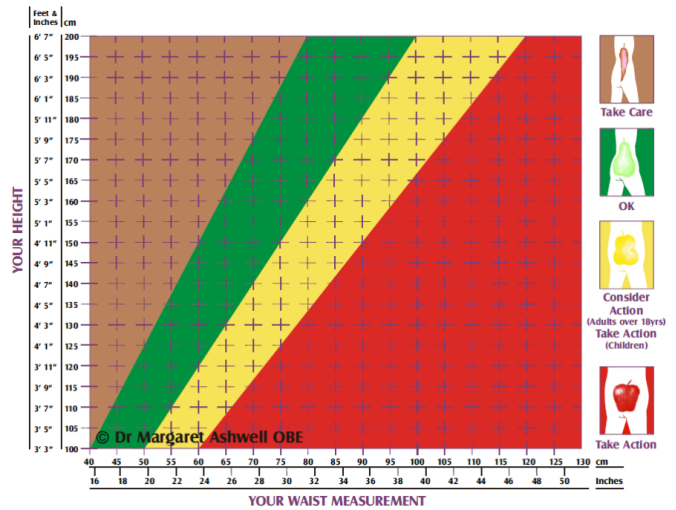
B.   Waist-to-Height Ratio Assessment

Fig. 4.   The shape chart was developed by Dr. Margaret Ashwell.

The study follows the shape chart shown in Fig. 4 developed by Dr. Margaret Ashwell, President of the Association of Nutrition in the United Kingdom. The waist-to-height ratio allows the same boundary values for children and adults [5]. It serves as reference data when the waist and height are read by the device. There are four regions in the chart described in Table I.

TABLE I.   BODY SHAPE REGIONS AND POSSIBLE ACTION OF THE PERSON

WHtR Value	Region	Action
less than 0.4	Chili	Take Care
between 0.4 and 0.5	Pear	Good or Ok
between 0.5 and 0.6	Pear-Apple	Consider Action
greater than 0.6	Apple	Health is probably at risk - Take Action

The WHtR is the value of waist circumference in centimeters divided by the value of the height in centimeters. The SI units of measurement were used in entering the waist circumference and height. The formula (1) is used by the device to calculate the WHtR value.

$$WHtR = \frac{Waist\ Circumference(cm)}{Height(cm)} \quad (1)$$

The ideal waist circumference (IWC) is the product of the normal WHtR value and the height in centimeters. It is used to identify the target waist circumference of the individuals for guidance concerning their health status. The formula (2) is used by the device in calculating the ideal waist circumference. Since the study of [6] found out that a mean WHtR of 0.50 was indicative of elevated risk cardiometabolic disorders, the normal WHtR value used to calculate the ideal waist circumference was set to 0.49 in the device. This value can be changed to a value between 0.40 to 0.49 of WHtR by reprogramming the microcontroller.

$$IWC = normal\ WHtR\ value\ x\ height\ (cm) \quad (2)$$

III. RESULTS AND DISCUSSION

Fig. 5 shows the functional WHtR assessment device developed in this study. It is a portable device with a rechargeable battery that can be taken anywhere. The case is 3D printed and the material used was a glycol-modified version of Polyethylene Terephthalate (PET), which is commonly used to manufacture water bottles. The battery and the Arduino Uno microcontroller are firmly connected to the case. The case also supports the whole upper part of the device holding the Nextion LCD which is used as an input and output unit and the rocker switch which is used to turn on or turn off the device.

Fig. 5. The WHtR assessment device.

The waist and height of twenty (20) individuals composed of ten (10) males and ten (10) females were used to test the features of the device. The features of the device that were tested are the ability to compute WHtR value, assess body shape region, suggest ideal waist circumference, and recommend an action to take concerning their health status.

The first test focused on the calculation of the WHtR value as shown in Table II. Using the formula (1), the WHtR was computed by the device giving a value with two decimal places. These values were compared to the values calculated using a web-based WHtR calculator. The web-based calculator shows WHtR values with four decimal places [7].

TABLE II. CALCULATION OF WHtR VALUE

Person	Gender	Waist (cm)	Height (cm)	WHtR Value	
				Device	Website
1	M	80	170	0.47	0.4706
2	M	95	175	0.54	0.5429
3	M	90	160	0.56	0.5625
4	M	72	162	0.44	0.4444
5	M	69	173	0.40	0.3988
6	M	83	165	0.50	0.5030
7	M	56	167	0.34	0.3353
8	M	96	151	0.64	0.6358
9	M	62	164	0.38	0.3780
10	M	75	168	0.45	0.4464
11	F	72	165	0.44	0.4364
12	F	54	169	0.32	0.3195
13	F	69	148	0.47	0.4662
14	F	94	154	0.61	0.6104
15	F	83	157	0.53	0.5287
16	F	77	164	0.47	0.4695
17	F	91	161	0.57	0.5652
18	F	67	171	0.39	0.3918
19	F	77	137	0.56	0.5620
20	F	56	169	0.33	0.3314

Rounding the WHtR value to two decimal places will give the same WHtR results that the device calculated. This proves that the device is highly accurate in calculating the WHtR value. Apps and devices used in clinical settings must be accurate because the scoring results can impact a clinician's decision [8]. The assessment of the body shape region where the individual falls was also tested using the same data from the first test as presented in Table III. Using the WHtR value calculated, the device assessed the body shape region. The assessment of the device is compared to manually looking at the chart in Fig. 4.

TABLE III. ASSESSMENT OF BODY SHAPE REGION

Person	Gender	Waist (cm)	Height (cm)	WHtR	WHtR Body Shape Region	
					Device	Chart
1	M	80	170	0.47	Pear	Pear
2	M	95	175	0.54	Pear Apple	Pear Apple
3	M	90	160	0.56	Pear Apple	Pear Apple
4	M	72	162	0.44	Pear	Pear
5	M	69	173	0.40	Chili	Chili
6	M	83	165	0.50	Pear Apple	Pear Apple
7	M	56	167	0.34	Chili	Chili
8	M	96	151	0.64	Apple	Apple
9	M	62	164	0.38	Chili	Chili
10	M	75	168	0.45	Pear	Pear
11	F	72	165	0.44	Pear	Pear
12	F	54	169	0.32	Chili	Chili
13	F	69	148	0.47	Pear	Pear
14	F	94	154	0.61	Apple	Apple
15	F	83	157	0.53	Pear Apple	Pear Apple
16	F	77	164	0.47	Pear	Pear
17	F	91	161	0.57	Pear Apple	Pear Apple
18	F	67	171	0.39	Chili	Chili
19	F	77	137	0.56	Pear Apple	Pear Apple
20	F	56	169	0.33	Chili	Chili

The device was very precise in determining the body shape of the individuals. The results of the assessment using the device can be seen from a liquid crystal display immediately instead of tracing it on a chart which can be difficult for users

with poor eyesight. Having poor eyesight is one common problem of obese individuals [9]. The feature of the device in suggesting an ideal waist circumference was also checked. The results shown in Table IV were compared to half of the height of the individual.

TABLE IV.   IDEAL WAIST CIRCUMFERENCE SUGGESTION

Person	Gender	Waist (cm)	Height (cm)	WHtR	Ideal Waist (cm)	Half of Height (cm)
1	M	80	170	0.47	83.30	85.00
2	M	95	175	0.54	85.75	87.50
3	M	90	160	0.56	78.40	80.00
4	M	72	162	0.44	79.38	81.00
5	M	69	173	0.40	84.77	86.50
6	M	83	165	0.50	80.85	82.50
7	M	56	167	0.34	81.83	83.50
8	M	96	151	0.64	73.99	75.50
9	M	62	164	0.38	80.36	82.00
10	M	75	168	0.45	82.32	84.00
11	F	72	165	0.44	80.85	82.50
12	F	54	169	0.32	82.81	84.50
13	F	69	148	0.47	72.52	74.00
14	F	94	154	0.61	75.46	77.00
15	F	83	157	0.53	76.93	78.50
16	F	77	164	0.47	80.36	82.00
17	F	91	161	0.57	78.89	80.50
18	F	67	171	0.39	83.79	85.50
19	F	77	137	0.56	67.13	68.50
20	F	56	169	0.33	82.81	84.50

The suggested ideal waist circumference by researchers is less than half the height of the person [10-11]. This can be deemed upon the test results where all of the suggested ideal waist circumferences are less than half the height of the person. It is worth noting that if the person has a body shape region under the pear category, there is no need to make drastic moves to reach the ideal waist circumference suggested by the device.

TABLE V.   HEALTH STATUS AND RECOMMENDED ACTION

Person	Gender	WHtR	Recommended Action	Health Status
1	M	0.47	Good	Healthy
2	M	0.54	Consider Action	Overweight
3	M	0.56	Consider Action	Overweight
4	M	0.44	Good	Healthy
5	M	0.40	Take Care	Healthy Slim
6	M	0.50	Consider Action	Healthy
7	M	0.34	Take Care	Extremely Slim
8	M	0.64	Take Action	Morbidly Obese
9	M	0.38	Take Care	Healthy Slim
10	M	0.45	Good	Healthy
11	F	0.44	Good	Healthy
12	F	0.32	Take Care	Extremely Slim
13	F	0.47	Good	Healthy
14	F	0.61	Take Action	Morbidly Obese
15	F	0.53	Consider Action	Overweight
16	F	0.47	Good	Healthy
17	F	0.57	Consider Action	Very Overweight
18	F	0.39	Take Care	Healthy Slim
19	F	0.56	Consider Action	Very Overweight
20	F	0.33	Take Care	Extremely Slim

The last feature that was verified is the ability of the device to recommend action for the person having the particular WHtR as shown in Table V. The recommendation of the device was correlated to the health status assessed based on

WHtR by a health-related calculator website [7]. The results of the health status assessed by the health-related calculator website confirm that the action recommended by the device is a good action for the individuals. Healthy individuals were not asked to take any action. For individuals who are healthy slim and extremely slim, the device recommends taking care of their body. Finally, individuals assessed as morbidly obese are recommended to take action. This assessment only serves as a guide and is not intended to substitute professional health care.

IV.   CONCLUSION

This study developed a working prototype of a waist-to-height ratio assessment device. The device is accurate in calculating the WHtR values and precise in determining the body shape region. It is also capable of suggesting an ideal waist and recommending corrective actions for users.

The device can be improved by incorporating a digital tape measure instead of manually entering the waist and height. A feature to send data from a web database can also be added to keep assessed information and make it accessible for future purposes.

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