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Waist-to-height ratio assessment device

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ABSTRACT

Many diseases are associated with excess abdominal fat like cardiovascular diseases. Monitoring and controlling abdominal fat led to one of the many factors that can change the status of a person's health. Awareness of the waist-to-height ratio (WHtR) can be a guide to adjusting to a person's lifestyle and maintaining a normal 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 testing that was 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 is one hundred percent (100%).

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1. INTRODUCTION

Obesity is becoming a worldwide epidemic [1], as it has been linked to a wide range of chronic diseases. The abnormally high and uneven distribution of body fat is what causes obesity [2], which is categorized as a chronic condition. Body mass index (BMI) is still the most used criterion for assessing obesity wherein numerous tools [3]–[5] have been developed to ease the assessment. However, research suggests the measurement of waist circumference [6] to assess the risks associated with obesity or excess weight.

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 [7]. Abdominal excess fat is a significant and independent risk factor for developing type 2 diabetes and cardiovascular diseases [8].

A study has found that the waist-height ratio (WHtR) is a good indicator of the risk of heart attack, stroke, or death [9]. 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 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 [10], [11].

Though there are lots of websites that calculate WHtR, there is still no hand-held device without an internet connection that calculates the WHtR 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. The methods section of the paper explains the fabrication and development of the device, while the results and discussion section present its testing results. The overall conclusion with regard to the use of the device and future improvements are discussed in the conclusion section.

2. METHOD

2.1. Design and specification

Figure 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 liquid crystal display (LCD) by Nextion, and a power supply unit. The Arduino microcontroller served as the processing unit of the device. It is a general-purpose microcontroller [12] that is commonly used for electronic projects. This microcontroller was chosen for data acquisition and calculation because it has been profusely applied for measurement tasks [13]. It is also a low-cost [14] and open-source electronics platform based on easy-to-use hardware and software [15]. The touchscreen LCD served as the input and output unit of the device. The power supply unit was responsible for giving the proper voltage input for the device to function.

Figure 2 is the schematic diagram of the waist-to-height ratio assessment device. The TX and RX of a 3.2 inches Nextion LCD are connected to D11 and D10 of the Arduino, respectively while the 5 V and the GND of the Nextion LCD are connected also to the 5 V and GND pins of the Arduino. The two 3.7 V 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 direct current (DC) power jack and Arduino Uno microcontroller, respectively. The DC power jack is used to charge the battery with a 7.4 V charger.

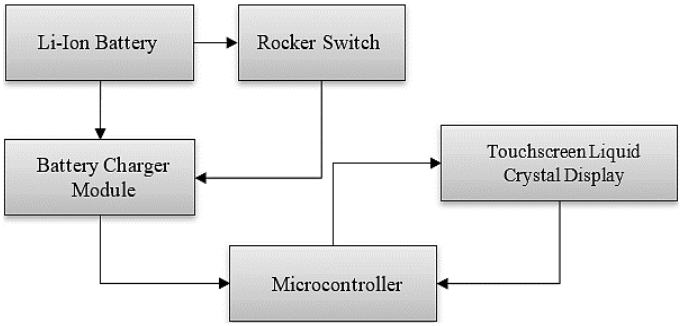

Figure 1. The block diagram of the device

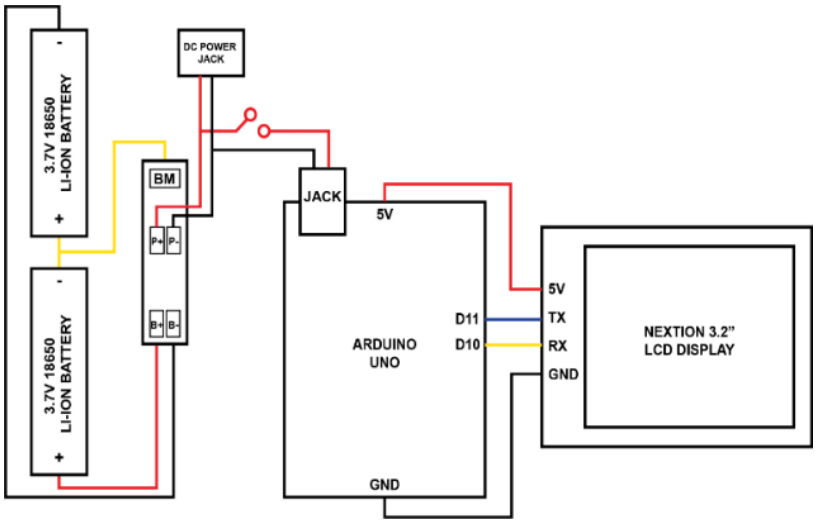

Figure 2. The schematic diagram of the device

Figure 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 on 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. In 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 WHtR 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 WHtR assessment screen that starts on 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.

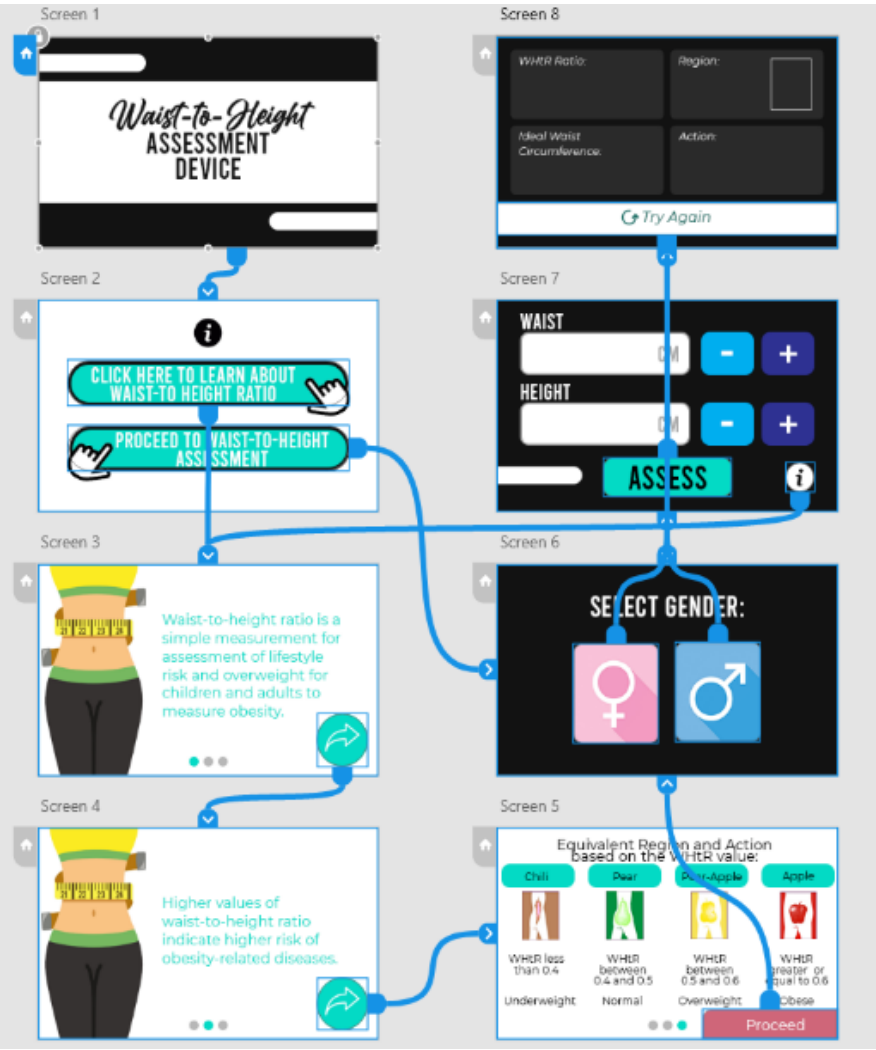

Figure 3. The wireframe of the screen in the device

2.2. Waist-to-height ratio assessment

The study follows the shape chart shown in Figure 4 developed by Ashwell and Hsieh [16], President of the Association of Nutrition in the United Kingdom. WHtR allows the same boundary values for children and adults. 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 1.

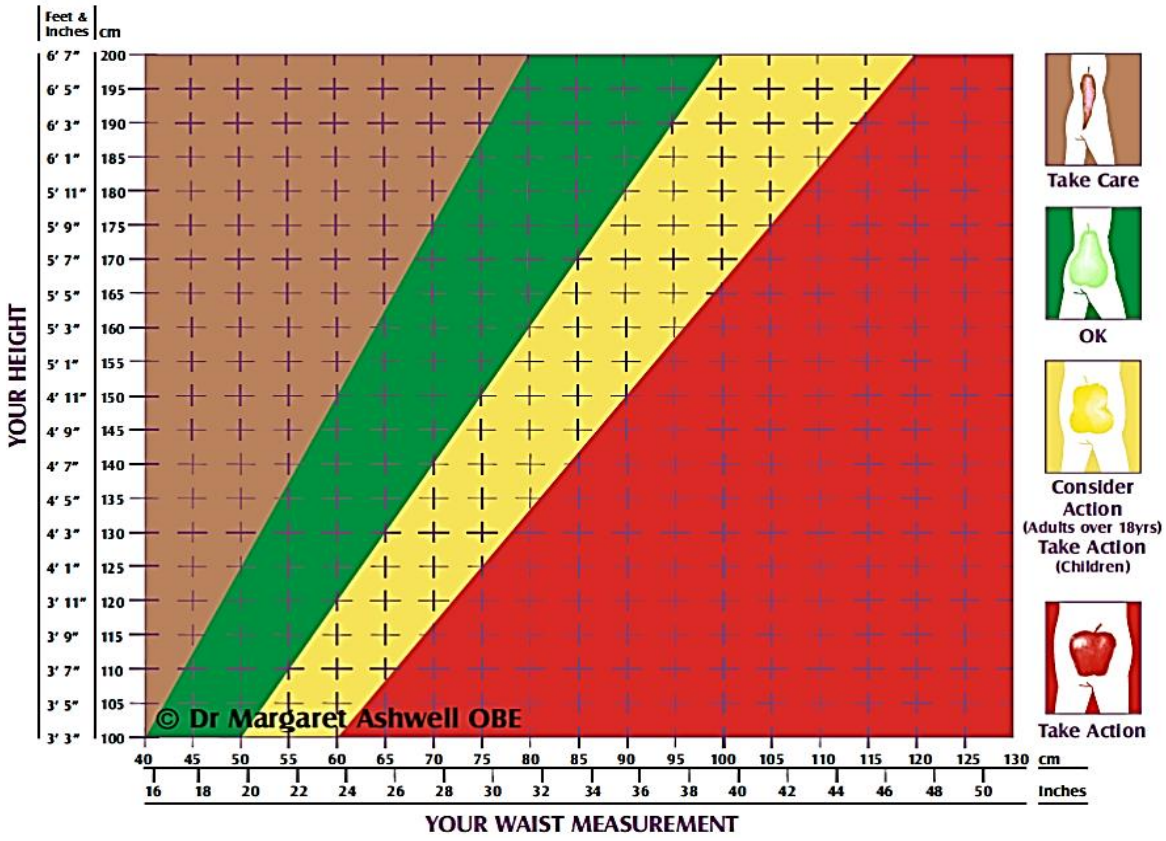

Figure 4. The shape chart developed by Ashwell and Hsieh [16]

Table 1. 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 unit of measurement was used in entering the waist circumference and height. The device uses (1) 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 device uses (2) in calculating the ideal waist circumference. Since the study of [17] 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.

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

3. RESULTS AND DISCUSSION

Figure 5 shows the 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 a lightweight and strong plastic [18], [19]. 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. The development cost of the device is 39 USD.

Figure 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 2. Using (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 [20]. The result of the testing shows that the device has 100% accuracy in terms of calculating the WHtR which is an important aspect of medical applications and devices [21], [22].

Table 2. 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

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 3. 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 Figure 4.

The device was very precise in determining the body shape of the individuals based on [23]. The results of the assessment using the device can be seen from a liquid crystal display immediately instead of tracing on a chart which can be difficult for users with poor eyesight and having poor eyesight is one common problem of obese individuals [24].

The feature of the device in suggesting ideal waist circumference was also checked. The results shown in Table 4 were compared to half of the height of the individual. The suggested ideal waist circumference by researchers is less than half the height of the person [25]–[28]. This can be deemed upon the test results where all 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 3. 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

Table 4. 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 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 5. The recommendation of the device was correlated to the health status assessed based on WHtR by an online source of healthcare data, tools, and services for patients, physicians, and other professionals throughout the world [29].

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 bodies. 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.

Table 5. Recommended action for users

Person	Gender	Waist (cm)	Height (cm)	WHtR	Recommended Action	
					Device	*Website*
1	M	80	170	0.47	Good or Ok	Keep eating healthy diet
2	M	95	175	0.54	Consider Action	Increase your activity
3	M	90	160	0.56	Consider Action	Increase your activity
4	M	72	162	0.44	Good or Ok	Keep eating healthy diet
5	M	69	173	0.40	Good or Ok	Keep eating healthy diet
6	M	83	165	0.50	Good or Ok	Keep eating healthy diet
7	M	56	167	0.34	Take Care	Gain normal weight
8	M	96	151	0.64	Take Action	Consult a doctor and fitness expert
9	M	62	164	0.38	Take Care	Gain normal weight
10	M	75	168	0.45	Good or Ok	Keep eating healthy diet
11	F	72	165	0.44	Good or Ok	Keep eating healthy diet
12	F	54	169	0.32	Take Care	Gain normal weight
13	F	69	148	0.47	Good or Ok	Keep eating healthy diet
14	F	94	154	0.61	Take Action	Consult a doctor and fitness expert
15	F	83	157	0.53	Consider Action	Increase your activity
16	F	77	164	0.47	Good or Ok	Keep eating healthy diet
17	F	91	161	0.57	Consider Action	Increase your activity
18	F	67	171	0.39	Take Care	Gain normal weight
19	F	77	137	0.56	Consider Action	Increase your activity
20	F	56	169	0.33	Take Care	Gain normal weight

4. 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. Moreover, an SD card can be incorporated into the device which can serve as a storage module to save the measured data from the device. 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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