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Image-Based Waist-To-Hip Ratio Determinant

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Abstract
This research determined the waist-to-hip ratio of individuals from their images. Sub-pixel processing and extreme value measurement was adopted and used to design a graphical user interface that carried out these measures efficiently. A sample of 229 persons randomly selected from persons involved in fitness activities in University of Nigeria, Nsukka stadium, were used for this study. The images (snapshots) of respondents were taken. To validate the accuracy of our model in determining the waist-to-hip ratio, the image-based measurements and the manual measurements were compared using standard mean error, mean, and standard deviation. The result showed that our system was 97.3% accurate in determining the waist-to-hip ratio with an error rating of 0.0514.

Keywords*: Waist-to-Hip Ratio, Image Processing, Obesity, Cardiometabolic complications.*

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I. Introduction

Overweight and obesity are the major causes of myocardial infarction and a variety of other cardiovascular diseases [1]. This is so because overweight and obesity describes fat accumulation in the body. Overtime, several methods for calculating predisposition to cardiovascular diseases have been proposed and adopted. Anthropometric methods such as Body Mass Index (BMI), Waist Circumference (WC) , Waist-to-Hip Ratio (WHR), Waist-to-Height Ratio (WHtR), Body Fat percent, and Conical Index (CI) have been applied, tested and compared to ascertain the most accurate [2].

Many authors have clearly stated that WHR is more superior to BMI in predicting cardiovascular risk [3][4]. This is because BMI checks for general obesity, which is an established risk factor for increased morbidity and mortality. Moreover, large studies conducted over the past years have showed that body fat distribution site contributes to morbidity and mortality beyond the degree of fat accumulation [4]. However, some international health organizations, (such as the National Institute for Health and Clinical Excellence) have recommended the use of BMI in addition to anthropometric indicators of central obesity in clinical assessment [5].

Waist-to-hip ratio is a measure of fat centrally distributed in the body. Thus, it is a measure of central/abdominal obesity. People who carry more fat around their waist region (android/abdominal obesity) may be at a higher risk of developing cardio-metabolic health conditions. Gynoid obesity (or lower body obesity/ fat around buttocks and thigh) rarely constitutes a risk for cardiometabolic complications. Thus, the location of fat accumulation is of great importance to determination of cardiometabolic risks[6].

The proposal for the use of anthropometric proxy indicators emerged from a 12-year follow-up of middle-aged people, which found that abdominal obesity (measured as waist – hip ratio) was correlated with increased risk of myocardial infarction , stroke, and premature death, while these diseases were not correlated with generalized obesity measures such as BMI [7].

WHR is a ratio of waist circumference to hip circumference. Standard protocols for measuring waist circumference and hip circumference should be followed to ensure accuracy. There are different protocols for measuring waist circumference using measuring tapes. The protocol recommended by WHO is the use of a stretch resistant tape that creates a constant pressure of 100g, held round the waist (midpoint between the last palpable rib and top of the iliac crest), thigh enough but not causing indentation, and reading taken at the end of normal expiration, values read to the nearest centimeter [7]. The hip circumference should be measured using a flexible non-elastic tape placed at the widest part of the buttocks. In both measurements, the subjects should stand erect with feet together, wearing minimal clothing [7].
The formulae for obtaining WHR is

$$WHR = \frac{waist(cm)}{hip(cm)}$$

WHR is gender specific and cut-off points are 0.80 for women and 0.9 for men. Abdominal obesity is evident for waist-hip ratio above 0.90 for males and above 0.80 for females[7]. This implies that women with waist-hip ratios of more than 0.80, and men with more than 0.90, are at increased health risk because of their body fat distribution site.
The chart below shows the classification of health risk associated with increasing WHR values

Health Risk	**Men**	**Women**
Low	0.95 or lower	0.80 0r lower
Moderate	0.96-1.0	0.81-0.85
High	1.0 or higher	0.86 or higher

Table 1. WHR table for male and female

Source: WHO (2008).

Although it has been proven that waist-to-height ratio has better correlation with cardiovascular disease [8], [9], however, waist-to-hip is still one of the most widely used metric for predicting cardiovascular diseases risk[10][8]. Hence, we focused on improving its mode of application in this research work.

II. Literature Review

Measurement has however been made easy nowadays with the introduction of image processing and computer vision. Image processing involves the application of computer algorithms on images to acquire a set of representative characteristics or property of the original image. It has found wide spread application in photography, remote sensing, medical imaging, forensic, transportation and military applications to mention a few [11].

Several authors who have explored image process in body measurements have proven that it is faster, efficient, accurate and cost effective than orthodox body measurement process using tape[12]–[14].

Several operations such as sharpening, noise removal, deblurring, edge extraction, binarization, blurring, contrast enhancement as well as object segmentation and labeling are carried out using image processing[15].

Waist and hip measurements have always been carried out using a flexible non-elastic measuring tape [7], and most automated processes for carrying-out body measurements have been developed for the textile industry for clothing fitness purposes [12], [16], [17] but few have paid attention to the medical significance of anthropometry.

In addition, most researches on image processing, use images obtained from a controlled environment, such as a room which dark background, with an individual putting on a tight white apparel to enable for good contrast, which is essential for image processing operations. However, how do we handle images we obtain from an uncontrolled environment, like street corners, markets and other public places?

This research tried to solve these two problems; measure waist-to-hip ratio from images obtained in an uncontrolled environment.

III. Methodology

Data collection methodology

This study adopted a cross-sectional survey design. A total number of 229 persons comprising of 64 female and 165 male between the ages of 8 to 80 were randomly selected from fitness centers in University of Nigeria, Nsukka (UNN) Stadium. The sex, age, waist circumferences, and hip circumferences were collected and their waist-to-hip ratio computed manually. In addition, images of respondents were collected as well. We carried out the data collection in the early hours of the day in agreement with World Health Organization (WHO) that stated that the amount of food, water or gas in the stomach at the time of measuring waist circumference leads to error; therefore, respondents should be measured after having fasted overnight.

Our sample size was restricted to 229 because of people's aversion to taking pictures even after explaining to them the purpose for the data collection.
Tools used for the data collection include

- A canon Powershot sx530 digital camera
- A flexible non-stretching measuring tape

WHO protocol for measuring waist circumference instructs that the measurement be made at the midpoint between the lower margin of the last rib palpable and the top of the iliac crest [7].
The hip circumference was also measured using a flexible non-elastic tape placed at the widest part of the lower abdomen. Hip circumference measure should be taken at the widest part of the buttocks as shown in the figure below.

The World Health Organization recommends that data for WHR is collected after night fast to ensure accuracy [7]. Hence, our sample data were collected at the University of Nigeria Nsukka (UNN) stadium from persons involved in fitness activities in the morning hours.

Confidentiality of data

Respondents were assured by verbal means that their information would be treated with uttermost confidentiality; it would not be commercially distributed or shared but would be strictly used for academic research work.

Image Measurement Methodology

The algorithm applied in processing the image data adopted two major approaches; the Region of interest processing using ROIpoly and Extreme value determination using the extrema property of RegionProps, all using the Matlab software package R2018A.

1. Region of interest processing (Roipoly)

The Roipoly is used for specifying the polygonal region of interest. The Roipoly has several syntaxes, and they determine how data is processed. Some syntaxes create an interactive polygon selection tool associated with the image, another specifies the polygon vertices based on predefined xi and yi default spatial coordinates, another defines a non-default spatial coordinate system using vector x and y while another returns the coordinates of the vertices of the closed polygon.

However, in all these, the first syntax was applied in this paper. It creates an interactive polygon tool that allowed us to define areas of the polygon. The pointer changing to cross hairs when the polygon is active and allows you to specify the region by selecting vertices of the polygon achieves this. The polygon can be moved or resized using the mouse. When the positioning and sizing of the polygon is completed, a mask is created by right clicking inside the region, and selecting **create mask** option**.** The mask is a binary image, which changes the region of interest to value 1 and other regions of the image to value zero (0).

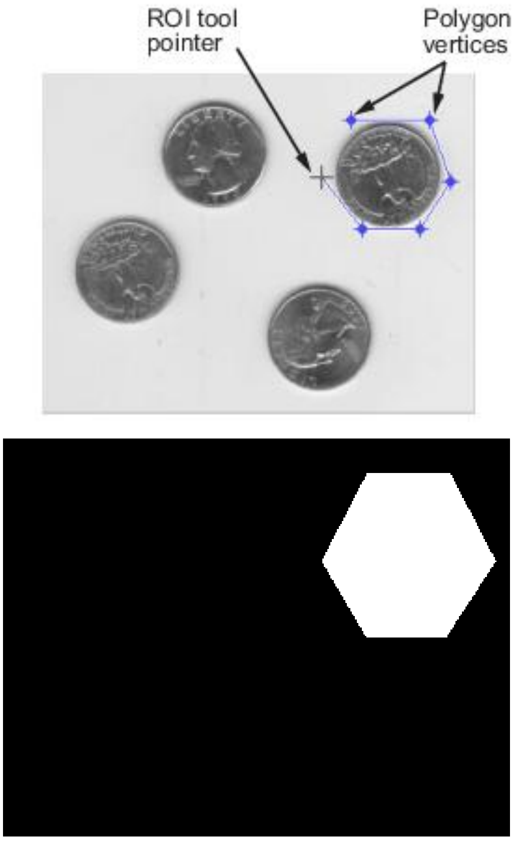

Figure 1. *ROI tool pointers and the image of a mask from Matlab 2018a documentation*

2. Extreme Value determination

The extreme value (pixel) determination is achieved using extrema property of **RegionProps.** RegionProps measures image region properties. When used without specifying the property of interest of a binary image, it returns measurements of properties specified by properties for each 8-connected component. The output variable is a ***struct*** array containing a structure for each object in the image.

This research however uses the extrema property of the Regionprops function. The extrema property points in the region returned as an 8-by-2 matrix. The vector has its format as [top-left top-right right-top right-bottom bottom-right bottom-left left-bottom left top] and follows same order during storage of measurements. The figure below illustrates the extrema of two shape regions.

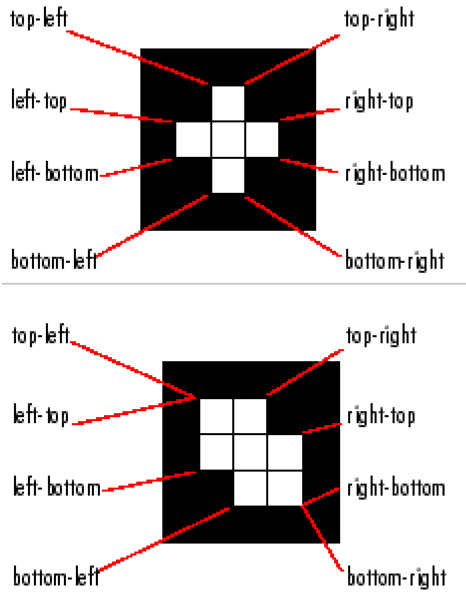

Figure 2. *Extrema properties of two shapes. Obtained from Matlab 2018a help.*

IV. General System Development Workflow

This section describes the whole steps taken to achieve the desired measure (waist-to-hip ratio measurement). Hence, a flowchart of the systems is shown below. It diagrammatically explains the series of steps taken to achieve our measurement.

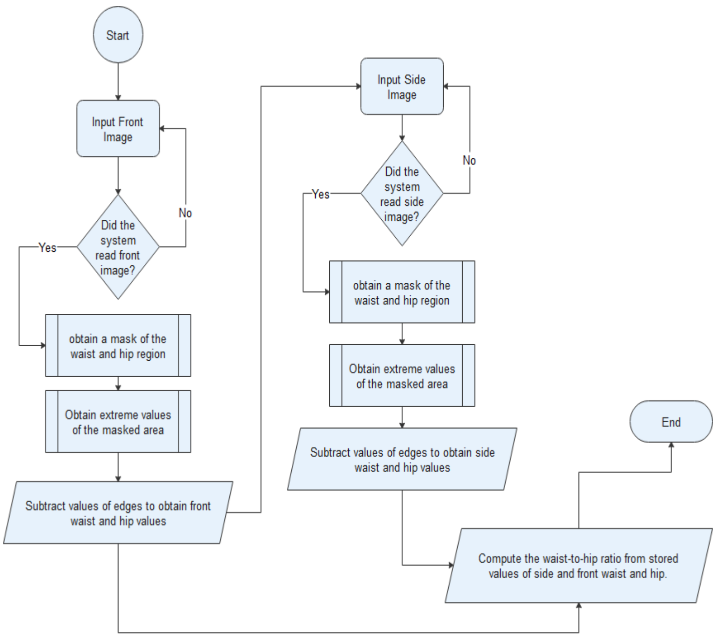

Figure 3. A flowchart of the image-processing algorithm

Firstly, the system reads the front image. The image does not need to go through any form of preprocessing as much as other researches do[12], [18], [19]. Rather, a mask of the region of interest (ROI) was created. The region of interest for us is the waist length and the hip length. The mask is parallelogram in shape containing information of the front waist and front hip. The mask is a binary image of the ROI.

Having obtained the ROI, the extrema property of RegionProps is applied to the mask of the ROI. Hence, generating values of the four edges, the top left, top right, bottom left and bottom right.

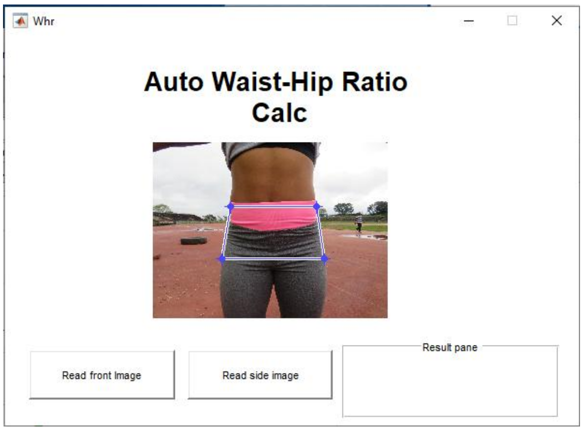

Figure 4. *Front view feature extraction*

To obtain the front waist (F_W), we subtract the top left pixel value from the top right pixel value.

$$F_W = top_{right} - top_{left} \quad [1]$$

For the front hip (F_H), similar process is followed but this time using the bottom values of the parallelogram.

$$F_H = Bottom_{right} - Bottom_{left} \quad [2]$$

Secondly, the system reads the side image. The user, creating a parallelogram too, also marks out the region of interest. As stated above, the mask is a binary image of the ROI. The RegionProps extrema property is applied to the image likewise, and the top left, top right, bottom left and bottom right pixel values are read and stored.

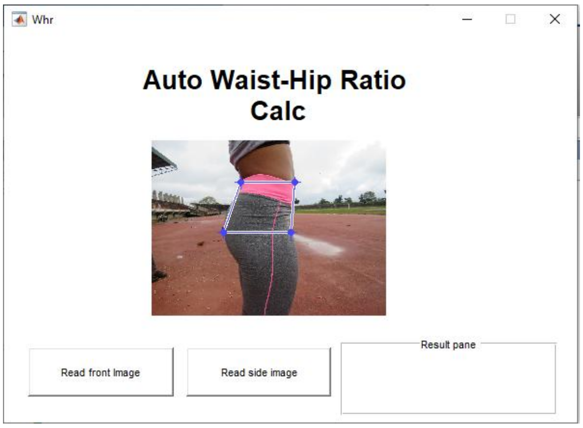

Figure 5. *Side view feature extraction*

For the Side waist (S_W), we subtract the top left from the top right. The formula is

$$S_W = Top_{right} - Top_{left} \quad [3]$$

$$fortheside\ hip(S_h), wesubtractthebottom$$
$$leftfromthebottomrightpixelvalues.$$
$$hencewe\ have$$

$$S_H = Bottom_{right} - Bottom_{left} \quad [4]$$

The waist circumference (WC) and hip circumference (HC) is calculated as shown below.

$$WC = 2(F_W + S_W) \quad [5]$$
$$HC = 2(F_H + S_H) \quad [6]$$

$$finally, Waist - to - hipratioiscomputedasfollows:$$

$$WHR = \frac{WC}{HC} \quad [7]$$

Figure eight (8), below shows the mask created from the side-view as well as the waist-to-hip ratio presentation in the software.

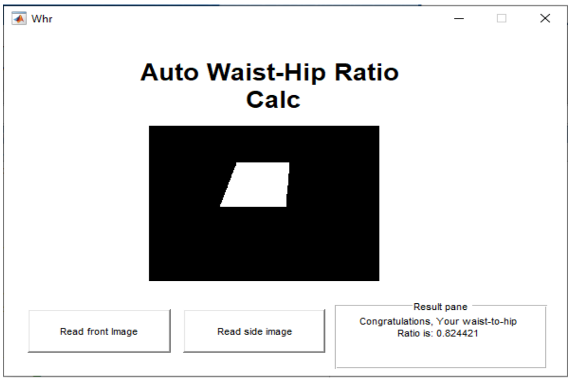

Figure 8. *Mask created from the side-view, and result presentation of the application*

V. Result And Discussion

Several experiments were carried out to ascertain the accuracy of our result. Firstly, we measured out the waist circumferences and hip circumferences of images using our image based system developed using the MATLAB software (See table 1 for the data distribution), which in turn gave out the resultant waist-to-hip ratio. We computed the mean and standard deviation of the waist-hip ratio for both the manual process and system based process as well as generated a comparison bar chart using Microsoft Excel 2010 version. Finally, the percentage accuracy of the system was computed using a standard percentage formula.

A result of the relationship between the manually measured result and that obtained using the image processing application designed in this project is presented below.

	N	Mean	Std. Deviation
Manual Measurements	229	.819908	.0542223
Image Based Measurement	229	.797728	.0514312
Valid N	229		

Table 2. *Relationship between manual measurement and image-based measurement*

Finally, a standard mean error was computed to explain the relationship between the manual measurement and the image based measure. The formula for the standard error mean is,

$$StandardError = \frac{SD}{\sqrt{n}} \qquad [8]$$

Where SD= the standard deviation of the distribution and n= the sample size.
The standard error for the manual measurement is 0.0541 while that of the Image based measurement is 0.0514.

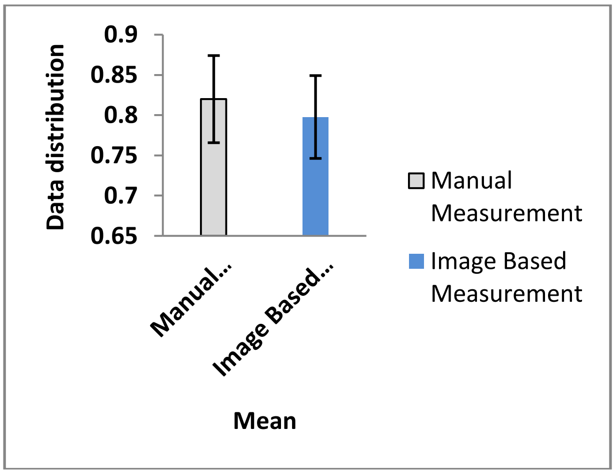

Figure 4.1 *A Bar chart of the comparison of manual and Image-Based measurements with a standard mean error bar plotted above them.*

The percentage accuracy is computed from the mean as shown below;

$$\frac{meanofImageBasedmeasures}{meanofManualmeasures} * \times 100 \quad [9]$$

Therefore; $\frac{0.7977}{0.8199} * 100 = 97.3\%$

With the above result, our image-based measurement system has proven to be 97.3% accurate in determining Waist-to-hip ratio of individuals from images.

In addition, since the error bar on the manual measurement and the error bar on the image based measure overlap including their mean, there is a strong indication that there is no difference between the manual measurements distribution and the image based measurements. To further buttress on it, it implies that the data distribution amongst manual and image based measurements are identical. Hence, the image-based system can be used in place of the manual measurement.

The image processing system was able to show 97.3% accuracy in determining waist-to-hip ratio of individuals from their respective image. It used more data for evaluating its reliability in comparison with manual measurements than works by M. Wang et al.,[20], and R. Sehgal et al.,[16]. Also whilst M. Wang et al.,[43] and R. Sehgal et al.,[21] focused on the apparel industry to design a system that would help in determining clothing fit, this research was primarily aimed on getting anthropometric data for medical applications in obtaining the waist-to-hip ratio which is an important predictor of cardiovascular disease risk.

It is noteworthy that 90% of our respondents were at low risk level because they engaged in physical activities at the UNN stadium. This conforms with the assertion made by Robles R. et al.,[18] that physical activity reduces the risk of having CVDs, diabetes and cancer. Physical activity is the sure way to prevent CVDs.

VI. Conclusion

Obesity is the major cause of health related diseases such as CVDs, type 2 diabetes and even cancer. Hence, researchers are working tirelessly on determining the best approach to determine overweight and obesity using one of the most accurate measures, waist-to-hip ratio (WHR), which measures adipose (abdominal) fat concentration as opposed to its counterpart (BMI) which measures overall body fat. Prompt calculation and classification of risk level, if automated is required and would help command a large majority of the world's populace into engagement in physical activities, which is a panacea to being at risk of CVDs.

To automate the process of measuring waist-to-hip ratio, I recommend that further research be carried out in aspects of using the webcam to measure out waist and hip ratio as well as efficiently assign the WHR to classes of risk. This would enable its quick implementation as a medical solution because of its ease of use, accuracy, reliability and transparency.

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