APPENDIX

APPENDIX A

International Conference on Information Technology and Statistics 2016 (ICITS2016): New Criterion of Height Weight Difference Index for Screening Obesity Status for Adults in Thailand, 2016, p.22-31.

Appendix A: New Criterion of Height Weight Difference Index for Screening Obesity Status for Adults in Thailand, 2016, p.22-31.

New Criterion of Height Weight Difference Index for Screening Obesity Status for Adults in Thailand

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Abstract. Height Weight Difference Index (HWDI) is the new simplest measurement which can be used for screening obesity status. There are still very limited data regarding the Prior-HWDI. The objective of this study is to propose a new cut-off of HWDI (New-HWDI) for each age group by sex, considering body-fat percentage (BF%) as gold standard. 2,771 healthy Thai volunteers were enrolled, 64% were women. The New-HWDI for screening obesity status are <98 in men and <90 in women age between 18-39, <96 in men and <94 in women age between 40-59, and <100 in men and <90 in women age ≥ 60. The obese prevalence as defined by New-HWDI was 36% in men and 25% in women. The kappa statistics for New-HWDI and BF% was 0.23 in men and 0.18 in women. Our results showing that the New-HWDI could be used as a simplified and effective index for screening obesity in Thai adult.

Keywords: Height Weight Difference Index, Obesity Status, Body Mass Index, Body-Fat Percentage, Screening Obesity

1. Introduction

Developed and developing countries are facing an obesity epidemic which carries substantial health implications for both chronic disease and mortality [1]. Thailand is now ranked second in Southeast Asia for the greatest number of people with obesity, and Thais are increasing in their tendencies to become obese [2]. This fact and its growing prevalence make obesity an urgent health concern.

Obesity is most commonly measured as body mass index (BMI = weight in kilograms divided by height in meters squared). Although other measurements have been developed, BMI is the most consistently used in the literature [3]. This simple measurement, however, has a number of drawbacks in clinical practice and is commonly used in conjunction with waist measurement to give a better estimate of disease risk in a specific individual [4]. Recently, there were studies showing that body-fat percentage (BF%) may be a better measurement for risk of weight-related diseases than BMI [5-9]. The BF% can be measured by hydrodensitometry (HD), bioelectrical impedance analysis (BIA), or dual-energy X-ray absorptiometry (DXA). These gold standard techniques are costly, time-consuming and require assistance. In addition, these measurements are not performed routinely. Therefore, alternative non-invasive methods of obesity assessment that are easier to administer have been developed.

The Height Weight Difference Index (HWDI) is a new simple measurement which focuses on the margin of weight and height. HWDI can be used as an applied index for diagnosis of different grades of obesity. Although, the index cannot determine different grades of thinness, it is useful in diagnosing the

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status as a whole [10]. However, there is very limited data regarding the HWDI and other factors including gender and age. Previous studies have shown that gender and age have significant differences of impact on obesity [7-11]. The objective of this study was to propose a new cut-off of HWDI (New-HWDI) that takes into account the gender and age for screening obesity status for adults in Thailand.

2. MATERIALS AND METHODS

2.1 Study Population

A cross-sectional analysis of baseline data was performed from all healthy adult Thai volunteer participants' enrolled by way of invitation at the Faculty of Medicine, Chiang Mai University via public information posters and the hospital web site, between May, 2010 and May, 2011. Volunteers whose ages were less than 18 years old were excluded.

2.2 Data Measurement

Body weight was measured using the same digital weighing apparatus each time (TCA-200 A-RT; Zepper, Bangkok, Thailand) and recorded in kilograms to one decimal point. Height was measured using a standard 4 board; the subjects' body positions ensured their head, shoulder blades, buttocks, and heels were touching the board during measurement. Height was recorded in centimeters.

The BF% was attained from BIA. The measurement of the BIA depends on the differences in electrical conductivity of fat free mass and fat. The technique measures the impedance of an electrical current passed between two electrodes (typically 800 µA; 50 kHz). Before analysis all participants were asked to observe the following pretest guidelines: (1) no alcohol consumption within 24 hours; (2) no exercise, caffeine, or food within four hours prior to taking the test, (3) drink two to four glasses of water two hours before examination. During the examination, two pairs of sensor electrocardiograph pads were placed on the participants, one on the right wrist and hand and the other on the right foot and ankle. At least, 75% of the electrode was required to be in contact with the participant's skin [12].

2.3 Variable Definitions

The BF% cutoffs chosen to perform sensitivity and specificity comparisons were the values frequently cited by international scientific literature [13]. The values for women are as follows: age 18-39 years <25% (thin), 25%-35% (normal), 36%-40.9% (overweight), ≥41% (obese); age 40-59 years and age ≥60 years <25% (thin), 25%-35.9% (normal), 36%-41.9% (overweight), ≥42% (obese); age ≥60 years <25% (thin), 25%-36.9% (normal), 37%-41.9% (overweight) and ≥42% (obese).

For men the values are: age 18-39 years, <13% (thin), 13%-23.9% (normal), 24%-28.9% (overweight), ≥29% (obese); age 40-59 years, <13% (thin), 13%-24.9% (normal), 25%-29.9% (overweight), ≥30% (obese); age ≥60 years, <14% (thin), 14%-24.9% (normal), 25%-29.9% (overweight) and ≥30% (obese).

For both sexes, thin was defined as BMI <18.5 5 kg/m^2, normal as BMI 18.5-22.9 5 kg/m^2, overweight as BMI 23-24.9 5 kg/m^2 and obese as BMI ≥25 5 kg/m^2 [14]. The HWDI was calculated as height (cm) minus weight (kg). The Prior-HWDI cutoff points used were those recommended by Sakda Prunglampoo et al. [15] (HWDI>111.7 (thin), >95.2-111.7 (normal), >82.5-95.2 (overweight) and ≤82.5 (obese).

2.4 Statistical Analysis

The following participant characteristics were retrieved from the date of enrollment: gender, age, weight, height and BF% were included in the analysis. Wilcoxon rank sum test was used to compare median characteristics between men and women. Kappa statistic for age 18-39 years, 40-59 years and ≥60 years were performed to determine consistency among markers. Sensitivity (Se), Specificity (Sp) and Area Under the Receiver Operating Characteristic curve (AUROC) were compared among markers to find New-HWDI for screening obesity status, considering BF% as the gold standard.

Youden's index (J) was also used as a criterion for selecting the optimum threshold value for the New-HWDI cutoffs [16]. J was estimated as Se + Sp – 1. Maximizing this index allows the determination of an optimal cut-off point. The New-HWDI optimal cutoff that takes into account the gender and age were

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selected at the point based on the maximum value of *J*. A scatterplot was used to display the visual inspection of the relationship between (A) Prior-HWDI, (B) New-HWDI and (C) BMI vs BF% stratified by gender and age groups.

All p reports were 2-sided and p less than 0.05 was considered statistically significant. All analyses were performed using STATA software version 12.0 (STATA Corp, College Station, Texas, USA) and SPSS version 17.0 (SPSS Inc., Chicago, USA).

2.5 Ethical Considerations

All participants provided written informed consent prior to participation in this study. This study was approved by the Faculty of Medicine, Chiang Mai University Ethics Committee.

3. RESULTS

Of the 2,771 participants, 1,772 (64%) were women, and their characteristics were summarized in Table 1. The median age was 60 years (Interquartile range [IQR], 47-68) in men and 52 years (IQR, 43-60) in women. Most of men were heavier and taller than women. Men had a median of BF% lower than women (27% and 34% respectively, P<0.001). The obese prevalence as defined by BMI, by BF% and by Prior-HWDI were 31%, 37% and 4% in men and 33%, 10% and 7% in women, respectively.

Table 2 demonstrates the most concordant values seen for age 18-39 years between classifications of obesity based on BF% versus BMI in both sex (Kappa=0.286 for men and 0.148 for women) and also based on BF% versus Prior-HWDI (Kappa=0.358). However, Kappa coefficient was small (<0.40), suggesting only fair agreement between these assessments. For all age groups, Kappa statistics were higher in men than women between classifications of obesity based on BF% versus BMI. For men age 18-39 years, there was agreement for 71% of the participants, 25% were misclassified as non-obese based on BF%, while meeting obesity criteria based on BMI. Only 4% were classified as obese based on BF%, but non-obese by BMI. For age 18-39 years, the concordance seen between classifications of obesity based on BF% versus Prior-HWDI. A total of 4.4% of participants were misclassified as non-obese by BF%, but were found to be obese by Prior-HWDI. In contrast, 4.6% were misclassified as obese by BF%, but were in fact non-obese by Prior-HWDI. The most concordance seen for age 18-39 years between classifications of obesity based on New-HWDI versus BF% in men (Kappa=0.255) and the most concordance was seen for age ≥ 60 years in women (Kappa=0.269). Kappa statistics suggested only fair agreement between the two assessments.

Table 3 demonstrates an optimal threshold value for the new criterion of HWDI for screening obesity status for each age group by sex. For men aged 18-39 years based on the Youden's index method, New-HWDI was 98. The sensitivity results demonstrated that 65% of those classified as obese by their measured New-HWDI were also classified as obese by BF% (Se=0.65). Specificity demonstrated that 78% of those not classified as obese by their measured New-HWDI were also not considered obese by their BF% (Sp=0.78). The New-HWDI for screening obesity status are <98 in men and <90 in women age between 18-39, <96 in men and <94 in women age between 40-59, and <100 in men and <90 in women age ≥ 60. (See Figure 1).

Figure 2 presents a scatter plot of (A) Prior-HWDI vs. BF%, (B) New-HWDI vs. BF% and (C) BMI vs. BF% classified by gender and by age group. Figure 2- (1A) (2A) and (3A) presented scatter plots between Prior-HWDI and BF%. While considered underestimated value, cut-off of Prior-HWDI identified non-obese but BF% identified obese, found that men (green area) received an underestimated value higher than women (blue area) in all age groups and most found in men age 60 years or over. Figure 2- (1B) (2B) and (3B) presented scatter plots between New-HWDI and BF%, which's found that when compared with the Figure 2- (1A) (2A) and (3A), the proportion of underestimated values deceased, especially in men age 60 years or over (from 46.7% to 23.8%. Figure (3A) vs. (3B)).

Moreover, New-HWDI underestimated values similar to when using BMI for screening obesity status (Figure 2- (1C) (2C) and (3C), when BMI ≥25 kg/m^2 (obese)), as well as proportion of underestimated value deceased in some age groups.

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4. DISCUSSION

Our study provides the New-HWDI for screening obesity status in adults based on measures obtained from a large number of enrolled healthy Thai volunteer participants. For the first time, we can establish the New-HWDI for different groups age and gender, so that it will be more accurate for evaluation of obesity. A criterion for selecting the optimum threshold value for the New-HWDI cutoffs was Youden's index, which give underestimated value similar to when using BMI. This shows that New-HWDI is an effective index of screening obesity in adults.

Although the mechanisms leading to increasing fatness with age are not fully understood, our analysis clearly shows the significant impact of age and also gender on the screening obesity status. Our findings are consistent with other studies showing that age and gender are significantly different in impact to obesity using BMI [17]. However, in the absence of comparative data among other potential independent variables such as ethnicity, it is impossible to evaluate the deficit in the New-HWDI for establishing an international obesity status.

In this study, BF% value from BIA was used as a gold standard in diagnosing obesity condition due to its reliability in comparison to other index values because it is capable of depicting fat levels which are the cause of obesity. Furthermore, the previously used BMI index was found to have limitations in categorizing and diagnosing obesity [18]. Despite its popularity, BMI index does not reflect important elements inside the body such as fat level and muscle volume which were used to categorize and diagnose obesity. This is consistent with a study by Romero-Coral et al. [19] which found the BMI cannot distinguish the individual who is of normal weight and height but has high fat level [18-20] It is also consistent with studies by Habib et al. [21] and Wang et al. [22] which indicate that BMI still has some limitations for giving accurate data about the prevalence of obesity. Hence, BF% is a better alternative to BMI for diagnosing obesity [21].

In our study, the obese prevalence as defined by BMI, by BF% and by Prior-HWDI were 31%, 37% and 4% in men and 33%, 10% and 7% in women, respectively, while the obese prevalence was defined by New-HWDI was 36% in men and 25% in women. When compared with other research, New-HWDI yields higher obese prevalence than those utilizing BF% index or BMI such as Akmal et al. [23] in Malaysia and Goonasegaran et al. [24] in Singapore.

In this study, it was found that the kappa value of BF% and BMI was low (kappa=0.14 in men and 0.14 in women) which is different from the studies by Habib et al. [21] (kappa=0.41 in men and 0.53 in women) and Wang et al. [22] (kappa=0.21 in men and 0.32 in women). The discrepancy may be caused by the difference in nationality, age of sample group, muscle volume, genetics, as well as the method and tool that was used to measure BF% value [22, 25-27].

The kappa value of BF% with New-HWDI in this study was found to be kappa=0.23 in men and 0.18 in women. However, when comparing the kappa value of New-HDWI with BMI using BF% as gold standard, it was found that New-HDWI can distinguish obesity condition in men and in women better than BMI value. (underestimate value of New-HWDI is lower in every age-range of both gender in comparison to BMI value)

In conclusion, our results showing the New-HWDI could be used as a simplified and effective index for screening obesity in adults. It will help Thai adults to realize their health status and avoid the risk of obesity and related diseases.

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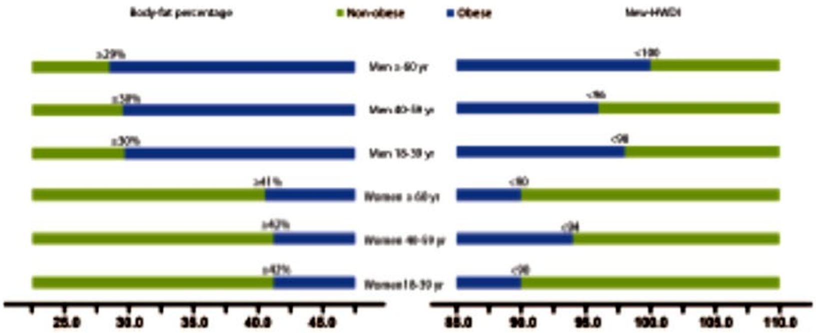

Figure 1 Body-fat percentage and New-HWDI points for screening obesity status.

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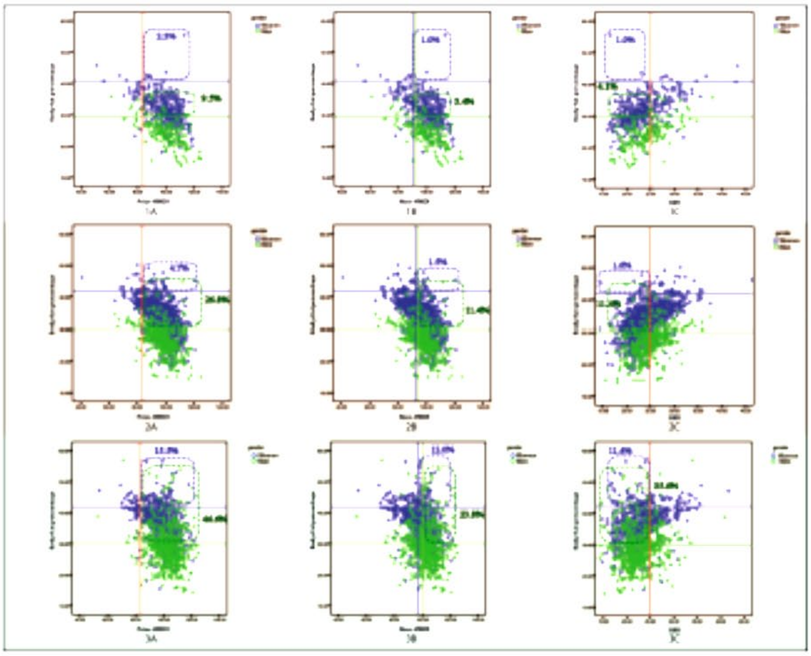

Figure 2 Scatter plot between (A) Price-HWDI, (B) New-HWDI and (C) BMI vs BF% stratified by gender (men in blue, women in green) and by age group (1) 18-39 years, (2) 40-59 years and (3) ≥60 years. For example for 1B Women (blue) who fall above blue line are obese according to body-fat percentage. Men (green) who fall above green horizontal line are obese according to body-fat percentage. The upper right quadrant bordered by blue horizontal line (body-fat percentage > 40%) and blue vertical line (New-HWDI=90) demonstrates number of women misclassified as "non-obese" by the New-HWDI.

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Table 1 General Characteristics

Characteristics	Men n (%) or Median(IQR)		Women n (%) or Median(IQR)		P*
Overall	999	(36.1)	1,772	(64.0)	
Age, years	60	(47-68)	52	(43-60)	<0.001
18-39	148	(14.8)	311	(17.6)	
40-59	351	(35.1)	959	(54.1)	
≥60	500	(50.1)	502	(28.3)	
Weight, kg	63	(55-71)	56	(50-62)	<0.001
Height, cm	165	(160-170)	155	(150-158)	<0.001
BMI, kg/m^2	23	(21-26)	24	(21-26)	0.310
Thin	67	(6.7)	115	(6.5)	
Normal	385	(38.5)	676	(38.2)	
Overweight	233	(23.3)	397	(22.4)	
Obese	314	(31.4)	584	(33.0)	
Body-fat percentage, %	27	(24-31)	34	(31-38)	<0.001
Thin	0	(0.0)	71	(4.0)	
Normal	250	(25.0)	973	(54.9)	
Overweight	376	(37.6)	549	(31.0)	
Obese	373	(37.3)	179	(10.1)	
Prior-HWDI,	101	(95-107)	98	(92-104)	<0.001
Thin	124	(12.4)	70	(4.0)	
Normal	594	(59.5)	1042	(58.8)	
Overweight	238	(23.8)	543	(30.6)	
Obese	43	(4.3)	117	(6.6)	

*Wilcoxon rank-sum test

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Table 2 Evaluation consistency and Kappa statistics for obesity status among markers

	Age (years)	Concordant n (%)		Discordant n (%)		Kappa
		Obese, Obese	Non-obese, Non-obese	Obese, Non-obese	Non-obese, Obese	
BF% vs BMI		253(9.1%)	1574(56.8%)	299(10.8%)	645(23.3%)	0.136
Men	18-39	17(11.5)	88(59.5)	6(4.0)	37(25.0)	0.286
	40-59	69(19.7)	159(45.3)	40(11.4)	83(23.6)	0.262
	≥60	63(12.6)	214(42.8)	178(35.6)	45(9.0)	0.089
Women	18-39	9(2.9)	232(74.6)	3(1.0)	67(21.5)	0.148
	40-59	50(5.2)	590(61.5)	15(1.6)	304(31.7)	0.140
	≥60	45(9.0)	291(58.0)	57(11.4)	109(21.7)	0.142
BF% vs Prior-HWDI		81(2.9%)	2140(77.2%)	471(17.0%)	79(2.9%)	0.152
	18-39	14(3.0)	404(88.0)	21(4.6)	20(4.4)	0.358
	40-59	35(2.7)	1097(83.7)	139(10.6)	39(2.3)	0.221
	≥60	32(3.2)	639(63.8)	311(31.0)	20(2.0)	0.079
BF% vs New-HWDI		311(11.2)	1613(58.2)	241(8.7)	606(21.9)	0.233
Men	18-39	18 (12.2)	81 (54.7)	5 (3.4)	44 (29.7)	0.255
	40-59	69 (19.7)	166 (47.3)	40 (11.4)	76 (21.7)	0.292
	≥60	122 (24.4)	176 (35.2)	119 (23.8)	83 (16.6)	0.187
Women	18-39	9 (2.9)	255 (82.0)	3 (1.0)	44 (14.2)	0.228
	40-59	51 (5.3)	593 (61.8)	14 (1.5)	301 (31.4)	0.147
	≥60	42 (8.4)	342 (68.1)	60 (12.0)	58 (11.6)	0.269

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Table 3 Sensitivity (Se), specificity (Sp), area under the receiver operating characteristic curve (AUROC) and Youden's Index for the selection of an optimal threshold value for the new criterion of HWDI for screening obesity status

Age (years)	Men					Women				
	Se	Sp	AUROC	Youden's Index	New-HWDI cut-off	Se	Sp	AUROC	Youden's Index	New-HWDI cut-off
18-39	0.71	0.61		0.32	96	0.90	0.58		0.48	88
	0.70	0.70		0.39	97	0.87	0.58		0.45	89
	0.65	**0.78**	0.754	**0.43**	**98**	**0.87**	**0.75**	0.819	**0.62**	**90**
	0.64	0.78		0.42	99	0.85	0.75		0.60	91
	0.57	0.83		0.39	100	0.84	0.75		0.59	92
40-59	0.75	0.54		0.29	94	0.76	0.65		0.41	92
	0.75	0.54		0.29	95	0.71	0.75		0.46	93
	0.72	**0.61**	0.679	**0.33**	**96**	**0.71**	**0.78**	0.797	**0.49**	**94**
	0.67	0.63		0.31	97	0.66	0.78		0.44	95
	0.62	0.64		0.27	98	0.61	0.80		0.41	96
≥60	0.80	0.35		0.15	98	0.90	0.37		0.27	89
	0.78	0.38		0.16	99	0.89	0.37		0.27	89
	0.68	**0.51**	0.596	**0.19**	**100**	**0.86**	**0.42**	0.662	**0.28**	**90**
	0.68	0.51		0.18	101	0.85	0.42		0.27	91
	0.63	0.53		0.16	102	0.82	0.42		0.24	92

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APPENDIX B

Relationship between Height-Weight Difference Index and Body-fat Percentage estimated by Bioelectrical Impedance Analysis in Thai Adults. (Preparing for submission)

Appendix B: Relationship between Height-Weight Difference Index and Body-fat Percentage estimated by Bioelectrical Impedance Analysis in Thai Adults.

Short title: Relationship between HWDI and BF% in Adults

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Abstract

Introduction: The height-weight difference index (HWDI) is a new tool for evaluating obesity status. While body-fat percentage (BF%) is considered to be the most accurate obesity evaluation tool, it is a more expensive method and more difficult to measure than the others. The objective of this study was to find the relationship between HWDI and BF% and to find a BF% prediction model in relation to age group and gender.

Method: Bioelectrical impedance analysis was used to measure BF% in healthy adult Thais aged over 18 who volunteered for the study during 2010 to 2011. Pearson's correlation coefficient was used to assess the relationship between HWDI and BF% with respect to age and gender. Multiple linear and non-linear regression analysis were used to construct the BF% prediction model.

Results: HWDI and BF% were found to be inversely related in that (r = -0.200 for men and r= -0.473 for women) with a tendency towards a linear relationship. Results of a multivariate linear regression analysis, which included HWDI and age as variables in the model, predicted BF% to be *34.508 - 0.159 (HWDI) + 0.161 (age)* for men and *53.35 - 0.265 (HWDI) + 0.132 (Age)* for women.

Discussion: The prediction model derived in this study is the first to take HWDI, which is more convenient than BMI, into consideration. This provides an easy-to-use obesity evaluation tool that, in turn, may help create awareness of underweight and obesity conditions.

Keywords: Height-weight difference index; body mass index; body-fat percentage; age; gender.

Introduction

Obesity is a common problem in many countries and has increasingly become a global epidemic resulting in lower quality of life all over the world. In 2014, the World Health Organization (WHO) reported that about 13%, or one in 10, of the world population aged over 18 (11% men and 15% women) suffered from obesity [1]. This problem is responsible for an increase in the mortality rate from chronic disease (44% from diabetes, 23% from heart disease, and 7% from cancer) [2, 3]. In the Asean community, Thailand ranks second highest behind Malaysia for the number of obese people. The main concern is the apparent increase in the number of children with obesity. A survey in the year 2010 reported 1 in 10 children aged between 1 and 14 in Thailand suffered from obesity. [4]

Currently, there are several widely used methods to assess overweightness and obesity. Body-fat percentage (BF%) is an accurate and reliable measurement method but is relatively expensive and difficult to use [5-9]. The body mass index (BMI) is the most common index for assessing weight status, and is calculated from weight (kg) and height (m^2) [10]. However, this method requires additional devices for measurement. In a study by the Research Institute for Health Sciences in Thailand, a simple index for screening overweightness and obesity called the height-weight difference index (HWDI) was developed by assessing the difference between height (cm) and weight (kg). They also found that HWDI was associated with determining obesity prevalence [11].

Although there have been previous studies that have analyzed the relationship between BMI and BF% [12-14], none were found to have focused on the relationship between HWDI and BF%. The objective of this study was to find the relationship between HWDI and BF% and to find a BF% prediction model for obesity evaluation.

Materials and Methods

Study Population

Between 2010 and 2011, a cross-sectional analysis was performed on healthy adult Thai volunteers by way of invitation at the Faculty of Medicine, Chiang Mai University via public information posters and the hospital web site. Volunteers aged less than 18 years old or pregnant women were excluded.

Data Measurement

Body weight was measured using the same digital weighing apparatus each time (TCA-200 A-RT; Zepper, Bangkok, Thailand) and recorded in kilograms to one decimal point. Height was measured using a standard 4 board; the subjects' body positions ensured their head, shoulder blades, buttocks, and heels were touching the board during measurement, and was recorded in centimeters. HWDI was calculated as the difference between height (cm) and weight (kg)(11).

We used the bioelectrical impedance analysis (BIA) method to estimate BF%. The BIA method validity was tested, taking BF% as the outcome variable, with a range of reference techniques, including total body water using hydrodensitometry (15). The measurement of bioelectrical impedance depends on the difference in electrical conductivity between fat free mass and fat, and the technique measures the impedance of an electrical current passed between two electrodes (typically 800 µA; 50 kHz). Before analysis, all participants were asked to observe the following pretest guidelines: (1) no prior alcohol consumption within 24 hours; (2) no exercise, caffeine, or food within four hours prior to taking the test; and (3) drink two to four glasses of water two hours before testing. During the examination, two pairs of sensor electrocardiograph pads were placed on the participants, one on the right wrist and hand and the other on the right foot and ankle; it was necessary for at least 75% of the electrode to be in contact with the participant's skin (16).

Statistical Analysis

All of the continuous variable data were reported as median and interquartile range (IQR). The Wilcoxon rank-sum test was used to compare differences between characteristics and gender. Pearson's correlation coefficients (r) were calculated to assess the degree of the association between HWDI and BF% in relation to age and gender. Age was divided into three groups (18-39 years, 40-60 years, and over 60 years).

We used regression analysis to examine the relationship between HWDI and BF% performed on men and women separately. Multiple linear regression analysis was first used, followed by an examination the possibility of a non-linear relationship existing by including quadratic and cubic forms. Adjusted R^2 and standard error of estimate (SEE) values was used to compare the performance of the predictive model of BF%.

All reports of p were two-sided and p of less than 0.05 was considered statistically significant. All analyses were performed using STATA software version 12.0 (STATA Corp, College Station, Texas, USA) and SPSS version 17.0 (SPSS Inc., Chicago, USA).

Ethical Considerations

All participants provided written informed consent prior to participation in this study. This study was approved by the Faculty of Medicine, Chiang Mai University Ethics Committee.

Results

Study population and baseline characteristics

All 2,771 participants in this study were over 18 years old and comprised of 64% women with a median age of 52 years (IQR, 43-60) and 36% men with a median age of 60 years (47-68). The BF% in men was statistically significantly lower than in women (27% and 34%, respectively; $p < 0.001$). The difference in HWDI between men and women was also statistically significant (101 [IQR, 95-107] for men and 98 [IQR, 92-104] for women; $p < 0.001$) (see Table 1).

Figure 1 shows the relationship between average BMI and age. It was found that, from age 18-39 years old, the mean BMI increases as age increases but, after reaching 60 years of age, the mean BMI decreases as age increases (see Figure 1-A). The reverse can be found for the relationship between mean HWDI and age.

Relationship between HWDI and BF%

Figure 2 shows the relationship between HWDI and BF%. Statistically, an inverse relationship between HWDI and BF% was found as HWDI increased while BF% value significantly decreased. Pearson's correlation coefficient (r) = -0.200 ($p < 0.001$) was found for men and r = -0.473 ($p < 0.001$) for women. Furthermore, the relationship between HWDI and BF% was statistically significant even when analyzed with respect to age group and gender ($p<0.001$).

The Effect of Age, Gender, and HWDI on BF%

The study of the effect of age, gender, and HWDI on BF% showed all three variables' relationship with BF% to be statistically significant for building a prediction model ($p<0.001$ for all variables). HWDI and BF% by age and gender resulted in r = 0.629/0.518 for the 18-39 years old age group, 0.372/0.560 for the 40-59 years old age group, and r = 0.125/0.369 for the over 60 years old age group for both men and women.

Predictive Modeling of BF% by Gender

In this study, several forms of relationship between HWDI and BF% were studied: linear, quadratic, and cubic. However, Figure 3 shows that the relationship tended to be in linear form more than the others, and so we elected to use a linear form in the construction of the BF% prediction model. The results of a multivariate linear regression analysis, which includes the HWDI and age variables, yielded a BF% for men of *34.508 - 0.159 (HWDI) + 0.161 (age)* [Adjusted R^2 = 0.215, Standard Error of Estimate (SEE) = 5.37%, $p < 0.001$], and, for women, *53.35 - 0.265 (HWDI) + 0.132 (Age)* [Adjusted R^2= 0.337, SEE = 4.39%, $p <0.001$] (see Table 2).

Discussion

In this study, we evaluated the relationship between HWDI and BF% with respect to gender. Our results show that obesity was proportionately higher in women than men, which is in accordance with previous studies which showed a higher risk of obesity in women both globally and in Asia [1, 3, 17, 18]. This may be due to differences in eating and exercising behaviors from men, as well as physical attributes, hormones, and metabolism [19-21].

The HWDI, a relatively new obesity measurement tool, was used in this research and was found to have an inverse relationship with BF% in both men and women.

However, the Pearson's correlation coefficients was found to be low (r = 0.20 for men and r = 0.47 for women) when compared to previous studies that utilized other obesity evaluation tools with BF% [13, 22, 23]. In 1996, Gallagher et al. studied the relationship between BMI and BF% and reported values of r = 0.58 for men and r = 0.72 for women. Later, Ranasinghe et al. (2013) have reported r = 0.75 for men and r = 0.82 for women and, more recently, Ilman et al. (2016) have reported r = 0.85 for men and r = 0.83 for women. Each study described a distinct BF% prediction model. It had been previously reported that, besides age and gender, other variables such as nationality, ethnicity, and religion can also help improve the accuracy of a BF% prediction model [13, 22-26].

A multivariate linear regression analysis showed that age and gender were statistically significant variables contributing to changes in BF%s, which supports the results of previous studies [23, 27-29]. However, many of those studies used BMI as an independent variable along with the others mentioned above in constructing a BF% prediction model and found that the use of BMI introduced some limitations. For example, BMI cannot distinguish between an obese or overweight individual when a group consists of a population with normal bodyweight but high BF%. This may result in an underestimation of the number of individuals in a population with obesity [14]. Because of that limitation, HWDI was used in the model in this study instead of BMI.

Results of this study showed that the relationship between HWDI and BF% was linear, whereas other researchers have reported different forms in the relationship between BMI and BF%, such as a curvilinear one [13, 30]. Our study concerning BF% prediction models consisting of HWDI and age grouped by gender resulted in better SEE values than that of Matt et al. where BMI was used in the prediction of BF% in four different groups of population with Asian, Black, Puerto Rican, and White ethnicity. In addition, the standard error of estimate values derived from this study were similar to, yet higher than, those of some other studies [13, 32]. This may be because the r value between HWDI and BF% in this research was lower in comparison to the others.

The prediction model derived from this study uses HWDI, which is more convenient and easier to use than BMI. This has resulted in an easier means to evaluate obesity, thus aiding the monitoring of high-risk groups in the population so as to avoid problems associated with it.

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Conflict of interest

All authors have no conflicts of interest.

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Table 1. Population characteristics

Characteristics	Men n (%) or Median (IQR)		Women n (%) or Median (IQR)		p
Overall	999	(36.1)	1,772	(64.0)	
Age (years)	60	(47-68)	52	(43-60)	**<0.001**
18-39	148	(14.8)	311	(17.6)	
40-59	351	(35.1)	959	(54.1)	
≥60	500	(50.1)	502	(28.3)	
Weight (kg)	63	(55-71)	56	(50-62)	**<0.001**
Height (cm)	165	(160-170)	155	(150-158)	**<0.001**
Body-fat percentage	27	(24-31)	34	(31-38)	**<0.001**
BMI (kg/m^2)	23	(21-26)	24	(21-26)	0.310
HWDI	101	(95-107)	98	(92-104)	**<0.001**

p from Wilcoxon rank-sum test

p in bold correspond to $p < 0.05$

Table 2. Regression analysis for changes in BF% with HWDI, age and gender

Covariates	Regression Coefficients	Standard Error	p	SEE (%)	Adjusted R^2
Overall			**<0.001**	4.80	0.452
Intercept	48.267	1.000			
HWDI	-0.221	0.010	**<0.001**		
Age	0.148	0.006	**<0.001**		
Gender	-6.791	0.195	**<0.001**		
Men			**<0.001**	5.37	0.215
Intercept	34.508	1.784			
HWDI	-0.159	0.017	**<0.001**		
Age	0.161	0.011	**<0.001**		
Women			**<0.001**	4.39	0.337
Intercept	53.35	1.210			
HWDI	-0.265	0.011	**<0.001**		
Age	0.132	0.008	**<0.001**		

p from Wald's test.

p in bold correspond to $p < 0.05$

SEE = Standard Error of Estimate

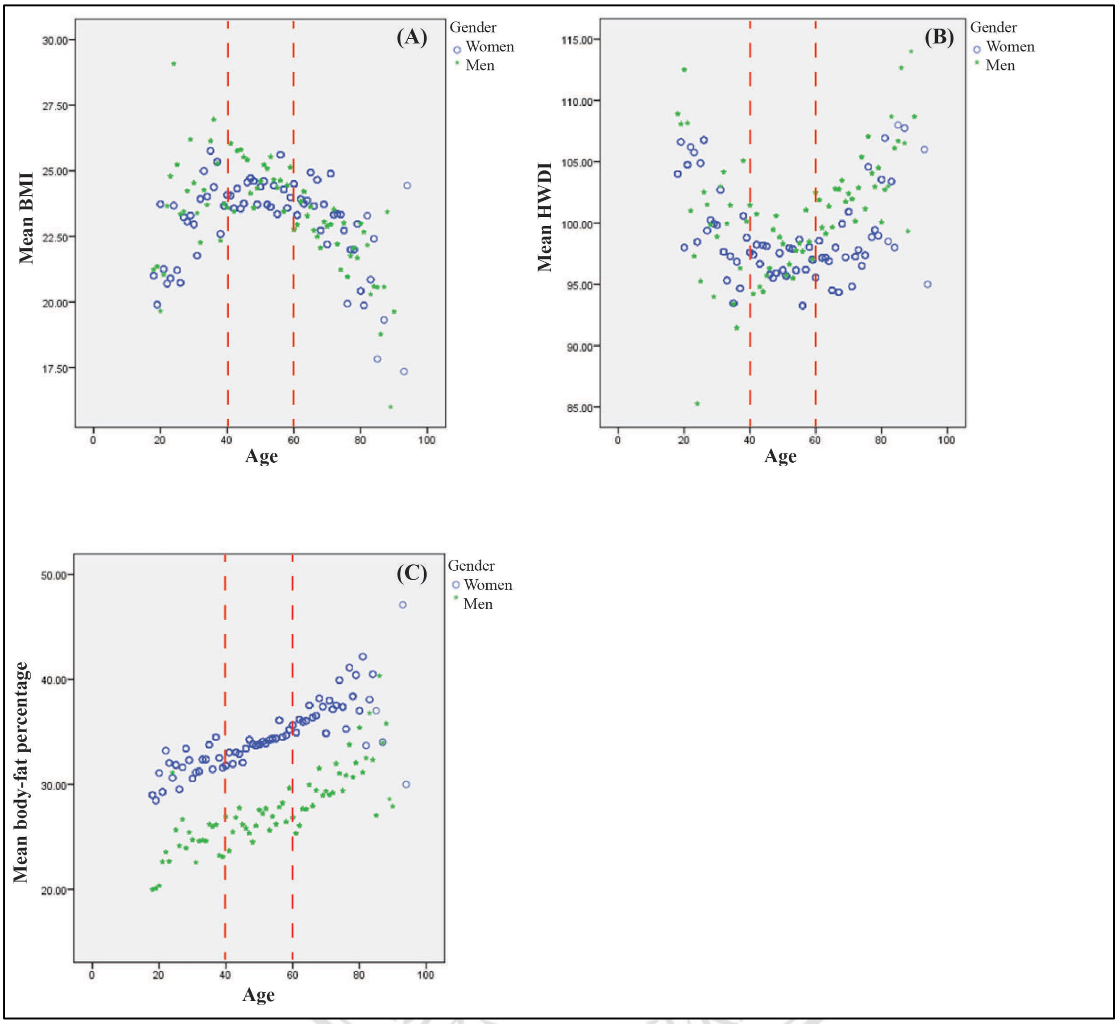


Figure 1. Relationship between (A) mean BMI and age, (B) mean HWDI and age, and (C) mean body-fat percentage and age, stratified by gender. , (o) for women and (*) for men.

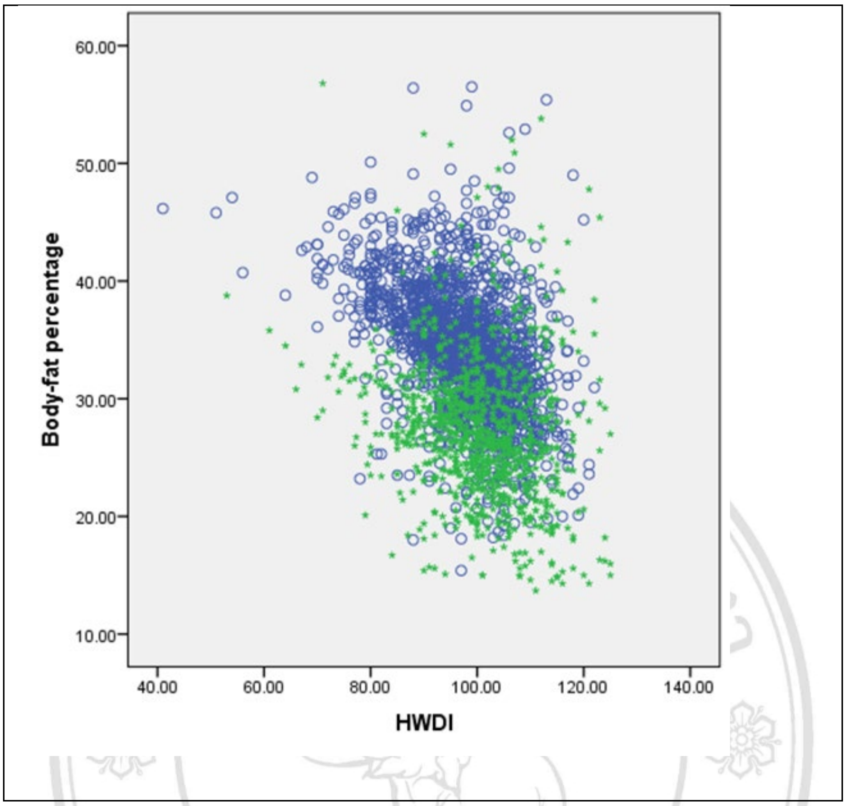


Figure 2. Relationship between HWDI and body-fat percentage, (o) for women and (*) for men.

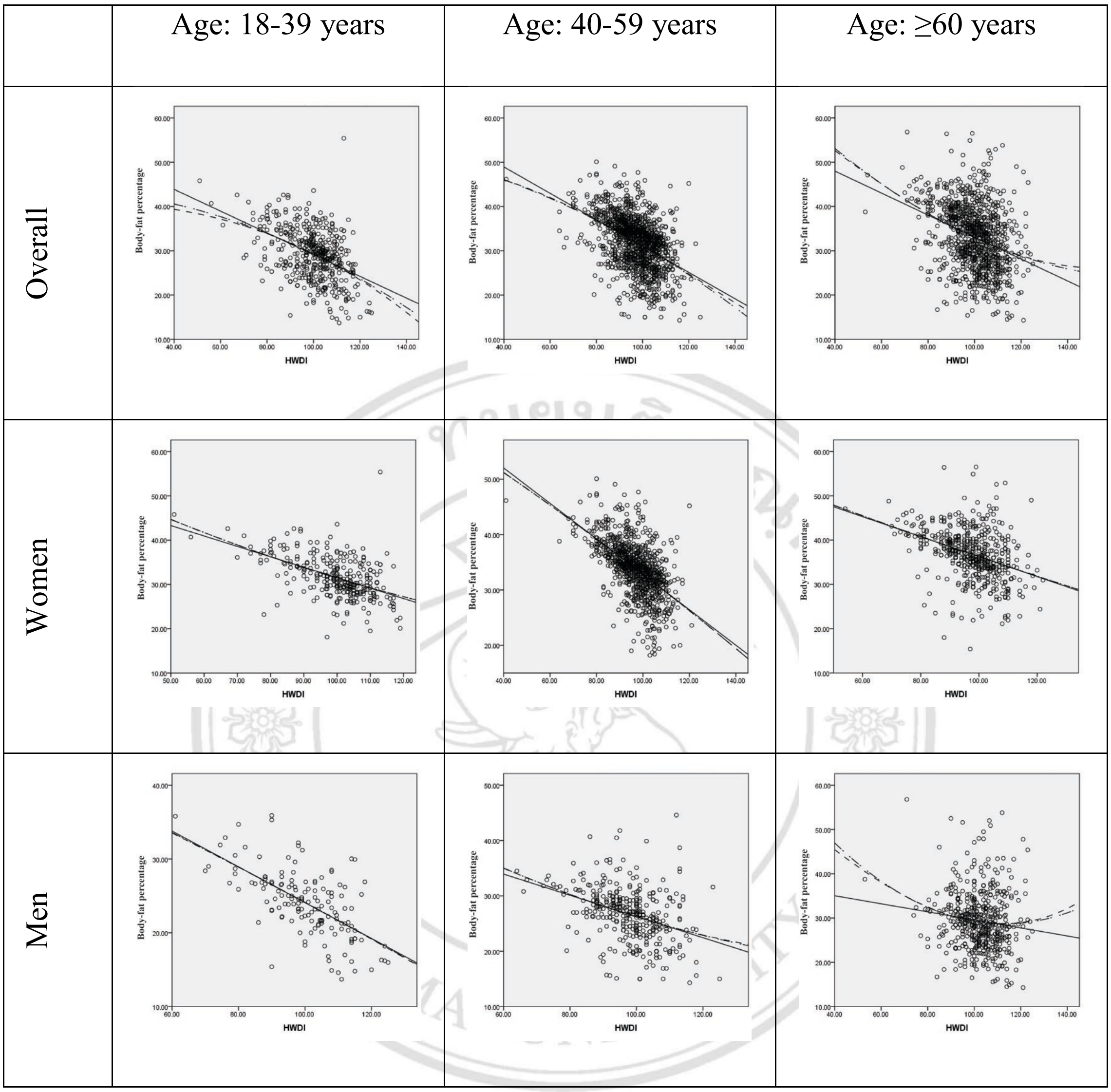


Figure 3. HWDI and body-fat percentage in relation to age and gender.

○ Observed

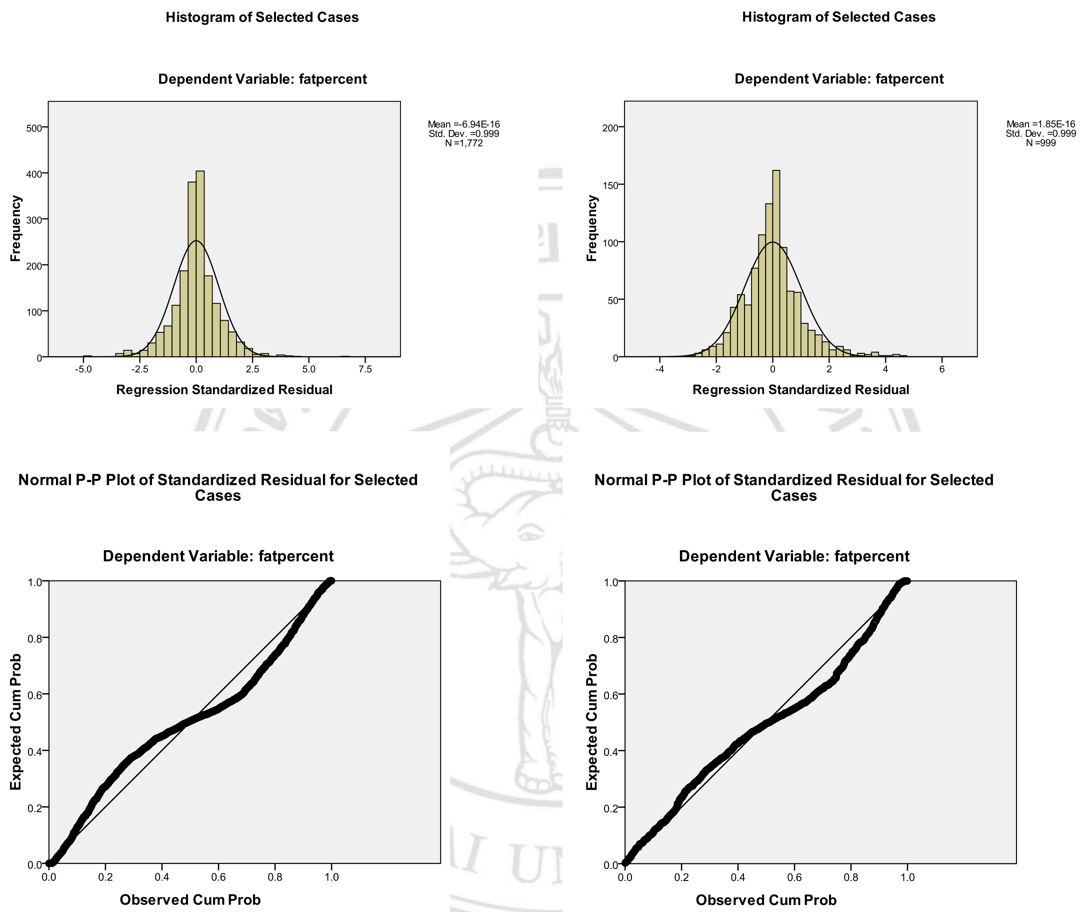
——— Linear

—•— Quadratic

---- Cubic

APPENDIX C

Checking principle assumption of linear regression model



Histogram and normal P-P plot of regression standardized residuals

Normality and homoscedasticity of regression model were considering using a plot of the standardized residuals (errors) including histogram and normal P-P plot. The results showed that the errors of regression model were normally distributed.

Regression model for women

1. Pairwise correlations of age, BF%, and HWDI were showed as below:

Correlations

		age	BF%	hwdi
age	Pearson Correlation	1	.369**	-.068**
	Sig. (2-tailed)		.000	.004
	N	1772	1772	1772
BF%	Pearson Correlation	.369**	1	-.473**
	Sig. (2-tailed)	.000		.000
	N	1772	1772	1772
HWDI	Pearson Correlation	-.068**	-.473**	1
	Sig. (2-tailed)	.004	.000	
	N	1772	1772	1772

**. Correlation is significant at the 0.01 level (2-tailed).

2. According to model 2 from table ANOVA, the p-value derived from ANOVA lower than 0.05. Therefore, the null hypothesis about regression coefficient of HWDI and age ($H_0 : \beta_1 = \beta_2 = 0$) was rejected. It stated that there was at least 1 independent variable associated with dependent variable.

ANOVA[c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11540.129	1	11540.129	509.417	.000[a]
	Residual	40096.905	1770	22.654		
	Total	51637.034	1771			
2	Regression	17428.001	2	8714.001	450.614	.000[b]
	Residual	34209.033	1769	19.338		
	Total	51637.034	1771			

a. Predictors: (Constant), HWDI

b. Predictors: (Constant), HWDI, age

c. Dependent Variable: BF%

3. According to model summary table, the coefficient of determination (r^2) of model 2 was 0.338. It means that the independent variables, HWDI and age, which included in model 2 from table model summary can predict BF% as 33.8%.

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.473[a]	.223	.223	4.75958	.223	509.417	1	1770	.000	
2	.581[b]	.338	.337	4.39751	.114	304.471	1	1769	.000	1.989

a. Predictors: (Constant), HWDI

b. Predictors: (Constant), HWDI, age

c. Dependent Variable: BF%

4. According to coefficients table, the unstandardized coefficients of constant, HWDI, and age in model 2 were 53.35 (95% CI: 50.98, 55.72), -0.27 (95% CI: -0.29, -0.24), and 0.13 (95% CI: 0.12, 0.15), respectively. The estimated 95% CI of regression coefficients (β) were not contains zero consistent with results of t-test which the coefficient of constant, HWDI, and age were not equal zero (p-value< 0.05). We can conclude that HWDI and age were independently associated with BF%. The regression model to predict BF% for women was:

$$\hat{y} = 53.350 - 0.265(HWDI) + 0.132(age)$$

Coefficients[a]

Model	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound	Correlations Zero-order	Correlations Partial	Correlations Part	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1 (Constant)	61.463	1.209		50.830	.000	59.092	63.835					
HWDI	-.279	.012	-.473	-22.57	.000	-.303	-.254	-.473	-.473	-.47	1.000	1.000
2 (Constant)	53.350	1.210		44.088	.000	50.977	55.724					
HWDI	-.265	.011	-.450	-23.19	.000	-.287	-.243	-.473	-.483	-.45	.995	1.005
age	.132	.008	.338	17.449	.000	.117	.147	.369	.383	.338	.995	1.005

a. Dependent Variable: BF%

5. Partial correlation coefficient was used to explained the correlation between predictors and BF% which considering other variables as constants. Partial correlation coefficients of HWDI and age were -0.48 and 0.38, respectively.

6. The assumption about independence of predictors was considered from tolerance and VIF. If tolerance of each predictor in regression model was high and closed to 1 and VIF was low and closed to 1, the predictor was independent from other variable in the model.

   Tolerance and VIF of HWDI and age were as below:

Variables	Tolerance	VIF
• HWDI	0.995	1.005
• age	0.995	1.005

According to high tolerance and low VIF of HWDI and age, it stated that both of HWDI and age were independent from other variables. Moreover, we can consider from condition index of each predictor in collinearity diagnostics table. There was less association between predictor and other variables if the condition index was low.

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	HWDI	age
1	1	1.996	1.000	.00	.00	
	2	.004	21.342	1.00	1.00	
2	1	2.948	1.000	.00	.00	.01
	2	.048	7.811	.02	.04	.93
	3	.004	26.761	.98	.96	.07

a. Dependent Variable: BF%

The results in table below showed that condition index of HWDI and age were low (7.81 and 26.76, respectively). That means both of HWDI and age was independent from other variables, consistent with considering from tolerance and VIF.

7. Independence of errors (e_i) was considered form Durbin-Watson test. The null hypothesis is errors were independent with each other. The p-value derived from Durbin-Watson test of model 2 in model summary table was equal to 1.989 which higher than 0.05, it was no evidence to reject the null hypothesis. Therefore, errors of model 2 were independent.

Regression model for men

1. Pairwise correlations of age, BF%, and HWDI were showed as below:

Correlations

		age	BF%	HWDI
age	Pearson Correlation	1	.388**	.138**
	Sig. (2-tailed)		.000	.000
	N	999	999	999
BF%	Pearson Correlation	.388**	1	-.200**
	Sig. (2-tailed)	.000		.000
	N	999	999	999
HWDI	Pearson Correlation	.138**	-.200**	1
	Sig. (2-tailed)	.000	.000	
	N	999	999	999

**. Correlation is significant at the 0.01 level (2-tailed).

2. According to model 2 from table ANOVA, the p-value derived from ANOVA lower than 0.05. Therefore, the null hypothesis about regression coefficient of HWDI and age ($H_0 : \beta_1 = \beta_2 = 0$) was rejected. It stated that there was at least 1 independent variable associated with dependent variable.

ANOVA[c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5546.665	1	5546.665	177.167	.000[a]
	Residual	31213.567	997	31.307		
	Total	36760.231	998			
2	Regression	7954.172	2	3977.086	137.512	.000[b]
	Residual	28806.059	996	28.922		
	Total	36760.231	998			

a. Predictors: (Constant), age

b. Predictors: (Constant), age, HWDI

c. Dependent Variable: BF%

3. According to model summary table, the coefficient of determination (r^2) of model 2 was 0.216. It means that the independent variables, HWDI and age, which included in model 2 from table model summary can predict BF% as 21.6%.

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.388[a]	.151	.150	5.59531	.151	177.167	1	997	.000	
2	.465[b]	.216	.215	5.37789	.065	83.242	1	996	.000	1.951

a. Predictors: (Constant), age

b. Predictors: (Constant), age, HWDI

c. Dependent Variable: BF%

4. According to coefficients table, the unstandardized coefficients of constant, HWDI, and age in model 2 were 34.51 (95% CI: 31.00, 38.01), -0.16 (95% CI: -0.19, -0.13), and 0.16 (95% CI: 0.14, 0.18), respectively. The estimated 95% CI of regression coefficients (β) were not contains zero consistent with results of t-test which the coefficient of constant, HWDI, and age were not equal zero (p-value< 0.05). We can conclude that HWDI and age were independently associated with BF%. The regression model to predict BF% for men was:

$$\hat{y} = 34.508 - 0.159(HWDI) + 0.161(age)$$

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1 (Constant)	19.270	.653		29.495	.000	17.987	20.552					
age	.147	.011	.388	13.310	.000	.126	.169	.388	.388	.388	1.000	1.000
2 (Constant)	34.507	1.784		19.340	.000	31.006	38.009					
age	.161	.011	.424	14.973	.000	.140	.182	.388	.429	.420	.981	1.019
hwdi	-.159	.017	-.258	-9.124	.000	-.194	-.125	-.200	-.278	-.26	.981	1.019

a. Dependent Variable: BF%

5. Partial correlation coefficients of HWDI and age among men were -0.28 and 0.43, respectively.

6. The tolerance and VIF of HWDI and age among men were as below:

Variables	Tolerance	VIF
• HWDI	0.981	1.019
• age	0.981	1.019

The results in table below showed that condition index of HWDI and age were low (7.77 and 24.90, respectively). That means both of HWDI and age was independent from other variables, consistent with considering from tolerance and VIF.

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	age	HWDI
1	1	1.963	1.000	.02	.02	
	2	.037	7.243	.98	.98	
2	1	2.946	1.000	.00	.01	.00
	2	.049	7.766	.03	.99	.03
	3	.005	24.895	.97	.00	.97

a. Dependent Variable: BF%

7. The p-value derived from Durbin-Watson test of model 2 in model summary table was equal to 1.951 which higher than 0.05, it was no evidence to reject the null hypothesis. Therefore, errors of model 2 were independent.

APPENDIX D

Regression with transformed variables

1. ln(BF%)

- Overall

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.381[a]	.145	.145	.19836

a. Predictors: (Constant), HWDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18.460	1	18.460	469.174	.000[b]
	Residual	108.946	2769	.039		
	Total	127.406	2770			

a. Dependent Variable: ln_BF%

b. Predictors: (Constant), HWDI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.286	.039		109.253	.000
	HWDI	-.009	.000	-.381	-21.660	.000

a. Dependent Variable: ln_BF%

- Men

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.232[a]	.054	.053	.21280

a. Predictors: (Constant), HWDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.575	1	2.575	56.858	.000[b]
	Residual	45.149	997	.045		
	Total	47.723	998			

a. Dependent Variable: ln_BF%

b. Predictors: (Constant), HWDI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.814	.069		55.211	.000
	HWDI	-.005	.001	-.232	-7.540	.000

a. Dependent Variable: ln_BF%

- Women

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.466[a]	.217	.217	.14404

a. Predictors: (Constant), HWDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10.207	1	10.207	491.979	.000[b]
	Residual	36.723	1770	.021		
	Total	46.931	1771			

a. Dependent Variable: ln_BF%

b. Predictors: (Constant), HWDI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.330	.037		118.329	.000
	HWDI	-.008	.000	-.466	-22.181	.000

a. Dependent Variable: ln_BF%

2. Log(BF%), log(HWDI)

- Overall

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.375[a]	.141	.140	.08636

a. Predictors: (Constant), log_ HWDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.380	1	3.380	453.247	.000[b]
	Residual	20.650	2769	.007		
	Total	24.030	2770			

a. Dependent Variable: log_BF%

b. Predictors: (Constant), log_ HWDI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.076	.074		41.383	.000
	log_ HWDI	-.794	.037	-.375	-21.290	.000

a. Dependent Variable: log_BF%

- Men

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.233[a]	.054	.053	.09241

a. Predictors: (Constant), log_ HWDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.488	1	.488	57.143	.000[b]
	Residual	8.513	997	.009		
	Total	9.001	998			

a. Dependent Variable: log_BF%

b. Predictors: (Constant), log_ HWDI

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	2.427	.132		18.416	.000
	log_ HWDI	-.498	.066	-.233	-7.559	.000

a. Dependent Variable: log_BF%

- Women

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.460[a]	.212	.211	.06278

a. Predictors: (Constant), log_ HWDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.875	1	1.875	475.739	.000[b]
	Residual	6.977	1770	.004		
	Total	8.852	1771			

a. Dependent Variable: log_BF%

b. Predictors: (Constant), log_ HWDI

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3.030	.069		44.031	.000
	log_ HWDI	-.755	.035	-.460	-21.811	.000

a. Dependent Variable: log_BF%

3. log(HWDI)

- Overall

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.382[a]	.146	.145	5.99967

a. Predictors: (Constant), log_ HWDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	16984.012	1	16984.012	471.830	.000[b]
	Residual	99672.983	2769	35.996		
	Total	116656.995	2770			

a. Dependent Variable: BF%

b. Predictors: (Constant), log_ HWDI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	144.056	5.165		27.891	.000
	log_ HWDI	-56.314	2.593	-.382	-21.722	.000

a. Dependent Variable: BF%

- Men

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.204[a]	.041	.040	5.94502

a. Predictors: (Constant), log_ HWDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1523.105	1	1523.105	43.095	.000[b]
	Residual	35237.243	997	35.343		
	Total	36760.348	998			

a. Dependent Variable: BF%

b. Predictors: (Constant), log_ HWDI

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	83.295	8.480		9.822	.000
	log_ HWDI	-27.830	4.239	-.204	-6.565	.000

a. Dependent Variable:BF%

- Women

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.469[a]	.220	.220	4.77005

a. Predictors: (Constant), log_ HWDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11363.061	1	11363.061	499.400	.000[b]
	Residual	40273.561	1770	22.753		
	Total	51636.623	1771			

a. Dependent Variable:BF%

b. Predictors: (Constant), log_ HWDI

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	151.122	5.229		28.900	.000
	log_ HWDI	-58.792	2.631	-.469	-22.347	.000

a. Dependent Variable: BF%

4. 1/(HWDI)

- Overall

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.373[a]	.139	.139	6.02341

a. Predictors: (Constant), 1/HWDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	16193.771	1	16193.771	446.338	.000[b]
	Residual	100463.225	2769	36.281		
	Total	116656.995	2770			

a. Dependent Variable: BF%

b. Predictors: (Constant), 1/HWDI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	9.695	1.057		9.172	.000
	1/HWDI	2166.462	102.546	.373	21.127	.000

a. Dependent Variable: BF%

- Men

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.206[a]	.042	.041	5.94240

a. Predictors: (Constant), 1/HWDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1554.123	1	1554.123	44.011	.000[b]
	Residual	35206.225	997	35.312		
	Total	36760.348	998			

a. Dependent Variable: BF%

b. Predictors: (Constant), 1/HWDI

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	16.134	1.745		9.248	.000
	1/HWDI	1143.957	172.437	.206	6.634	.000

a. Dependent Variable: BF%

- Women

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.456[a]	.208	.207	4.80721

a. Predictors: (Constant), 1/HWDI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10733.211	1	10733.211	464.455	.000[b]
	Residual	40903.412	1770	23.109		
	Total	51636.623	1771			

a. Dependent Variable: BF%

b. Predictors: (Constant), 1/HWDI

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	11.463	1.065		10.760	.000
	1/HWDI	2205.053	102.317	.456	21.551	.000

a. Dependent Variable: BF%

APPENDIX E

Non-linear regression

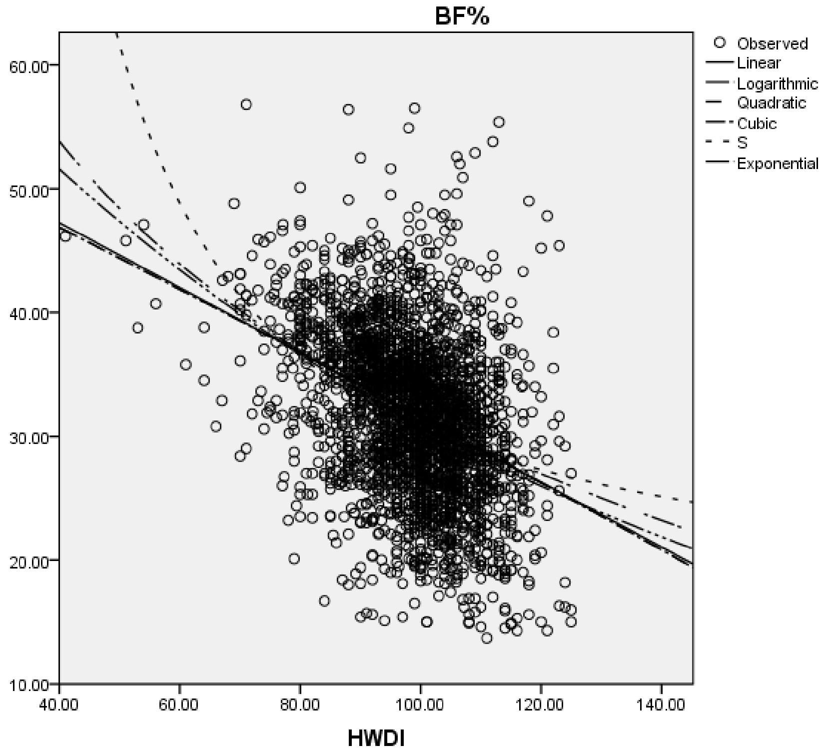
1. Overall

Model Summary and Parameter Estimates

Dependent Variable: BF%

Equation	Model Summary				
	R Square	F	df1	df2	Sig.
Linear	.148	479.326	1	2769	.000
Logarithmic	.146	471.830	1	2769	.000
Quadratic	.148	239.593	2	2768	.000
Cubic	.148	239.593	2	2768	.000
S	.132	420.204	1	2769	.000
Exponential	.145	469.174	1	2769	.000

The independent variable is HWDI



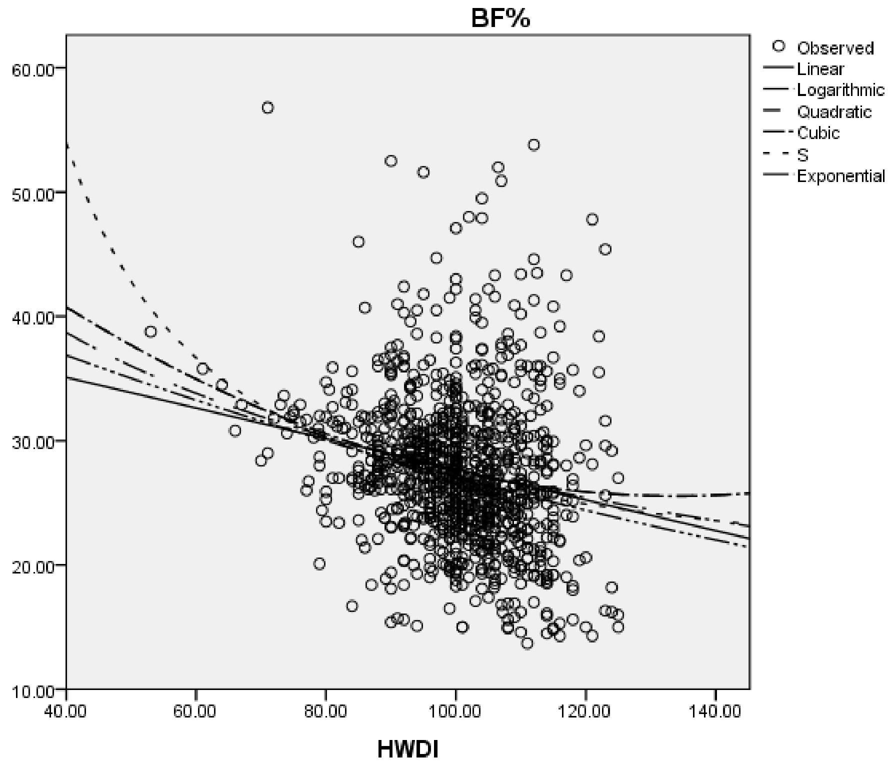
2. Men

Model Summary and Parameter Estimates

Dependent Variable: BF%

Equation	Model Summary				
	R Square	F	df1	df2	Sig.
Linear	.040	41.538	1	997	.000
Logarithmic	.041	43.095	1	997	.000
Quadratic	.042	21.870	2	996	.000
Cubic	.042	21.870	2	996	.000
S	.054	56.389	1	997	.000
Exponential	.054	56.858	1	997	.000

The independent variable is HWDI.



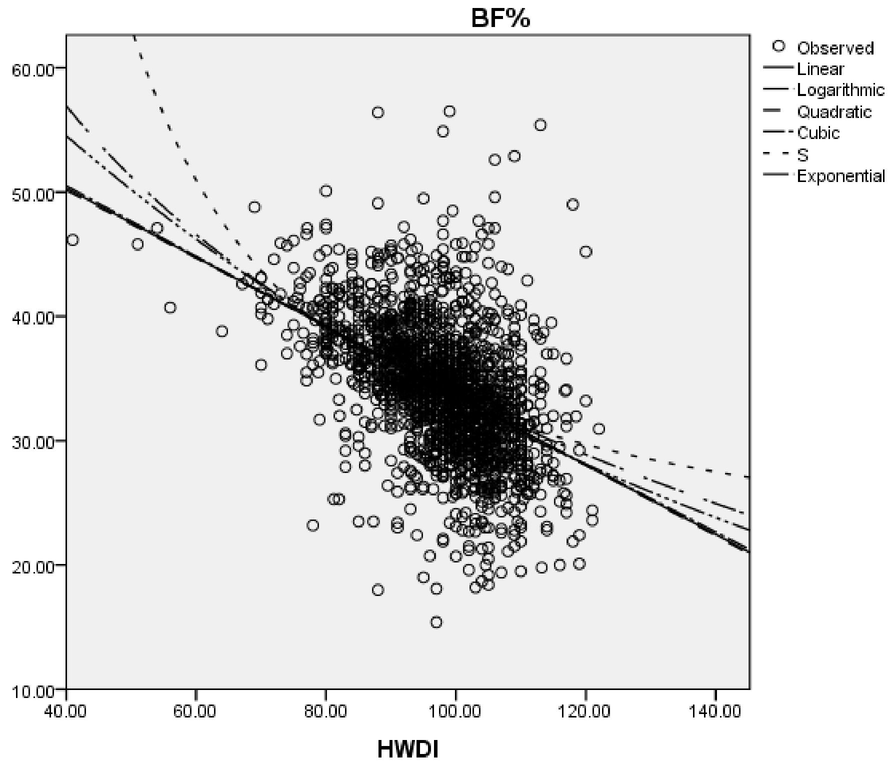
3. Women

Model Summary and Parameter Estimates

Dependent Variable: BF%

Equation	Model Summary				
	R Square	F	df1	df2	Sig.
Linear	.223	509.398	1	1770	.000
Logarithmic	.220	499.400	1	1770	.000
Quadratic	.223	254.559	2	1769	.000
Cubic	.223	254.562	2	1769	.000
S	.198	435.851	1	1770	.000
Exponential	.217	491.979	1	1770	.000

The independent variable is HWDI.



Note: We didn't study in multiple non-linear regression.

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