Ordinal regression model for analyzing factors affecting obesity levels in middle-aged adults in Indonesia

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Abstract. Obesity is one of the major issues in many countries, including in Indonesia. In this study, the obesity category based on body mass index (BMI) is categorized into four levels, namely non-obese with BMI below 30 kg/m², obesity I with BMI 30 – 34.9 kg/m², obesity II with BMI 35 – 39.9 kg/m², and obesity III with BMI above 40 kg/m². The objective of this study was to assess factors affecting Indonesian obesity levels using ordinal logistic proportional odds models for each gender aged 40-65 years based on the fifth Indonesian Family Life Survey (IFLS 5) data. In totals of 4,658 male participants and 4,772 female participants were included in the analyses. The prevalence of severe obesity was associated with age, education, working status, and waist-hip circumference ratio for both men and women. With addition that the frequency of eating affects the prevalence of severe obesity for women. Men and women who had smaller waist-hip circumference ratio occurred to have higher probability of non-obese.

1. Introduction

Obesity is an excessive accumulation of fat in an individual’s body and is at risk for health, which is one of the major issues in developing and developed countries [1]. In 2016, the prevalence of obesity in adults (18 years of age and older) reached over 650 million people and more than 340 million children and adolescents aged 5-9 years were obese [1]. The prevalence of obesity in Indonesia in 2007 showed that 19.1% of Indonesia's adult population (over 18 years of age) was obese with a body mass index (BMI) of more than 27 [2]. The prevalence of obesity continued to increase by 21.7% in 2010 and by 28.9% in 2013 [3]. North Sulawesi is the province in Indonesia with the highest proportion of obesity in adolescents (over 18 years of age) with a BMI average of 30.2% [4].

Obesity can lead to chronic diseases, including diabetes, coronary heart disease, and osteoarthritis as well as increasing the risk of developing certain cancers and influencing their outcomes. [5]. Several indicators can show an individual affected by obesity, including body mass index (BMI), waist circumference, waist-hip circumference ratio (WHR), skinfold thickness, and body fat levels [6]. The simplest and most frequently used indicator for obesity is the BMI, calculated from the weight of a person in kilograms divided by the height square in meters [1].

In this study, we are interested in assessing the relationship between obesity causes and obesity levels based on the BMI, where obesity factors as predictor variables and obesity levels as a response variable. Obesity factors used in this study are socio-demographic factors including age [7], sex [8], education [9,10], working status [7]; anthropometric measurement including waist-hip circumference ratio (WHR) [6]; obesogenic behaviors including frequency of eating [11], smoking status [12]; and physical and mental health status including sleep quality [13] and stress level [14-15]. The obesity category based on body mass index (BMI) is categorized into four levels, non-obese with BMI below 30 kg/m², obesity I with BMI 30-34.9 kg/m², obesity II with BMI 35-39.9 kg/m², and obesity III with BMI above 40 kg/m² [1].
An ordinal logistic model with proportional odds is used to analyze factors affecting the obesity levels, as we focus on low to high levels of obesity. Moreover, we assume that the individual-level predictors have the same impact in transitioning, for example, between non-obese and obesity I as between obesity II and obesity III. Therefore, the odds proportional model is more appropriate.

Women and men who have reached more than 40 years tend to be fatter and find it harder to lose weight than when they were in their 20s. Their body’s metabolism may slow down and increase weight. Many researchers have found that the obesity prevalence tends to rise as people aged over 40 years, especially for women compared to men [16, 17, 18]. In this study, we suggest two models of the prevalence of obesity for men and women aged 40-65 years, taking into account factors in sociodemographic, behavioral, and physical and mental health. Understanding factors driving the gender-based burden of obesity in middle-aged adults in Indonesia is crucial. Using recent national representative data from the fifth wave of the Indonesia Family Life Survey (IFLS-5) conducted in 2014/2015 [19], we report on the prevalence of obesity levels in Indonesia among men and women and examine how these patterns vary throughout sex.

2. Materials

2.1. Data

Data used in this study are secondary data from the fifth wave of Indonesia Family Life Survey (IFLS-5). The IFLS-5 was conducted by RAND Labor and Population in collaboration with Survey Meter Indonesia [19]. The sample in IFLS 5 is a continuous survey that includes samples from IFLS 1, IFLS 2, IFLS 2+, IFLS 3, and IFLS 4 [19]. The IFLS 1 began in 1993 and held in 13 of 26 provinces in Indonesia, including 297 districts and 1698 sub-districts [19]. Samples were selected using the stratified sampling scheme, a sampling technique that divided the population into several strata (sub-populations), then each sample was sampled [20]. The selection of provinces as a sample is based on the aim of maximizing the representation of the population reflecting cultural and socio-economic diversity in Indonesia in addition to the cost efficiency goal [20]. The selected provinces in the IFLS-5 were four provinces in Sumatra Island (North Sumatra, West Sumatra, South Sumatra, and Lampung), five provinces on Java Island (DKI Jakarta, West Java, Central Java, DI Yogyakarta, and East Java), and four provinces include Bali, West Nusa Tenggara, South Kalimantan, and South Sulawesi [20]. In this study, we restricted our analysis to the IFLS-5 cross sectional survey for individuals aged 40 and older.

2.2. Measures

 Anthropometric measurements. Heights were measured in centimeter, where respondents were asked to remove footwear [20]. Weights were measured in kilogram, where respondents were asked to remove footwear [20]. Body mass index (BMI) was calculated as weight in kg divided by height in meter squared and classified according to Asian criteria, wherein this study the categories of underweight (< 18.5 kg/m²), normal (18.5 – 24.9 kg/m²), and overweight (25 – 29.9 kg/m²) were included in the category of not obese. The obesity levels in this study consist 4 categories of not obese with BMI (< 30 kg/m²), obesity I with BMI (30 – 34.9 kg/m²), obesity II with BMI (35 – 39 kg/m²), and obesity III with BMI (≥ 40 kg/m²) [1].

Waist and hip circumference were measured in centimeter, where respondents do not wear thick clothes [20]. Waist-hip circumference ratio (WHR) was calculated as a waist circumference in centimeter divided by hip circumference in centimeter [20].

Socio-demographic factor questions included age (≥ 40 years), gender (male or female), education (in three categories of elementary schools, middle and high schools, diploma or higher), and working status (indicator 1 for any activities work for pay) [20].

Frequency of eating was assessed with a question on, “Do you normally eat, ... 3 times per day, 2 times per day, 1 times per day, 5-6 times per week, etc.” [20]. Responses were coded as 1 = 3 times per day, 2 = 2 times per day, 3 = 1 times per day.

Smoking status was assessed with a question on, “Have you ever chewed tobacco, smoked a pipe, smoked self-rolled cigarettes, or smoked cigarettes/cigars? [20]. Responses were grouped into yes and no.
Sleep quality was assessed with a question on, “My quality of sleep was, ... very poor, poor, fair, good, very good” [20]. Responses were grouped into bad (very poor, poor, fair), and good (good, very good).

Stress level was assessed with a part of the positive and negative effects, with a question on, “Yesterday, did you feel... not at all, a little, somewhat, quite a bit, and very? [20]”. Responses were grouped into low (not at all, a little), medium (somewhat, quite a bit), and high (very).

3. Methods

The ordered logistic regression or proportional odds model was originally proposed in 1980 [21]. Let $Y_i$ represents the dependent variable for the obesity levels of an individual $i$. The four categories for $Y_i$ are not obese, obesity I, obesity II, and obesity III labeled from $j = 1, 2, 3, 4$. The proportional odds model is given by

$$
\logit(P(Y_i \leq j)) = \log \left( \frac{P(Y_i \leq j)}{1 - P(Y_i \leq j)} \right) = \alpha_j - X_i' \beta, \ j = 1, 2, 3
$$

(1)

where $X_i$ represents a vector of individual-level covariates, $\alpha_j$ is an unknown intercept that separates the dependent variable categories, and $\beta$ is a vector of unknown regression parameters [22]. The model assumes that the effect of $X_i$ is identical for all three cumulative logits. The unknown intercept is assumed to follow $\alpha_1 \leq \alpha_2 \leq \alpha_3$. The matrix of $X_i$ contains continuous and categorical independent variables. If the independent variable is a categorical, then the model includes indicator variables to represent its various levels that omit the category of reference. The negative sign in Equation (1) is used to ensure that large values of $X_i' \beta$ represents an increase of probability in the higher-numbered categories [21].

Model (1) is called as the proportional odds model as the odds ratio is independent of the response variable category $j$ [21]. Suppose two different individuals $r$ and $s$ had the same values of the dependent variable but different covariates, the odds ratio of the two individuals is

$$
\frac{p(Y_r \leq j)/(1-p(Y_r \leq j))}{p(Y_s \leq j)/(1-p(Y_s \leq j))} = \frac{\exp(\alpha_j - X_r' \beta)}{\exp(\alpha_j - X_s' \beta)} = \exp(- (X_r' - X_s' \beta))
$$

(2)

Equation (2) shows that the odds ratio does not depend on $j$. For an individual $i$ when its $X_i$ has two categories, the odds ratio for the single categorical variable which is compared to the reference category is defined as

$$
\frac{\text{odds}(Y_i \leq j | 1)}{\text{odds}(Y_i \leq j | 0)} = \exp(-X_i' \beta), \ j = 1, 2, 3.
$$

(3)

The parameters in Model (1) are estimated using a maximum likelihood method by applying a Fisher scoring iterative algorithm simultaneously for all $j$. A Wald test ($Z = \hat{\beta}_r / \sqrt{\text{Var}(\hat{\beta}_r)}$) is used to test individual regression parameters by formulating the hypotheses as $H_0: \beta_r = 0$ versus $H_0: \beta_r \neq 0$. When the null hypothesis is rejected (p-value < $\alpha$), then log-odds for each cumulative probability becomes larger or smaller with $X_r$ following the sign of $\beta_r$. For testing the effects of all variables simultaneously equal to zero, we can compute an Likelihood Ratio (LR) test, $\chi^2 = -2 \log(\Lambda)$ where $\Lambda = L(\hat{\beta}^{(0)}|y)/L(\hat{\beta}^{(0)}|y)$. The LR test statistic is a ratio between the maximum of likelihood function under the null hypothesis ($L(\hat{\beta}^{(0)}|y)$) and under the null or alternative hypothesis ($L(\hat{\beta}^{(0)}|y)$). If the null hypothesis is rejected (p-value < $\alpha$), then at least one of the parameters is not equal to zero. In this study, we use a polr function in MASS package in R for fitting the model [23].

4. Results and discussions

4.1. Sample characteristics

The samples used in this study were 4,658 men and 4,772 women aged 40-65 years. Overall, both men and women were considered non-obese on the basis of most of the explanatory variables in which women showed higher-numbered in obesity compared to men (table 1). Overall, 93.3% (CI = 92.6, 94.0) of males reported to have higher percentage of non-obese than females (81.9%, CI = 80.8, 83.0). Small percentage values were distributed along class obesity I to obesity III among men and women. In all age
groups, the prevalence of non-obese among men was higher than women, except for comparable numbers in age groups 50-54.

Individuals with higher education were reported to have lower percentages of non-obese (men, 11.7% (CI = 10.7, 12.6); women, 7.5% (CI = 6.7, 8.2)) than those with middle or low education for both men and women. The majority of the respondents who work (men, 84.7% (CI = 83.7, 85.7); women, 54.2% (CI = 52.8, 55.6), their prevalence of non-obese were higher than those who do not work. Regarding various WHR, women who have waist-hip circumference ratio of 0.8-0.9 and 0.9-1 were reported to have high numbers of the prevalence of obesity III (37.4% and 37.1%) while in these groups’ men were reported in the prevalence of non-obese (35% and 51.3%). Individuals who have once times a day and twice a day eating were reported to have high percentages of non-obese. Women who do not smoke cigarettes were reported to have high number of the prevalence of non-obese (77.8%, CI = (76.7, 79.0)). For men, however, their prevalence of non-obese was greater for those who smoke cigarettes (72.5%, CI = (71.2, 73.7)) than those who do not (20.8%, CI = (19.7, 22.0)). The prevalence of non-obese for those who have bad quality of sleep was higher than those who have not for either men or women. Individuals with low level of stress were reported to have high prevalence of non-obese for both sexes.

### Table 1. The sample characteristic of respondents to the level of obesity

| Variables                  | Men (n = 4,658) | Women (n = 4,772) |
|----------------------------|-----------------|-------------------|
| Sex                        | Non-obese (%)   | Obesity I (%)     | Obesity II (%)  | Obesity III (%) |
| Sex                        | 93.3 (92.6, 94.0) | 6.0 (5.3, 6.7)    | 0.6 (0.4, 0.8)  | 0.1 (0.0, 0.2)  |
| Age in years               |                 |                   |                  |                 |
| 40-44                      | 28.2 (26.9, 29.5) | 1.6 (1.2, 2.0)    | 0.2 (0.1, 0.3)  | 0.0 (0.0, 0.1)  |
| 45-49                      | 22.0 (20.8, 23.2) | 1.9 (1.5, 2.3)    | 0.2 (0.1, 0.4)  | 0.0 (0.0, 0.1)  |
| 50-54                      | 16.8 (15.7, 17.9) | 1.1 (0.8, 1.4)    | 0.0 (0.0, 0.1)  | 0.0 (0.0, 0.1)  |
| 55-59                      | 13.8 (12.8, 14.8) | 0.9 (0.6, 1.1)    | 0.1 (0.0, 0.2)  | 0.0 (0.0, 0.1)  |
| 60-65                      | 12.4 (11.5, 13.4) | 0.5 (0.3, 0.6)    | 0.0 (0.0, 0.0)  | 0.0 (0.0, 0.0)  |
| Education                  |                 |                   |                  |                 |
| Low                        | 40.7 (39.3, 42.1) | 1.5 (1.1, 1.8)    | 3.2 (2.7, 3.7)  | 1.3 (1.0, 1.7)  |
| Middle                     | 40.9 (39.5, 42.3) | 0.1 (0.0, 0.2)    | 0.3 (0.1, 0.4)  | 0.2 (0.1, 0.4)  |
| High                       | 11.7 (10.7, 12.6) | 0.0 (0.0, 0.0)    | 0.1 (0.0, 0.2)  | 0.0 (0.0, 0.1)  |
| Working status             |                 |                   |                  |                 |
| No                         | 8.6 (7.8, 9.4)   | 0.7 (0.4, 0.9)    | 0.0 (0.0, 0.1)  | 0.0 (0.0, 0.1)  |
| Yes                        | 84.7 (83.7, 85.7) | 5.3 (4.7, 5.9)    | 0.6 (0.3, 0.8)  | 0.1 (0.0, 0.2)  |
| WHR                        |                 |                   |                  |                 |
| 0.5 or less                | 0.1 (0.0, 0.1)   | 0.0 (0.0, 0.0)    | 0.0 (0.0, 0.0)  | 0.0 (0.0, 0.0)  |
| 0.6-0.6                    | 0.1 (0.0, 0.2)   | 0.0 (0.0, 0.0)    | 0.0 (0.0, 0.0)  | 0.0 (0.0, 0.0)  |
| 0.7-0.8                    | 0.4 (0.2, 0.6)   | 0.0 (0.0, 0.0)    | 0.0 (0.0, 0.0)  | 0.0 (0.0, 0.0)  |
| 0.9-0.9                    | 2.1 (1.7, 2.6)   | 0.0 (0.0, 0.0)    | 0.0 (0.0, 0.0)  | 0.0 (0.0, 0.0)  |
| 1 or more                  | 53.0 (49.9, 57.2) | 4.3 (3.7, 4.8)    | 0.5 (0.3, 0.7)  | 0.1 (0.0, 0.2)  |
| Frequency of eating        |                 |                   |                  |                 |
| Once a time                 | 66.0 (64.6, 67.4) | 3.9 (3.4, 4.5)    | 0.3 (0.2, 0.5)  | 0.1 (0.0, 0.2)  |
| Twice a times               | 26.2 (24.9, 27.5) | 2.0 (1.6, 2.4)    | 0.2 (0.1, 0.4)  | 0.0 (0.0, 0.1)  |
| Three times a day           | 1.1 (0.8, 1.4)   | 0.1 (0.0, 0.1)    | 0.0 (0.0, 0.1)  | 0.0 (0.0, 0.0)  |
| Smoking status             |                 |                   |                  |                 |
| No                         | 20.8 (19.7, 22.0) | 1.7 (1.3, 2.1)    | 0.1 (0.0, 0.2)  | 0.0 (0.0, 0.1)  |
| Yes                        | 72.5 (71.2, 73.7) | 4.3 (3.7, 4.9)    | 0.5 (0.3, 0.7)  | 0.1 (0.0, 0.2)  |
| Quality of sleep           |                 |                   |                  |                 |
| Bad                        | 59.5 (58.1, 60.9) | 3.8 (3.2, 4.3)    | 0.4 (0.2, 0.6)  | 0.1 (0.0, 0.2)  |
| Good                       | 33.8 (32.4, 35.1) | 2.2 (1.8, 2.7)    | 0.2 (0.1, 0.3)  | 0.0 (0.0, 0.1)  |
| Stress level               |                 |                   |                  |                 |
| Low                        | 86.9 (85.9, 87.9) | 5.6 (4.9, 6.3)    | 0.3 (0.2, 0.5)  | 0.0 (0.0, 0.1)  |
| Medium                     | 5.0 (4.4, 5.7)   | 0.5 (0.3, 0.6)    | 0.2 (0.0, 0.3)  | 0.0 (0.0, 0.0)  |
| High                       | 1.4 (1.0, 1.7)   | 0.1 (0.0, 0.2)    | 0.0 (0.0, 0.0)  | 0.0 (0.0, 0.0)  |

### 4.2. Results and discussions

We first checked the proportional odds assumption by using the likelihood ratio test. The hypotheses for the test of the proportional odds assumption are $H_0: \beta_{ij} = \cdots = \beta_{kj}$ for $j = 1, 2, 3$ and $H_1$: Not all equal. In this study, we use eight independent variables and one dependent variable with four categories in the ordinal regression model. There are $p(J - 2) = 8(4 - 2) = 16$ additional parameters in the non-proportional odds model compared to the proportional odds model. The LRT results in p-values of near 1 (men) and 0.154 (women) indicate that each model satisfies the proportional odds assumption.

An LRT test for all parameters corresponding to the explanatory variables is used to test the hypotheses of $H_0: \beta_1 = \beta_2 = \cdots = \beta_4 = 0$ versus $H_a$: any $\beta_r \neq 0$, $r = 1, 2, \ldots, 8$. For men, the LRT results in a statistic of $-2\log(\Lambda) = 428.05$ and a p-value of $<0.001$. For women, the LRT results in a
statistic of $-2 \log(\Lambda) = 207.60$ and a p-value of $< 0.001$. Since each p-value is very small, then there is sufficient evidence that these eight variables are important explanatory variables on each model.

A Wald test is used to test an individual predictor’s regression coefficient which is zero considering the remaining predictors in the model, $H_0: \beta_r = 0$ versus $H_1: \beta_r \neq 0$. The Wald test results for each predictor are given in table 2. For men, the Wald tests suggest that age, education, working status, WHR are important explanatory variables in estimating obesity levels (all p-values $< 0.05$). For women, the Wald tests suggest that age, education, working status, WHR, frequency of eating are important explanatory variables (p-values less or near to 0.05).

Table 2 includes the estimated odds ratios of the explanatory variables reflecting the probability of severe obesity. For men, the estimated odds ratios of age variable (OR = 1.030, CI = (1.010, 1.050)) is statistically significant and greater than 1. This indicates that the probability of severe obesity increases as age increases. This finding corresponds to [24] that ageing is associated with an increase in abdominal obesity. A similar pattern occurs for women (OR = 1.029, CI = (1.017, 1.041)). The probabilities of reporting severe obesity for men and women are lower for individuals with medium and high education compared to low education. This result is consistent with a study of [9] where the percentage of obesity in individuals with low education is higher than the percentage of obesity in individuals with moderate and high education. A study in Canada found that individuals with secondary education or less had a higher risk of obesity 2.17 times in males and 1.48 times in females, compared with individuals with higher education in the same gender [10].

Men who work have higher probability of reporting severe obesity than those who do not work. Similarly, women who work are more likely to report severe obesity compared to those who do not work. This result is following a study of [25] that a high prevalence of obesity is found in respondents who work. The estimated odds ratios of WHR are very small and close to zero for both men and women. It is no clear how to interpret this value. The probabilities of reporting severe obesity are higher for individuals who eat three times a day compared to once time a day for both men and women. This result has been consistent to [26-28].

Regarding smoking behavior for both men and women, the chances of reporting severe obesity are higher for individuals who smoke than who do not smoke. This finding corresponds to [29] that smokers had higher risk of obesity than never smokers. Having a good quality of sleep for groups of men and women decreases the chances of reporting severe obesity compared to those with a bad quality of sleep. This result follows from [30] that someone who has slept less than 7 hours has a risk of obesity. The probability of severe obesity increases as the high stress level increases compared to low stress level for both men and women. This finding corresponds to [15] that higher the stress level experienced by individuals; the individuals tend to be obese.

| Variable                          | Wald test Men | Odds ratio | Wald test Women | Odds ratio |
|----------------------------------|---------------|------------|-----------------|------------|
|                                  | Est. | Std. Error | P-value | Est. | Std. Error | P-value | Est. | Std. Error | P-value |
| Age                              | 0.029 | 0.010 | 0.003 | 1.030 | (1.010, 1.050) | 0.029 | 0.006 | <0.001 | 1.029 | (1.017, 1.041) |
| Education                        |     |         |        |       |         |        |       |         |        |
| Reference category: Low          |     |         |        |       |         |        |       |         |        |
| Medium                           | -0.575 | 0.156 | <0.001 | 0.563 | (0.412, 0.762) | -0.149 | 0.086 | 0.084 | 0.862 | (0.728, 1.021) |
| High                             | -0.987 | 0.186 | <0.001 | 0.373 | (0.258, 0.537) | -0.367 | 0.127 | 0.004 | 0.693 | (0.542, 0.891) |
| Working status                   |     |         |        |       |         |        |       |         |        |
| Reference category: No           |     |         |        |       |         |        |       |         |        |
| Yes                              | 0.368 | 0.205 | 0.073 | 1.445 | (0.954, 2.139) | 0.234 | 0.080 | 0.003 | 1.264 | (1.081, 1.477) |
| WHR                              | -22.194 | 1.374 | <0.001 | 0.000 | (0.000, 0.000) | -8.996 | 0.687 | <0.001 | 0.000 | (0.000, 0.000) |
| Frequency of eating              |     |         |        |       |         |        |       |         |        |
| Reference category: Once time a day |     |         |        |       |         |        |       |         |        |
| Twice a day                      | -0.231 | 0.561 | 0.680 | 0.794 | (0.226, 2.139) | 0.356 | 0.224 | 0.113 | 1.428 | (0.907, 2.191) |
| Three times a day                | 0.150 | 0.556 | 0.787 | 1.162 | (0.333, 3.096) | 0.694 | 0.221 | 0.002 | 2.001 | (1.278, 3.052) |
| Smoking status                   |     |         |        |       |         |        |       |         |        |
| Reference category: No           |     |         |        |       |         |        |       |         |        |
| Yes                              | 0.155 | 0.143 | 0.277 | 1.168 | (0.879, 1.540) | 0.285 | 0.196 | 0.147 | 1.329 | (0.918, 1.984) |
| Quality of sleep                 |     |         |        |       |         |        |       |         |        |
| Reference category: Bad          |     |         |        |       |         |        |       |         |        |
| Good                             | -0.161 | 0.132 | 0.221 | 0.851 | (0.658, 1.104) | -0.006 | 0.080 | 0.945 | 0.995 | (0.851, 1.164) |
| Stress level                     |     |         |        |       |         |        |       |         |        |
| Reference category: Low          |     |         |        |       |         |        |       |         |        |
| Medium                           | -0.393 | 0.246 | 0.110 | 0.675 | (0.425, 1.118) | 0.036 | 0.160 | 0.824 | 1.036 | (0.763, 1.432) |
| High                             | 1.133 | 0.747 | 0.129 | 3.106 | (0.904, 19.611) | 0.163 | 0.266 | 0.539 | 1.178 | (0.717, 2.044) |
In Table 3, we investigate how WHR alone affects the probability of severe obesity. The estimated proportional odds model for each gender is given as follows.

Men:
\[
\logit (\hat{P}(Y_i \leq j)) = \hat{\alpha}_j - 21.843 \text{ WHR}
\]

where \( \hat{\alpha}_{\text{Non-obese}|\text{Obesity} \, I} = 23.299 \), \( \hat{\alpha}_{\text{Obesity} \, I|\text{Obesity} \, II} = 25.680 \), and \( \hat{\alpha}_{\text{Obesity} \, II|\text{Obesity} \, III} = 27.431 \).

Women:
\[
\logit (\hat{P}(Y_i \leq j)) = \hat{\alpha}_j - 7.299 \text{ WHR}
\]

where \( \hat{\alpha}_{\text{Non-obese}|\text{Obesity} \, I} = 8.135 \), \( \hat{\alpha}_{\text{Obesity} \, I|\text{Obesity} \, II} = 9.891 \), and \( \hat{\alpha}_{\text{Obesity} \, II|\text{Obesity} \, III} = 11.509 \).

Table 3 provides estimates of the regression coefficients, coefficient p-values based on Wald tests, and the estimated odds ratios. All p-values of the Wald tests are less than 5%. As the WHR variable is the only continuous variable in the model, we can make a plot of the estimated probabilities for each category of obesity levels.

![Figure 1](image_url)

**Figure 1.** Estimated proportional odds regression models for the obesity data where age is the only explanatory variable included in the model.

Figure 1(b) shows that the estimated probability for men in the non-obese category begins to decrease by 0.4 in the WHR. The estimated probability of the obesity I increases between 0.50 and 1.22 in the WHR and then decreases. For obesity II, the estimated probability falls in this category increases by 0.75 in the WHR. The estimated probability of obesity III begins to increase by 0.80 in the WHR.
Women with the WHR above 0.4 are more likely to experience obesity. Overall, women appear to increase their probabilities of obese compared to men. This finding corresponds to [29] that the prevalence of obesity among adults was higher in women than in men.

5. Conclusion
This study used the ordinal logistic regression models to investigate the association between age, education, WHR, frequency of eating, smoking status, quality of sleep, stress level, and the prevalence of severe obesity among men and women. The age, education, working status, and WHR were found to be the important factors affecting the prevalence of severe obesity among men and women. In addition to women, frequency of eating of three times a day was a significant factor to increase the prevalence of severe obesity. Men and women with small WHR were more likely to have high probability of non-obese, but their cut offs of the WHR are different. The prevalence of severe obesity was greater among women than among men.

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