The Adjusted Measure of Body Mass Index and its Impact on Health

Qiu, Tian
Department of Economics and International Development, University of Bath

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Tian Qiu

Department of Economics and International development, University of Bath, UK.

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Abstract

The aim of this paper is to examine the impact of socio-economic status (SES) on the Body Mass Index (BMI), a formula based on the ratio of height to weight, linked to health, using a four-year (1991, 1993, 1997 and 2000) panel data set which comes from the Physical Examination in China Health and Nutrition Survey. To an extent we confirm the results with respect to the linkage between SES and the documented healthy BMI found for other developing countries. Furthermore, apart from using the existing specification of BMI, we develop a little further the issue on how to define BMI with respect to the adjustment of gender and age. This leads to a slightly different formulation for the BMI and a substantially different healthy range based on self-reported health. We also find that the healthy BMI has a significant impact on health together with SES.

Keywords: Body Mass Index; Health; China
JEL Classification: I12

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1. Introduction

The concept of a healthy weight range is based on a measurement known as the Body Mass Index (BMI). It is one of the anthropometric indices of obesity, and has been suggested as an acceptable proxy to identify individuals at risk of cardiovascular diseases[1]. From the economic point of view, some researchers have taken BMI as an element of a life style which is closely related to health behaviours (Contoyannis and Jones, 2004). The interest in the relation between the components of socio-economic status (SES) and BMI has been renewed within the recent years. Body mass and the prevalence of obesity have been shown to be inversely associated with SES in the United States and other industrialized countries (Sobal and Stunkard, 1989; Jeffery and French, 1996; Montgomery, *et al*., 1998; Wardle, *et al*., 2004). However, for developing countries, the positive association between SES and BMI has been observed in many studies (de Vasconcellos, 1994; Delpeuch, *et al*., 1994; Reddy, 1998).

The BMI is calculated as weight in kilograms over height in meters squared (weight (kg)/height (m)^2). The World Health Organization (WHO) has devised a classification where persons with BMIs below the range 19-25 are considered underweight, those with BMIs above this range are considered overweight or "at risk", and those with BMIs greater than or equal to 30 are considered obese. These WHO BMI classifications of overweight and obesity are intended for international use. However, a growing body of literature in anthropometry indicates that these cut-off points are likely to be lower among Asian populations because the greater prevalence of cardiovascular disease risk factors is

[1] BMI is highly correlated with body fat, and, subsequently, health risk, specifically type 2 diabetes and cardiovascular disease, which are rapidly becoming major causes of death in adults in all populations (WHO Expert Consultation, 2004).

at lower BMIs in Asian populations than in Western populations[2] (see, e.g. Moon, *et al.*, 2002). In response to this, the Western Pacific regional office of the WHO, the International Association for the Study of Obesity (IASO), and the International Obesity Task Force (IOTF) collaborated in the creation of new recommendations for BMI among Asian populations, and overweight is defined as a BMI>=23[3]. This recommendation is provisional and is based on a limited literature concerning the distribution of BMI in Asian populations and the associations mainly between BMI and the prevalence of cardiovascular disease risk factors or risk of cardiovascular disease (Wildman, *et al.*, 2004). In addition, it has also been suggested that BMI is gender and age dependent when used as an indicator of body fatness (see, e.g., Gallagher, *et al.*, 1996). For example, when people are getting old, their body fat increases and muscle diminishes, while the BMI stays stable during these changes (Prentice and Jebb, 2001). However, there are no clear cut-off points after adjusting age and gender to be found in the literature.

After the start of social economic reform in 1978 in China, there has been increased attention on how to improve the awareness of health problems, and how these problems are distributed across people with different personal and social characteristics. In this paper, we use the panel data of the Physical Examination in China Health and Nutrition Survey (CHNS) covering the years of 1991, 1993, 1997 and 2000. We attempt to develop further the issue of how to define BMI with respect to the adjustment of gender and age. Based on our adjusted measure of BMI, we further examine the 'healthy range' based on a self-reported measure of health (SRH). Note that most studies relating BMI to health have focused on particular diseases and mortality. However, there is evidence to suggest that SRH is a powerful predictor of future medical care usage (see e.g. van Doorslaer, *et al.*, 2000; 2002) and subsequent mortality (see e.g. Idler and Kasl, 1995; Idler and Benyamini, 1997).

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[2] Evidence shows that Asian populations have a higher percentage of body fat than do Western populations for a given BMI (see, e.g. Gallagher, *et al.*, 2000 and Deurenberg, *et al.*, 2002). This may be partially responsible for the greater prevalence of cardiovascular disease risk factors at low BMI.

[3] The World Health Organization Western Pacific Region, The International Association for the Study of Obesity, and The International Obesity Task Force. The Asia-Pacific perspective: redefining obesity and its treatment. Sydney: Health Communications Australia Pty Limited, 2000 (Wildman, *et al.*, 2004).

This paper is organized as follows: In the next section, we describe data specifications. Preliminary statistics are provided in this section. Section 3 presents the empirical results. This will be in two stages. Firstly the impact of SES on documented healthy BMI, followed by examining the healthy BMI range based on the adjusted measure of BMI. We conclude this paper in the final section.

2. Data Specification

The dataset we use comes from the Physical Examination in China Health and Nutrition Survey which is a four-year panel data survey including 1991, 1993, 1997 and 2000. This dataset was collected mainly by the Carolina Population Centre and it provides a valuable national sample for researchers in health and nutrition fields. CHNS utilizes a multistage, random cluster-sampling scheme. The sample households were randomly drawn from eight provinces including Liaoning/Heilongjiang, Shandong, Jiangsu, Henan, Hubei, Hunan, Guangxi, and Guizhou[4], and in each province, both rural and urban residents are sampled. We restrict our sample to those between 15 and 75. After also excluding observations with less than full information, it provided 27882 observations (14285 males; 13597 females) in the four years altogether. All the variables are defined in Table 1, and Table 2 shows sample means.

Insert Table 1 and Table 2 here.

Educational attainment, occupational status and income are three dominant components of SES. In the survey, completed years of formal education were measured by primary school (1-6 years), lower middle school (1-3 years), upper middle school (1-3 years), middle technical or vocational school (1-2 years) and college/university (1-6 years or more). We aggregate these discrete values based on China's education system to obtain continuous values of the formal education years[5]. It thus takes a value from 0 to 18 with

[4] Liaoning was replaced by Heilongjiang in 1997 and both Liaoning and Heilongjiang were included in 2000.

[5] In China, basic formal education includes primary education (normally six years) and secondary education. Secondary education is divided into academic secondary education

an average value of 6.6 years (7.51 for males and 5.66 females) for all four years of the sample together. From Table 1, we can see the information on 15 types of occupations in the survey. Because the number of the observations in some types of occupations is relatively small, we select seven occupations which are professionals, administrators, office staff, farmers, skilled-workers, drivers and service workers. Income is measured as deflated[6] total annual household income (ladhinc). It is the sum of household incomes from all sections including income from wages, home gardening, household farms or farming collectives, raising livestock/poultry, collective and household fishing, household business, welfare subsidies or ration coupons, housing subsidy and other sources income. This variable is transformed to natural logarithms to allow for concavity of the health-income relationship (see e.g. Frijters, *et al*., 2003; Contoyannis, *et al*., 2004). Table 2 shows that the average value for the logarithm of this variable is 8.36 for whole sample. We also include data on marital status.

SRH is defined by a response to 'how would you describe your health compared to that of other people of your age?' The responses to this question take the ordered scale: poor, fair, good and excellent. SRH has been used in previous studies to estimate the relationship between BMI and health (see e.g. Gerdtham and Johannesson, 1999; Zhao, 2005). Figure 1 describes the distribution of SRH across all four years. The distributions show that the majority of observations reflect good health, but there is a trend for the distribution of health to become worse, specifically for the year 2000. Figure 2 describes the average health status across all four years and it shows the same trend as indicated in Figure 1[7]. Table 3 gives further descriptive statistics on self-reported health across gender,

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(normally three years of lower and three years of upper middle school) and specialized/vocational/technical secondary education, i.e., after graduated from the lower middle school, one can apply for upper middle school or middle technical/vocational school.

[6] According to CHNS, there is no published absolute consumer price index for China that provides a way to compare provinces or urban and rural areas. Rather the State Statistical Bureau publishes annually a consumer price index ratio that shows for urban and rural areas in each province the shift in the cost of living within that geographic area. The CHNS urban and rural price data are used to create a ratio of urban and rural costs for elements of the consumer goods basket, and they create their own costs (yuan) of the consumer basket for each time period for urban and rural areas in each province in the CHNS. Their deflator is based on 1988 prices.

[7] To rule out the possible health-related attrition in the data, we redo Figure 2 using balanced data

urban/rural and province.

Insert Figure 1, Figure 2 and Table 3 here.

Figure 3 shows the distribution of healthy weight, underweight and overweight based on WHO BMI classifications across all four years. The distributions indicate that the majority of observations are in the healthy weight range (19-25), and there is a trend for the distribution of BMIs to become less healthy and more overweight. Figure 4 describes the percentages of healthy weight, underweight and overweight in different health status, and it shows that the highest percentage of overweight BMIs is in excellent health status. As a dependent variable, we calculate the 'healthy BMI' as follows:

BMI_u' = BMIs < 19

BMI_o' = BMIs > 25

BMI_u = BMI_u'*(19-BMIs) (1)

BMI_o = BMI_o'*(BMIs-25)

Healthy BMI = BMI_u+ BMI_o

In equation (1), we assume that BMI_u measures the distance of the individuals' BMI values from 19 (if their BMIs are less than 19, underweight), and BMI_o measures the distance of the individuals' BMIs from 25 (if their BMIs are more than 25, overweight). The Healthy BMI increases with the distance from either side of the healthy range. For healthy people, it takes the value zero. As expected, the BMI_u and BMI_o are negatively correlated with our SRH measure[8].

Insert Figure 3 and Figure 4 here.

with 9216 observations, and we obtain a very similar figure.

[8] The negative correlation between BMI_o and self-reported measure of health is far from strongly significant. To put it differently, based on WHO classifications, overweight, instead of underweight, is highly correlated with better health (see also Zhao, 2005). This is not surprising in developing countries, such as China, since ill nutrition is still a major cause for poor health.

3. Empirical Analysis

3.1. The Documented Healthy BMI Range

Because health has many dimensions, it is of interest to obtain results by using several health measures, although this is restricted by the data availability. In this section, we take the Healthy BMI calculated in equation (1) as the dependant variable, and run the regression with gender, age and SES. The Healthy BMI as shown in equation (1) measures the distance of the individuals' BMI values from the healthy range (19-25), and the greater the distance from either side the less healthy people are.

The total value range of BMI is from 9 to 47, and Table 2 shows that the BMI is within the healthy range for 72% of the individuals (73% of the men and 70% of the women). In the regressions with the Healthy BMI, BMI_o and BMI_u, a Tobit model is selected for its ability to account for the effects of censoring at the lower bound of the BMI risk ladder (i.e., at value 0). We further allow for the random-effects as the estimation of a fixed-effects Tobit model is problematic (see e.g. Greene, 2004). Table 4 presents the estimation results.

Insert Table 4 here.

The first two columns of Table 4 show coefficient estimates of the pooled and random-effects Tobit with the dependant variable of Healthy BMI. The likelihood ratio test shows that the panel-level variance component is important, thus we will focus on the results of random effects. Individuals' gender is a significant predictor of the Healthy BMI, and men are less frequently overweight/underweight than women[9]. People are more likely to have a healthy BMI when they are getting older, but this is only until age 20. In other words, for the majority of our observations, older people are increasingly less likely to be in the healthy BMI range. As to the impact of SES, people with healthy BMIs are

[9] This is predicted on the assumption that the same healthy range is applicable for both men and women.

most common among individuals with lower household income. Overweight/underweight is overrepresented among administrators, whereas healthy BMIs are common among farmers. In addition, people's education attainment fails to have significant effect on their BMIs.

The third and fourth columns of Table 4 show coefficient estimates of the pooled and random-effects Tobit with the dependant variable on BMI_o. Not surprising, compared to the second column of Table 4, results in the fourth column show a clearer trend of the impact of age and SES on healthy BMIs. People are more likely to be overweight when they are getting older till approximately 60. Overweight is a characteristic most common among married people, and together with the results in the last two columns of Table 4, married people are generally less likely to be underweight. People living in urban areas tend to be overweight, as individuals living in rural areas usually have more outdoor activities than urban ones. In addition, people's education plays a role in determining their BMIs as more educated people are less likely to be overweight. Compared to the results with the dependant variable of Healthy BMI, the positive association between household income and overweight is more robust. This is consistent with many other studies for developing countries. As Reddy (1998) argued that this positive association is qualitatively different from the negative association characterizing contemporary Western populations[10]. For example, the economically well-off upper strata of the population in developing countries tend to consume more protein where the average population is undernourished.

3.2. Alternative Measure of BMI and its Impact on SRH

As argued before, BMI is generally calculated as weight in kilograms over height in meters squared ($weight(kg)/height(m)^2$), and it is currently the most commonly used method in the empirical work. But this formula appears to be somewhat arbitrary. Why divide weight by exactly the square of height? Why not the cube, why not simply the

[10] Reddy (1998) argued that in the industrialized West, the richer upper strata of the populations, at least, are known to eat a more balanced diet, more possibly exercise during their leisure time and being more conscious of the need to check their weight.

ratio itself? In order to investigate this more closely, it is necessary to consider how to define BMI. Considering for cross-sectional data for simplicity, we start by estimating the following equation:

$$\text{Log}(W_i) = \beta_0 + \beta_1 \log(H_i) + \boldsymbol{\beta_2 X_i} \quad (2)$$

Where W_i and H_i denote the weight and height of the *i*'th individual, $\boldsymbol{X_i}$ is a vector of gender, age and socio-economic characteristics and the log is to the base e. If we exponentiate both sides of equation (2), we get:

$$W_i = e^{\beta_0} H_i^{\beta_1} e^{\boldsymbol{\beta_2 X_i}} \quad (3)$$

According to the literature, it suggests that an individual's Body Mass can be formulated by:

$$BMI_0 = W_i / H_i^{\beta_1} \quad (4)$$

where the superscript denotes that the equation (4) is linked to the 'standard way' of calculating BMI, indeed if β_1=2, then it is exactly the equation documented in the literature. A potential problem revolves around this measure in whether there are systematic differences in people's weight given their height. Thus whether an individual's BMI should be adjusted for gender, age and SES? Arguably it should if it is to reflect an unambiguous measure of BMI. In this case, equation (4) should be amended to:

$$BMI_a = W_i / (H_i^{\beta_1} e^{\boldsymbol{\beta_2 X_i}}) \quad (5a)$$

Or viewed alternatively

$$e^{\boldsymbol{\beta_2 X_i}} BMI_0 = W_i / H_i^{\beta_1} \quad (5b)$$

Equation (5a) shows an amended BMI (BMI_a) based on gender, age and SES, and alternatively equation (5b) shows a 'standard' BMI which should be adjusted by gender, age and SES when interpreting it. $\mathbf{X}_i$ presents the gender, age and SES of i'th individual as in equation (2). In what follows we shall first base our estimates on equation (4) as is consistent with the traditional approach. The estimated regression based on panel data with random-effects is:

$$\text{Log}(W_i) = \underset{(289.816)}{3.04} + \underset{(94.878)}{2.09}\text{Log}(H_i)$$

$$R^2 = 0.40,\ n=26366 \qquad (6)$$

Where the figures in parentheses represent t-statistics and the time subscript is implicit. From this we can calculate the BMI as:

$$BMI_0 = W_i / H_i^{2.09} \qquad (7)$$

The coefficient is close, but a bit higher to the standard measure of 2.00 in the literature. Still, it provides some justification for it.

We now turn to consider the equations with gender, age and SES included, and we start by the inclusion of gender and age. Note that gender and age are reflecting people's physical characteristics, thus they should be both adjusted for, if we want to obtain an unambiguous measure of BMI. We take $\text{Log}(W_i)$ as a dependant variable and run the regression on $\text{Log}(H_i)$, gender and age, and we obtain a value for β_1 of 2.40. The whole regression result is as follows:

$$\text{Log}(W_i) = \underset{(189.035)}{2.65} - \underset{(13.252)}{0.039}\text{gender} + \underset{(35.446)}{0.011}\text{age} - \underset{(27.440)}{0.0001}\text{age}^2 + \underset{(83.827)}{2.40}\text{Log}(H_i)$$

$$R^2 = 0.44,\ n=26366 \qquad (8)$$

Based on these results, we can calculate BMI by:

$$BMI_a = W_i / (H_i^{2.40} \exp(-0.039*gender + 0.011*age - 0.0001*age^2)) \quad (9a)$$

Or

$$\exp(-0.039*gender + 0.011*age - 0.0001*age^2) BMI_0 = W_i / H_i^{2.40} \quad (9b)$$

Equations (9a) and (9b) could arguably contain a constant term, but β_0 reflects other influences and hence should not perform this role. But if we assume that people on average are healthy this could be used to normalize (9a). Equation (8) shows that the coefficient on height has significantly increased. To put it differently, the coefficient in height changes when account is taken of gender and age. We also see that for a given height and weight, the healthy BMI is different from men and women at different ages.

We can divide the part (exp(.)) in equation (9a) into two components: exp(–0.039*gender) and $\exp(0.011*age - 0.0001*age^2)$, and we will look at them separately. The coefficient of gender suggests that for a given height, weight and age, a BMI_a value for a man (gender=1) is some 4% (= 1 – exp(-0.039)) lower than for a woman (gender=0). As to age, the coefficients indicate that the maximum value for $\exp(\beta_2 age + \beta_3 age^2)$ is when age equals to 55[11]. This suggests that BMI_a values are greatest for people aged 55, i.e., given an individual's weight, height and gender, a BMI_a value for someone who is 20, 40 or 70 is systematically lower than someone who is 55. To sum up, for example, the BMI_a value for a woman aged 50 is some 10% higher than a man aged 30[12]. This is consistent with the discussions mentioned before that the BMI values are age and gender dependent when used as an indicator of body fatness, and specifically they gradually increase with age, until after age 50 to 60.

Now we run the regression on Log(H_i) and all SES variables and from this way we obtain

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[11] $(e^{(0.011age-0.0001age^2)})' = e^{(0.011age-0.0001age^2)} * (0.011-0.0002age) = 0$, within this equation, $e^{(0.011age-0.0001age^2)}$ can not equal to 0, thus we can only let (0.011 – 0.0002*age*) = 0, and get age=55.

[12] $(e^{(0.011*50-0.0001*50*50)} - e^{(-0.039+0.011*30-0.0001*30*30)})/e^{(-0.039+0.011*30-0.0001*30*30)} = 0.104$

an estimate of β_1 of 2.24 as shown in Table 5. In this case, more interesting than the significance of height, gender and age, is the significance of the other variables. Education, household income and administrative and service occupations are all significant at the 1% level and urban is significant at the 5% level. In all cases weight increases with the variable, i.e. it increases with education and income and is higher for executives or those in the service sector and or those living in towns. Hence to answer the question posed earlier there are systematic differences in people's weight given their height which are unrelated to physical characteristics such as gender and age. We cannot say that the healthy values of BMI for more educated people, for example, should be lower or higher than less educated people, it depends upon their other physical characteristics. In addition, if height is correlated with education, urban, income, etc, then the exclusion of these variables in the equation will bias the coefficient on height[13]. In addition, it seems reasonable to suggest that all of these variables are ones which tend to be associated with less exercise. For example, people who live in towns will tend to have access to better public transport and walk less than people in rural areas. Similarly less well-educated people probably tend to have more manual jobs.

Insert Table 5 here.

What does this imply about the measure of BMI? In particular should it be adjusted for people's socio-economic status as well as their physical characteristics – gender and age? The answer is no. There seems little reason why someone of a given age, gender, height and weight should have his optimal BMI adjusted because they are an executive or live in the city[14]. However, what it does suggest is that such socio-economic characteristics impact on people's BMI values and hence on health, and also that failing to take cognizance of socio-economic characteristics when estimating the relationship between

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[13] Such correlations may exist because of inter-generational advantages, for example, the children of richer families tend to eat better during childhood and hence arguably become taller.

[14] Of course certain life styles are unhealthy which are linked to unhealthy BMI values. An executive life style, for instance, may be a stressful one – as indeed may be a coal miner's. That is not the issue. Instead we are asking whether the characteristics of a 12 stone, 6 foot, 35 year old man should have different interpretations vis-à-vis BMI values, depending on the individuals level of education or geographic location and on this we believe the answer is no.

weight and height can lead to biased results.

So far we have developed a little further the issue on how to define BMI. We now face the question of examining the 'healthy range' based on this adjusted measures of BMI and estimating its impact on SRH together with SES. We will start with BMI_0 derived from equation (7), which is close to that used in the literature. However, our main focus is on the relatively complex one (BMI_a) taking into account gender and age from equation (9a). The total value ranges of BMI measure based on equation (7) is (8-42) and (5-33) when based on (9a), but most observations are within (15-35) and (10-25) respectively[15]. For BMI_0, we now construct two variables BMI_0^1 and BMI_0^2 as follows:

$$BMI_0^1 = (\alpha_L - BMI_0), \text{ operative if } BMI_0 < \alpha_L$$
$$BMI_0^2 = (BMI_0 - \alpha_H), \text{ operative if } BMI_0 > \alpha_H \qquad (10)$$

and similarly for BMI_a:

$$BMI_a^1 = (\alpha_L - BMI_a), \text{ operative if } BMI_a < \alpha_L$$
$$BMI_a^2 = (BMI_a - \alpha_H), \text{ operative if } BMI_a > \alpha_H \qquad (11)$$

The range α_L - α_H is what we term the 'healthy range'. People outside this range are unhealthy, and the greater the distance the less healthy they are. We now seek to identify the critical points α_L and α_H through regression analysis. Self-reported health is regressed on (BMI_0^1, BMI_0^2) and (BMI_a^1, BMI_a^2) by an iterative search technique where the critical values for α_L and α_H included all possible combinations from (15-35) and (10-25), which amounted to 231 and 136 regressions based on equation (7) and (9a) respectively. We choose the optimal combination on the basis of i) significantly negative coefficients for both (BMI_0^1, BMI_0^2) and (BMI_a^1, BMI_a^2), and ii) by identifying the best fit by the highest log likelihood ratio. Based on this, two BMI healthy ranges have been identified: using

[15] Both around 98%.

BMI_0 as in equation (7), we find critical values for α_L of 22 and α_H of 27[16]; Using the modified BMI (BMI_a) in equation (9a), we identify critical values of 15 to 19. Table 6 shows the random-effects ordered probit results[17] which underlie these calculations.

Insert Table 6 here.

At this stage, the 'best' results based on the log likelihood appear marginally to be those based on the standard measure. Note that the healthy BMI range based on BMI_0 in equation (7), i.e., (22-27) per se is higher than (19-25) as documented in literature. The main reason is that we are using different measure of BMI. In addition, people with BMIs above 25 are considered overweight or 'at risk', however, these risks are mainly relevant to obesity-related disease, instead of self-report measure of health which we use in our estimate. There is some suggestion from the size of the coefficients in Table 6 that BMI_0^2 and BMI_a^2 may have greater impact on health than BMI_0^1 and BMI_a^1, i.e. being underweight has more secure consequences than being overweight. Although this is not something we develop further in this section. The significance of the other variables is largely as before.

Finally we construct a New BMI variable based on BMI_a with the optimal value range of 15 (α_L) and 19 (α_H) obtained from equation (9a). It is defined as the sum of BMI_a^1 and BMI_a^2. The distance between the BMI_a values and either 15 (α_L) or 19 (α_H) represents a deviation of BMI_a from its healthy range. We attempt to estimate how this healthy range is associated with SES in its impact on health. We construct the following interaction terms: New BMI*gender, New BMI*age, New BMI*age^2, New BMI*education, and New BMI*log(household income). Being as we are using panel data, we also include year dummies. Table 7 shows the results.

Insert Table 7 here.

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[16] For a comparison purpose, we also use the traditional measure of BMI based on the formula weight(kg)/height(m)^2, we find critical values for α_L of 23 and α_H of 28.
[17] Note that we obtain the same healthy ranges based on pooled and random-effects results.

The first two columns of Table 7 show the estimated coefficients for the ordered probit models based on pooled and random-effects specifications with the inclusion of the New BMI variable. The coefficient of New BMI is significantly negative as expected, which shows that when a person's BMI (based on the equation of BMI_a) value moves away from either 15 (α_L) or 19 (α_H), he/she tends to be less healthy. We now look at whether the impact of this New BMI on health changes by different SES. Through the last two columns of Table 7, we can see that the impact of New BMI on health is affected by gender, age, education and income[18]. Males are basically healthier than females, but this is changed when account is taken of the interaction with the New BMI. The coefficient of New BMI*gender is significantly negative, which indicates that, for a given BMI, there is a greater adverse impact on health for a man than a woman. Similarly, the impact of New BMI on health also depends on age, and more specifically, it is convex, first increasing and then decreasing after reaching a certain age. In addition, higher income neutralizes to some extent an adverse New BMI. Finally and interestingly, a given value of New BMI has a greater adverse impact on health with more education. Viewed in another light, we have concluded that educated people tend to be healthier than less educated people, presumably because they have increased awareness of what constitutes 'healthy living'. An adverse BMI for an educated person, however, suggests that they are not utilizing this knowledge, thus reducing the 'educational advantage' in health. These results give further credence to the view that in interpreting BMI we need to make distinctions on the basis of age and gender. In addition, there is the possibility that the consequences of an adverse BMI can be reduced by greater income, possibly because of better access to medical facilities.

4. Conclusions

BMI is closely related to nutrition taken and health behaviour, and it thus to some extent reflects individuals' *real* health status. In this respect, the estimation of the relationship between SES and BMI is even more important. We use a four-year (1991, 1993, 1997

[18] Note that we have also included the New BMI interactive variables with married, urban and occupations, however, all of them fail to be significant. Results do not report in Table 7.

and 2000) panel data set and find consistent results with many other studies for developing countries on the positive association between income and certain occupations, such as administrators and farmers, and overweight. As to the impact of education, we find that overweight is least common among more highly educated. Furthermore, we have confirmed that the concept of the BMI is a valid one in the literature, and have further argued that it is reasonable that it should be calculated in such a manner as adjusts for gender and age. We examine the healthy range of this adjusted measure of BMI based on the self-reported measure of health. Note that we are using a different measure of BMI, thus the comparison of the healthy range with other studies is rather difficult.

Health research generally has focused on the least ambiguous outcomes, such as the use of medical services, mortality, and prevalence of disease (Schultz, 1994). More specifically according to Wildman, et al. (2004), any decision rules to determine BMI cut-off values must balance the need to prevent a significant proportion of cardiovascular disease events, and the clinical practice burden of labeling a patient as being at risk for cardiovascular diseases. We admit the possibility that the self-reported measure may not be as accurate as those outcomes, still, it is of interest in its own right. Importantly, we have found that the impact of healthy BMI on health adjusted by gender and age varies according to SES.

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Table 1 Data Description

Socio-economic Status	Data Description
Education (Educ)	A continuous value from 0 to 18
Gender	A dummy variable: Males ('1') & Females ('0')
Age	A continuous value, restricted from 15 to 75. Age and age-squared are used in the main regressions.
Marital Status	A dummy variable: Married ('1') & Non-married ('0'). Non-married includes never married, divorced, widowed and separated.
Living Area	A dummy variable: Urban ('1') & Rural ('0')
Household Income (ladhinc)	Total deflated (by 1989 price index) annual household income, log value is used in the regression.
Occupation	Dummy variables. Seven occupations have been chosen based on the sample size, which include: Professionals, Administrators, Office Staff, Farmers, Skilled-workers, Drivers and Service Workers[1].
Regions	Dummy variables. Nine provinces include Liaoning, Heilongjiang, Jiangsu, Shandong, Henan, Hubei, Hunan, Guangxi and Guizhou.
BMI	Body Mass Index (weight (kg)/height (m)²) – Healthy range is identified with BMIs of 19-25[2].
Self-Reported Health	Ordinal scales: Excellent ('3'), Good ('2'), Fair ('1'), and Poor ('0')[3].

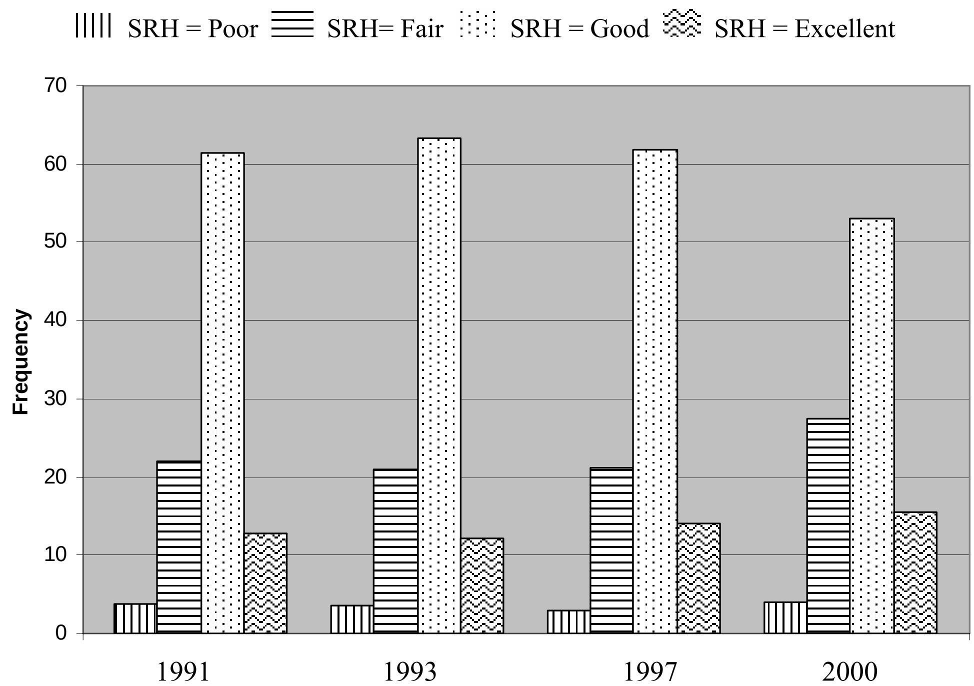
Notes: [1] There are 15 occupations in the China Health and Nutrition Survey: 01, senior professional/technical personnel (doctor, professor, lawyer, architect, engineer, etc.); 02, professional/technical personnel (midwife, nurse, teacher, editor, photographer, etc.); 03, administrator/executive/manager, factory manager, government official, section chief, director, administrative cadre; 04, office staff (secretary, office helper, etc.); 05, farmer, fisherman, hunter, logger, etc.; 06, technical, skilled worker (foreman, craftman, etc.); 07, non-technical, non-skilled worker (laborer); 08, army officer, police officer; 09, ordinary soldier, policeman; 10, driver; 11, service worker (housekeeper, cook, waiter, doorkeeper, barber/beautician, counter sales, launderer, childcare, etc.); 12, homemaker-with no other work; 13, student; 14, athlete, actor, musician; 15, other; 16, none. [2] The figures come from the World Health Organization. [3] We have reversed the scales of the health measure in the CHNS survey to emphasize that higher numbers correspond to better health.

Table 2 Sample Means

	Whole Sample		Males		Females	
Health Status	1.84		1.88		1.80	
Males	0.51		-		-	
Education	6.60		7.51		5.66	
Age	40.24		40.62		39.84	
Married	0.80		0.80		0.80	
Urban	0.29		0.29		0.29	
Ladhinc	8.36		8.36		8.36	
Professionals	0.05		0.06		0.05	
Administrators	0.04		0.07		0.02	
Office Staff	0.03		0.04		0.03	
Farmers	0.57		0.51		0.62	
Skilled-workers	0.07		0.09		0.05	
Drivers	0.01		0.03		0.00	
Service workers	0.07		0.05		0.08	
Liaoning	0.07		0.07		0.07	
Heilongj	0.05		0.06		0.05	
Jiangsu	0.13		0.13		0.13	
Shandong	0.11		0.11		0.10	
Henan	0.12		0.12		0.12	
Hubei	0.13		0.13		0.13	
Hunan	0.11		0.12		0.11	
Guangxi	0.14		0.14		0.14	
Guizhou	0.14		0.14		0.14	
BMIs in healthy range (19-25)		0.72		0.73		0.70
BMIs underweight (<19)		0.13		0.13		0.13
BMIs overweight (>25)		0.15		0.14		0.17
No. of the Observations	27882	26366	14285	13356	13597	13010

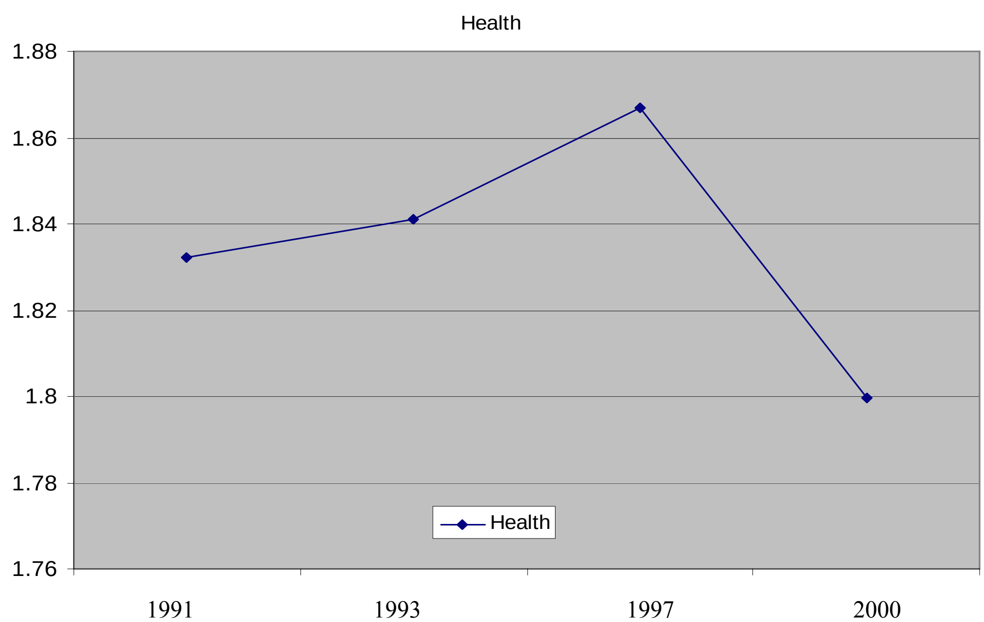
Source: Physical Examination in China health and Nutrition Survey, various years.

Figure 1 Self-reported Health Status by Year



Source: Physical Examination in China health and Nutrition Survey, various years.

Figure 2 Average Status of Self-reported Health by Year



Source: Physical Examination in China health and Nutrition Survey, various years.

Table 3 Self-Reported Health by Genders, Urban/Rural and Provinces

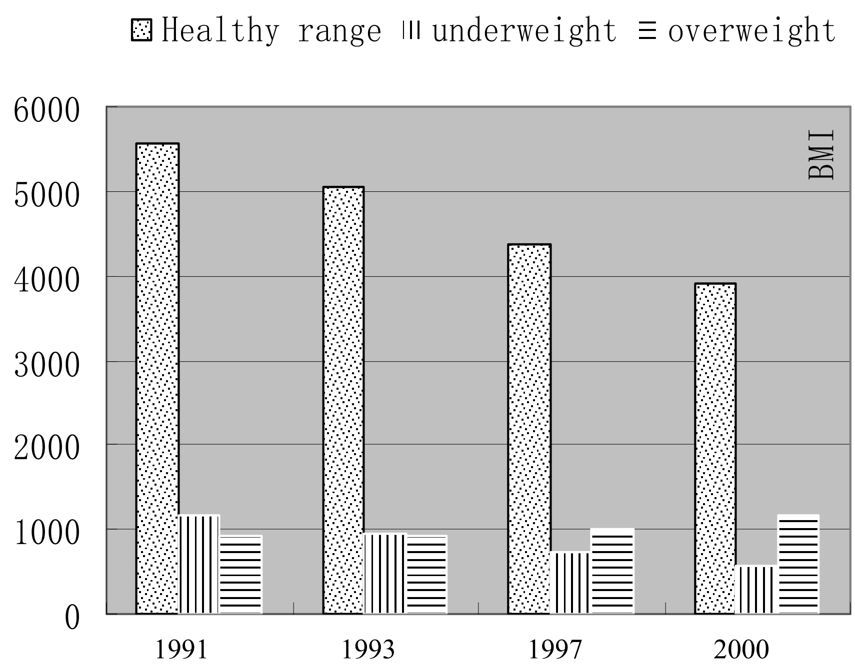
			Whole Sample	Liaoning	Heilongjiang	Jiangsu	Shandong	Henan	Hubei	Hunan	Guangxi	Guizhou
Female	Poor	Freq.	512	39	20	54	31	84	73	50	90	71
		%	3.8%	3.9%	3.0%	3.1%	2.2%	5.1%	4.1%	3.5%	4.7%	3.6%
	Fair	Freq.	3352	227	139	397	260	442	449	355	639	444
		%	24.7%	22.7%	20.8%	22.6%	18.4%	27.1%	25.3%	24.5%	33.1%	22.5%
	Good	Freq.	8130	596	332	1009	808	884	1141	911	1132	1317
		%	59.8%	59.5%	49.7%	57.4%	57.3%	54.1%	64.4%	62.9%	58.6%	66.9%
	Excellent	Freq.	1603	140	177	299	312	224	110	132	71	138
		%	11.8%	14.0%	26.5%	17.0%	22.1%	13.7%	6.2%	9.1%	3.7%	7.0%
	Total	Freq.	13597	1002	668	1759	1411	1634	1773	1448	1932	1970
		%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Male	Poor	Freq.	476	42	18	50	22	71	71	46	67	89
		%	3.3%	4.0%	2.3%	2.8%	1.4%	4.2%	4.0%	2.7%	3.4%	4.4%
	Fair	Freq.	2977	190	122	312	226	407	409	360	540	411
		%	20.8%	18.1%	15.5%	17.4%	14.7%	24.3%	22.8%	21.4%	27.5%	20.4%
	Good	Freq.	8676	625	404	1049	900	926	1143	1050	1260	1319
		%	60.7%	59.6%	51.4%	58.6%	58.5%	55.3%	63.8%	62.5%	64.1%	65.6%
	Excellent	Freq.	2156	192	242	379	390	269	169	225	99	191
		%	15.1%	18.3%	30.8%	21.2%	25.4%	16.1%	9.4%	13.4%	5.0%	9.5%
	Total	Freq.	14285	1049	786	1790	1538	1673	1792	1681	1966	2010
		%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 3 continued

			Whole Sample	Liaoning	Heilongjiang	Jiangsu	Shandong	Henan	Hubei	Hunan	Guangxi	Guizhou
Rural	Poor	Freq.	702	54	12	74	39	124	90	64	113	132
		%	3.5%	4.2%	1.2%	2.9%	1.7%	5.3%	3.6%	2.9%	4.2%	4.6%
	Fair	Freq.	4233	261	112	431	367	556	548	510	809	639
		%	21.4%	20.1%	11.1%	16.6%	16.1%	23.6%	22.0%	23.0%	30.1%	22.5%
	Good	Freq.	12008	777	544	1511	1336	1297	1655	1419	1655	1814
		%	60.7%	59.8%	53.7%	58.3%	58.7%	55.0%	66.6%	64.0%	61.5%	63.8%
	Excellent	Freq.	2833	208	345	574	535	382	193	224	112	260
		%	14.3%	16.0%	34.1%	22.2%	23.5%	16.2%	7.8%	10.1%	4.2%	9.1%
	Total	Freq.	19776	1300	1013	2590	2277	2359	2486	2217	2689	2845
		%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Urban	Poor	Freq.	286	27	26	30	14	31	54	32	44	28
		%	3.5%	3.6%	5.9%	3.1%	2.1%	3.3%	5.0%	3.5%	3.6%	2.5%
	Fair	Freq.	2096	156	149	278	119	293	310	205	370	216
		%	25.9%	20.8%	33.8%	29.0%	17.7%	30.9%	28.7%	22.5%	30.6%	19.0%
	Good	Freq.	4798	444	192	547	372	513	629	542	737	822
		%	59.2%	59.1%	43.5%	57.0%	55.4%	54.1%	58.3%	59.4%	61.0%	72.4%
	Excellent	Freq.	926	124	74	104	167	111	86	133	58	69
		%	11.4%	16.5%	16.8%	10.8%	24.9%	11.7%	8.0%	14.6%	4.8%	6.1%
	Total	Freq.	8106	751	441	959	672	948	1079	912	1209	1135
		%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

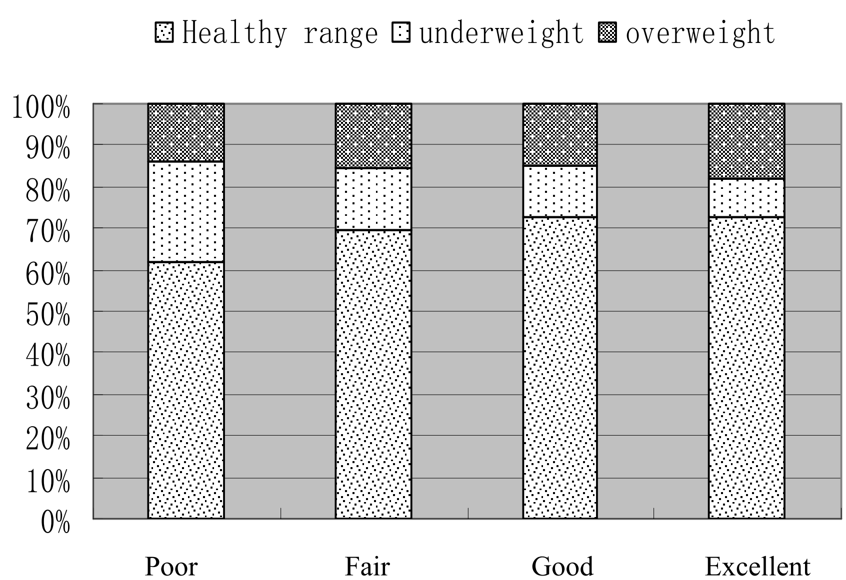
Source: Physical Examination in China health and Nutrition Survey, various years.

Figure 3 Healthy Weight, Underweight and Overweight by Year



Source: Physical Examination in China health and Nutrition Survey, various years.

Figure 4 Healthy Weight, Underweight and Overweight in Different Health Status



Source: Physical Examination in China health and Nutrition Survey, various years.

Table 4 The Impact of SES on Healthy BMI: (Random-Effects) Tobit Model

Explanatory Var.	**Full Sample**		**Healthy & Overweight**		**Healthy & Underweight**	
	Tobit	RE-Tobit	Tobit	RE-Tobit	Tobit	RE-Tobit
Gender	-0.431***	-0.343***	-0.953***	-0.677***	-0.069**	-0.046*
	(-8.93)	(-7.56)	(-11.10)	(-10.55)	(-1.97)	(-1.91)
Educ	-0.016**	-0.010	-0.032**	-0.019*	-0.002	-0.004
	(-1.99)	(-1.42)	(-2.39)	(-1.89)	(-0.40)	(-0.96)
Age	-0.041***	-0.020**	0.197***	0.164***	-0.126***	-0.090***
	(-3.55)	(-1.97)	(8.78)	(10.36)	(-15.60)	(-16.64)
Agesq	0.0007***	0.0005***	-0.0016***	-0.0013***	0.0015***	0.0011***
	(5.95)	(4.37)	(-6.40)	(-7.74)	(16.69)	(17.54)
Married	-0.110	-0.063	0.459***	0.299***	-0.248***	-0.139***
	(-1.49)	(-1.02)	(3.25)	(3.07)	(-4.92)	(-4.12)
Urban	0.079	0.091*	0.234**	0.205***	-0.050	-0.035
	(1.47)	(1.80)	(2.55)	(3.01)	(-1.22)	(-1.25)
Ladhinc	0.091***	0.068***	0.244***	0.165***	-0.060***	-0.039***
	(2.98)	(2.92)	(4.45)	(4.52)	(-2.72)	(-2.77)
Profes	0.296**	0.151	0.334*	0.200	0.113	0.062
	(2.55)	(1.56)	(1.78)	(1.51)	(1.17)	(0.96)
Adminis	0.497***	0.321***	0.706***	0.441***	-0.148	-0.078
	(4.09)	(3.26)	(3.70)	(3.34)	(-1.31)	(-1.07)
Staff	0.023	0.001	-0.078	-0.049	0.109	0.070
	(0.17)	(0.01)	(-0.36)	(-0.34)	(1.00)	(0.99)
Farmers	-0.609***	-0.415***	-1.656***	-1.066***	0.113**	0.077**
	(-8.49)	(-7.17)	(-13.18)	(-12.35)	(2.10)	(2.20)
Skilled	-0.028	-0.015	-0.039	0.01	0.010	0.002
	(-0.28)	(-0.20)	(-0.23)	(0.09)	(0.13)	(0.05)
Drivers	0.26	-0.019	0.663**	0.28	-0.063	-0.109
	(1.27)	(-0.12)	(1.99)	(1.24)	(-0.37)	(-0.99)
Service	0.180*	0.084	0.337**	0.183	-0.014	-0.025
	(1.73)	(1.04)	(1.98)	(1.59)	-(0.17)	(-0.48)
Reg. Dummies	yes	yes	yes	yes	yes	yes
Year Dummies	yes	yes	yes	yes	yes	yes
Log likelihood	-26970.73	-25240.07	-17027.71	-16236.79	-12117.40	-11754.57
Likelihood-ratio		3461.33		1580.83		725.68
No. of the Obs.	26366	26366	22931	22931	22336	22336

Notes: t statistics in parentheses, *** Significant at 1%; **Significant at 5%; * Significant at 10%. Regressions estimated by Tobit and random-effects Tobit (RE-Tobit).

Table 5 Determinants of BMI Values

Explanatory Variable		**Log(weight)**	
	RE-REG	RE-REG	RE-REG
Gender		-0.039***	-0.036***
		(-13.252)	(-12.392)
Age		0.011***	0.011***
		(35.446)	(30.646)
Agesq		-0.0001***	-0.0001***
		(-27.440)	(-23.485)
Education			0.003***
			(10.646)
Married			-0.0004
			(-0.186)
Urban			0.005**
			(2.223)
Ladhinc			0.002***
			(2.766)
Profes			0.0001
			(0.024)
Admins			0.011***
			(3.627)
Staff			0.002
			(0.708)
Farmer			-0.016***
			(-8.739)
Skilled			0.0004
			(0.193)
Driver			0.009*
			(1.955)
Service			0.009***
			(3.658)
Log(height)	2.094***	2.395***	2.247***
	(94.878)	(83.827)	(76.840)
R-squared	0.40	0.44	0.45
No. of the Obs.	26366	26366	26366

Notes: t statistics in parentheses, *** Significant at 1%; **Significant at 5%; * Significant at 10%. Regressions are estimated based on panel data with random-effects (RE-REG).

Table 6 The Optimal Calculations for (BMI_0^1, BMI_0^2) and (BMI_a^1, BMI_a^2)

Explanatory Variable	**Self-reported Health**	
	RE-OP1	RE-OP2
Gender	0.253***	0.224***
	(7.946)	(7.067)
Education	0.024***	0.024***
	(4.737)	(4.741)
Age	-0.043***	-0.025***
	(-5.761)	(-3.363)
Agesq	0.00003	-0.0001*
	(0.339)	(-1.677)
Married	-0.011	-0.004
	(-0.244)	(-0.087)
Urban	-0.385***	-0.385***
	(-10.578)	(-10.582)
Ladhinc	0.109***	0.108***
	(5.945)	(5.925)
Profes	-0.123*	-0.118
	(-1.648)	(-1.581)
Admins	0.186**	0.190**
	(2.398)	(2.449)
Staff	0.148*	0.156*
	(1.792)	(1.884)
Farmer	-0.091**	-0.094**
	(-2.019)	(-2.070)
Skilled	0.171***	0.177***
	(2.725)	(2.811)
Driver	0.292**	0.304**
	(2.128)	(2.223)
Service	0.108	0.108
	(1.582)	(1.574)
BMI_0^1/ BMI_a^1	-0.123***	-0.192***
	(-13.453)	(-13.165)
BMI_0^2 / BMI_a^2	-0.103***	-0.119***
	(-4.441)	(-3.476)
Regional dummies	Yes	Yes
Year dummies	Yes	Yes
Log likelihood	-25497.53	-25504.45
Restricted log likelihood†	-25658.92	-25666.20
No. of the Obs.	26366	26366

Notes: t statistics in parentheses, *** Significant at 1%; **Significant at 5%; * Significant at 10%. † Log-likelihood ratio is calculated by $2(L_{unrestricted} - L_{restricted})$. Regressions are estimated by random-effects ordered probit. BMI_0 is defined by equation (7), and BMI_a is defined by equation (9a). The results of first column (RE-OP1) are based on (BMI_0^1, BMI_0^2). The results of second column (RE-OP2) are based on (BMI_a^1, BMI_a^2).

Table 7 The Impact of New BMI together with SES on SRH

Explanatory Var.	**Self-reported Health**			
	OProbit	RE-OProb	OProbit	RE-OProb
Gender	0.205***	0.223***	0.261***	0.286***
	(7.823)	(7.053)	(7.665)	(7.135)
Education	0.021***	0.024***	0.027***	0.031***
	(4.789)	(4.708)	(5.223)	(5.084)
Age	-0.024***	-0.026***	-0.013*	-0.012
	(-3.811)	(-3.440)	(-1.744)	(-1.368)
Agesq	-0.0001	-0.0001	-0.0002**	-0.0003***
	(-1.512)	(-1.623)	(-2.513)	(-2.752)
Married	0.012	-0.003	0.012	-0.002
	(0.290)	(-0.060)	(0.306)	(-0.042)
Urban	-0.352***	-0.384***	-0.354***	-0.386***
	(-11.818)	(-10.557)	(-11.869)	(-10.604)
Ladhinc	0.109***	0.109***	0.084***	0.084***
	(6.627)	(5.982)	(3.974)	(3.603)
BMINEW	-0.160***	-0.182***	-0.029	0.024
	(-13.101)	(-13.264)	(-0.194)	(0.143)
BMI*gender			-0.062**	-0.070**
			(-2.531)	(-2.535)
BMI*age			-0.013***	-0.016***
			(-2.765)	(-3.071)
BMI*agesq			0.0001**	0.0002***
			(2.495)	(2.820)
BMI*education			-0.008**	-0.008**
			(-2.263)	(-2.106)
BMI*Ladhinc			0.028**	0.028*
			(1.972)	(1.790)
Occupations	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Log likelihood	-25668.41	-25506.37	-25655.74	-25493.98
Restricted log likelihood	-27238.45	-25668.41	-27238.45	-25655.74
No. of the Obs.	26366	26366	26366	26366

Notes: t statistics in parentheses, *** Significant at 1%; **Significant at 5%; * Significant at 10%. Regressions are estimated by ordered probit (OProbit) and random-effects ordered probit (RE-OProb).