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ORIGINAL ARTICLE

Determinants of body weight status in Malaysia: an ethnic comparison

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Abstract
Objective To investigate the roles of sociodemographic and health lifestyle factors in affecting body mass index (BMI) across ethnic groups in Malaysia.
Methods Data are obtained from 2,436 observations from the Malaysia Non-Communicable Disease Surveillance-1. The multi-ethnic sample is segmented into Malay, Chinese, and Indian/other ethnicities. Ordered probit analysis is conducted and marginal effects of sociodemographic and health lifestyle variables on BMI calculated.
Results Malays between 41 and 58 years are more likely to be overweight or obese than their 31–40 years counterparts, while the opposite is true among Chinese. Retirees of Chinese and Indian/other ethnicities are less likely to be obese and more likely to have normal BMI than those between 31 and 40 years. Primary educated Chinese are more likely to be overweight or obese, while tertiary-educated Malays are less likely to suffer from similar weight issues as compared to those with only junior high school education. Affluent Malays and Chinese are more likely to be overweight than their low-middle income cohorts. Family illness history is likely to cause overweightness or obesity, irrespective of ethnicity. Malay cigarette smokers have lower overweight and obesity probabilities than non-cigarette smokers.
Conclusions There exists a need for flexible policies to address cross-ethnic differences in the sociodemographic and health-lifestyle covariates of BMI.

Keywords BMI · Ethnicity · Health lifestyle · Malaysia · Sociodemographics

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Introduction

Malaysians are facing many of the health problems predominantly encountered in other advanced economies. The Third National Health and Morbidity Survey (NHMS III) conducted in 2006 revealed that the prevalence of overweight in terms of body mass index (BMI) increased from 16.6 to 28.6%, while obesity prevalence tripled from 4.5 to 14.2% as compared to statistics from NHMS II in 1996 (Ministry of Health Malaysia 2008). These statistics do not augur well for the health of the Malaysian population given that three of the five leading causes of death are obesity-related diseases and account for over one-third of all medically certified deaths in the country (Ministry of Health Malaysia 2005).

The NHMS III also revealed that the 8.5% prevalence of underweight among adults was three times lower than that (25.5%) reported in the NHMS II in 1996 (Ministry of Health Malaysia 2008). Although this encouraging outcome has been attributed to progression in socioeconomic status and improvement in food intake in the country, Suzana et al. (2007) noted that a significant portion of elderly Malaysians are still susceptible to being underweight and malnutrition risks. Thus, the problems of

underweight and malnutrition should not be discounted as the population ages (Ministry of Health Malaysia 2008).

Ethnicity is often identified as a factor in body mass anomalies. Most existing studies however compared only Caucasians, Blacks, Hispanics, and Asians in their ethnicity/race categories (e.g., Flegal et al. 2010; Paeratakul et al. 2002; Amarasinghe et al. 2006). Others did not consider ethnic backgrounds due to the homogeneous nature of their populations (Ali and Lindström 2006; Maennig et al. 2008; Mikolajczyk and Richter 2008).

The contributions of this study are fourfold. First, in view of the often-ignored role of ethnicity in body weight, the multi-ethnic population in Malaysia allows an examination of the differentiated roles of sociodemographic and health-lifestyle factors across ethnic groups in body mass disparities. Second, while studies have examined factors of BMI risks in Malaysia (e.g., Khor et al. 1999; Chee et al. 2004; Narayan and Khan 2007; Rampal et al. 2007a; Rosnah et al. 2009; Sidik and Rampal 2009), these studies are limited in scope given the sectoral nature of the data. In this study, a nationally representative sample is used. Third, this study draws on the World Health Organization's (WHO) recommended BMI cut-off criteria for Asian adults (WHO 2000). Finally, previous studies (e.g. Sabanayagam et al. 2007; Tan et al. 2010) have utilized more conventional binary probability models to examine the health risks of overweight/obesity. We extend the analysis using an ordered probit model to examine body mass irregularities of under-, at-risk-, over-, obese-weight as well as normal weight categories.

A good understanding of how BMI status may vary by sociodemographic and health-lifestyle factors across ethnic groups can provide policy makers with baseline information for monitoring disparities in weight status and nutritional health in Malaysia.

Methods

Data

Data for this study were obtained from the Malaysia Non-Communicable Disease Surveillance-1 (MyNCDS-1) report of the Ministry of Health Malaysia (2005). This population-based survey covers the 13 states in Malaysia and the federal territory of Kuala Lumpur. Data collection was carried out from September 2005 to February 2006. From a sample of 3,040 respondents ages 25–64, 2,436 (80.1%) observations are retained for analysis due to missing data and incomplete information.

During the survey, field survey teams described the survey to household members and upon receiving a verbal consent, each eligible respondent was interviewed to gather sociodemographic information, own medical history, family medical history and lifestyle behaviors. After this initial interview, written consent was acquired and appointment arranged for a clinical examination at a designated health clinic. At the clinic, the individual was measured for height and weight.

Outcome variables

The outcome variables of BMI by weight categories—underweight (BMI $\leq$ 18.4), normal (18.5 $\leq$ BMI $\leq$ 22.9), overweight at-risk (23 $\leq$ BMI $\leq$ 24.9) (henceforth referred to as at risk), overweight obese I (25 $\leq$ BMI $\leq$ 29.9) (overweight), and overweight obese II (BMI $\geq$ 30) (obese)—are presented in Table 1 and classified according to adult Asian criteria (WHO 2000). These categories correspond to low, average, increased, moderate, and severe risk of co-morbidities, respectively.

Exposure variables

The selection of exposure variables likely to affect BMI relies on insights from previous studies (Chee et al. 2004; Chou et al. 2004; Tur et al. 2005; Ali and Lindström 2006; Yoon et al. 2006; Sabanayagam et al. 2007; Maennig et al. 2008). The following socio-demographic and health-lifestyle related variables are considered: (1) age groups; (2) levels of formal education; (3) monthly household income levels; (4) gender; (5) marital status; (6) location of residence; (7) family health history; (8) smoking status; (9) region of residence; (10) hours of vigorous exercise per day; and (11) length of typical work-day (Table 1).

Age of the respondent is coded into four categories, education into four levels, and income into five categories (Table 1). Also included are dummy variables indicating gender (male), marital status (single), and location of residence (rural) as well as regions: Region 1 (consisting of respondents hailing from the metropolitan states of Penang, Selangor and Kuala Lumpur in West Peninsular Malaysia), Region 2 (representing the less metropolitan states of Perlis, Kedah, Perak, Melaka, Negeri Sembilan, Johor, Pahang, Kelantan and Terengganu in West Peninsular Malaysia), and Region 3 (representing the Borneo states of Sabah and Sarawak in East Malaysia).

For health-lifestyle factors, dummy variables denoting the presence of a history of family illness (family history) and smoking status (smoker) are included. Likewise, average daily length of time spent in vigorous exercise and length of the typical work day are recorded in hours (Table 1).

Statistical analysis

Our outcome variable, weight status, is categorical and ordinal with a clear ordering, although the difference in

Table 1 Sample statistics of BMI by ethnicity and definitions and summary statistics of explanatory variables

Variable	Definition	Under weight	Normal	At risk	Over weight	Obese	Total
Malay (n = 1,343)	Ethnicity of the respondents is Malay	6.3	25.7	15.8	33.7	18.5	100.0
Chinese (n = 439)	Ethnicity of the respondents is Chinese	8.9	32.8	17.8	28.7	11.9	100.0
Indian/other (n = 654)	Ethnicity of the respondents is Indian or others	6.9	30.3	15.9	28.9	18.0	100.0
Pooled (n = 2,436)	Pooled sample	6.9	28.2	16.2	31.5	17.2	100.0
Continuous variables							
Vigorous exercise	Hours of vigorous (activities carried out at 6.0 metabolic equivalent or METs or higher, e.g. running, jogging) exercise per day	0.14 (0.76)	0.32 (1.12)	0.28 (1.08)	0.27 (1.07)	0.14 (0.72)	0.25 (1.02)
Work hours	Length of typical work day (hours)	7.38 (3.33)	7.52 (3.10)	7.56 (3.13)	7.19 (3.27)	7.41 (3.09)	7.39 (3.17)
Binary variables (1 = yes; 0 = no)							
Age ≤30	Age is 30 years or below	18.3	16.0	13.2	9.4	12.4	13.0
Age 31–40	Age is between 31 and 40 years (ref.)	27.8	29.7	23.9	27.8	24.8	27.2
Age 41–58	Age is between 41 and 58 years	41.4	44.8	53.8	55.0	55.4	51.1
Age ≥59	Age is 59 years or above	12.4	9.5	9.1	7.8	7.4	8.7
Primary	Primary as highest level of education	39.1	39.3	40.4	43.0	48.4	42.2
Junior high	Junior high as highest level of education (ref.)	21.9	21.8	21.8	22.9	22.7	22.3
Senior high	Senior high as highest level of education	30.2	26.1	29.4	25.6	21.5	25.9
Tertiary	Tertiary as highest level of education	8.9	12.8	8.4	8.5	7.4	9.5
Poverty	Monthly household income is RM0–399	22.5	18.2	16.0	16.4	17.7	17.5
Low income	Monthly household income is RM400–999	44.4	34.4	32.0	34.4	40.3	35.7
Low mid income	Monthly household income is RM1,000–2,999 (ref.)	27.8	37.8	44.7	38.2	34.6	37.8
Up mid income	Monthly household income is RM3,000–5,999	4.1	7.3	4.8	8.0	4.5	6.4
High income	Monthly household income is ≥RM6,000	1.2	2.3	2.5	3.0	2.9	2.6
Male	Gender is male	45.9	43.2	48.0	40.4	31.7	41.3
Single	Marital status is single, divorced or widowed	16.6	14.7	9.6	11.5	16.0	13.2
Rural	Reside in rural area	53.3	48.9	50.3	49.4	49.2	49.6
Family history	Family history of either hypertension/diabetes/ CHD/stroke/sudden death	43.2	48.9	56.3	55.1	58.7	53.4
Smoker	Currently smoking cigarettes	24.3	24.7	25.9	18.3	14.3	21.1
Region 1	Penang, Selangor, Kuala Lumpur	18.9	17.5	12.7	18.1	31.0	19.3
Region 2	Perlis, Kedah, Perak, Melaka, Negeri Sembilan, Johor, Pahang, Kelantan, Terengganu (ref.)	47.3	55.6	58.4	59.7	49.9	55.8
Region 3	Sabah, Sarawak	33.7	26.9	28.9	22.2	19.1	24.9

Compiled from Ministry of Health Malaysia (2005). As of 2 June 2009, exchange rate was approximately US$1.00 = RM3.51. The five income categories correspond to poverty (US$0–113.90), low (US$114–284.90), low-middle (US$285–853.90), middle-high (US$854–1708.90) and high (≥US$1709)

Values for continuous variables are sample means, while values for binary variables are in percentages. Standard deviations in parenthesis for continuous variables

body weight between weight categories need not be consistent. One statistical model suitable for explaining variations on such ordinal weight status outcomes is the ordered probability model (McCullaph 1980; McKelvey and Zavoina 1975):

$$\begin{aligned} \text{Weight status} &= \text{Under} && \text{if } -\infty < x\beta + u \le 0 \\ &= \text{Normal} && \text{if } 0 < x\beta + u \le \mu_1 \\ &= \text{At risk} && \text{if } \mu_1 < x\beta + u \le \mu_2 \\ &= \text{Overweight} && \text{if } \mu_2 < x\beta + u \le \mu_3 \\ &= \text{Obese} && \text{if } \mu_3 < x\beta + u \le \infty, \end{aligned} \quad (1)$$

where x is a vector of explanatory variables, β is a vector of parameters, u is a random error term, and the μ's are threshold parameters delineating the weight categories. The probability of each category can be derived from (1). For instance, the probability of being at-risk is

$$\Pr(\text{at risk}) = F(\mu_2 - x\beta) - F(\mu_1 - x\beta), \quad (2)$$

where $F(\cdot)$ is a cumulative distribution function (cdf). The probabilities of other weight categories are similar, with the use of proper threshold parameters. To complete the econometric specification, a distributional assumption of the error term is needed. If the error term is assumed to be distributed as the standard normal distribution, the probability $F(\cdot)$ is the standard normal cdf and the model is known as the ordered probit model. An alternative is the ordered logit model, with $F(\cdot)$ specified as the logistic cdf. The difference between the ordered probit and ordered logit models is largely historical, as they were developed independently in separate disciplines, with the former in social sciences (McKelvey and Zavoina 1975) and the latter in biostatistics (McCullaph 1980). A choice between the two should be inconsequential in practice (Powers and Xie 2008, p. 232). To validate this assertion, we perform a non-nested specification test (Vuong 1989) and find that the two models perform equally well (standard normal statistic = 0.686, $p = 0.493$). We choose the ordered probit model, which is estimated by the method of maximum likelihood (ML) (Maddala 1983, pp. 46–49), based on the probability expressions similar to (2). Using the ML estimates, the effects of explanatory variables are derived by differentiating (or differencing, in the case of a discrete variable) the category probabilities, such as (2) (Powers and Xie 2008, p. 236).

We first test for the appropriateness of the use of a pooled sample versus stratified samples by ethnicity. This is accomplished by estimating the ordered probit model for the pooled sample (with racial dummy variables) and for each of the segmented samples. Denote the maximum log likelihoods for the Malay, Chinese, Indian/others, and pooled samples as $\log L_M$, $\log L_C$, $\log L_I$ and $\log L_P$, with corresponding numbers of parameters k_M, k_C, k_I, and k_P. Then, the test statistic $LR = 2(\log L_M + \log L_C + \log L_I - \log L_P)$ is χ^2-distributed with $k_M + k_C + k_I - k_P$ degrees of freedom (df). ML estimates are not presented due to space considerations but are available upon request. According to the separate and pooled sample results, the hypothesis of equal regression (slope) parameters across ethnic groups is rejected ($LR = 62.81$, $df = 44$, $p = 0.033$), suggesting analysis by segmented samples.

To check for multicollinearity among exposure variables, we calculate the variance inflation factor (VIF) for each variable. A value in excess of 20 is indicative of a multicollinearity problem (Belsley et al. 2004). The VIFs for all variables are <2 for all samples considered. Thus, no evidence of multicollinearity among the exposure variables exists.

Results

Characteristics of respondents

Sample statistics of variables is provided in Table 1. Of the sample of 2,436 respondents, 169 (6.9%) are underweight, 687 (28.2%) normal, 394 (16.2%) at risk, 767 (31.5%) overweight, and 419 (17.2%) are obese. The ethnic breakdown consists of 1,343 (55.1%) Malays, 439 (18.0%) Chinese, and 654 (26.8%) "Indians and others". Of the total sample, respondents on an average participate in 0.25 h of vigorous exercise and work 7.4 h per day. The majority (51.1%) consists of individuals age 41–58 (middle-age matured). About 42.2% had primary school and only 9.5% completed tertiary education. Approximately 37.8% are from the low-middle income group with monthly household income between RM1000–2999 (as of 2 June 2009, exchange rate was US$1.00 = RM3.51). Females (58.7%), individuals with a history of family illnesses (53.4%), non-smokers (78.9%), and residents in the less developed states of Peninsular Malaysia (55.8%) form the majority of the sample. Further description of the sample is available upon request.

Effects of explanatory variables by ethnic groups

Malays

Table 2 presents the marginal effects of explanatory variables on BMI category probabilities for the Malay sample. Compared to those in the 31–40 age group, middle-age matured (age 41–58) Malays are more likely to be overweight (3.7%) or obese (6.8%), while having a lower likelihood of be underweight (3.0%) or having normal BMI (6.3%).

Table 2 Marginal effects of explanatory variables on BMI category probabilities: Malay sample

Variable	Under weight	Normal	At risk	Overweight	Obese
Vigorous exercise	0.10 (0.36)	0.22 (0.75)	0.04 (0.14)	–0.13 (0.44)	–0.24 (0.81)
Work hours	−0.01 (0.11)	−0.02 (0.23)	0.00 (0.04)	0.01 (0.13)	0.02 (0.24)
Age ≤30	1.92 (1.36)	3.70 (2.37)	0.54 (0.27)*	−2.36 (1.67)	−3.79 (2.32)
Age 41–58	−3.03 (0.88)***	−6.33 (1.77)***	−1.13 (0.34)***	3.67 (1.06)***	6.82 (1.90)***
Age ≥59	0.73 (1.49)	1.49 (2.91)	0.25 (0.44)	−0.90 (1.84)	−1.56 (3.00)
Primary	−0.25 (0.92)	−0.53 (1.97)	−0.10 (0.36)	0.30 (1.12)	0.57 (2.12)
Senior high	1.56 (1.07)	3.15 (2.06)	0.52 (0.31)*	−1.91 (1.31)	−3.32 (2.12)
Tertiary	4.98 (2.14)**	8.20 (2.72)***	0.74 (0.19)***	−6.00 (2.44)**	−7.93 (2.38)***
Poverty	0.48 (1.09)	1.00 (2.22)	0.17 (0.36)	−0.60 (1.35)	−1.07 (2.32)
Low income	1.33 (0.85)	2.76 (1.71)	0.48 (0.29)*	−1.63 (1.04)	−2.94 (1.80)
Up mid income	−0.25 (1.49)	−0.53 (3.26)	−0.10 (0.63)	0.30 (1.81)	0.58 (3.57)
High income	−2.92 (1.52)*	−7.83 (5.15)	−2.16 (1.92)	3.05 (0.99)***	9.87 (7.63)
Male	0.76 (0.87)	1.61 (1.80)	0.28 (0.32)	−0.94 (1.07)	−1.72 (1.92)
Single	−0.61 (0.94)	−1.34 (2.13)	−0.26 (0.44)	0.74 (1.13)	1.46 (2.38)
Rural	−0.23 (0.72)	−0.49 (1.52)	−0.09 (0.27)	0.28 (0.88)	0.52 (1.63)
Family history	−1.66 (0.69)**	−3.48 (1.41)**	−0.61 (0.25)**	2.04 (0.85)**	3.72 (1.50)**
Smoker	3.48 (1.28)***	6.46 (2.06)***	0.87 (0.23)***	−4.25 (1.54)***	−6.55 (1.97)***
Region 1	−1.65 (0.74)**	−3.74 (1.77)**	–0.77 (0.42)*	1.97 (0.86)**	4.18 (2.06)**
Region 3	1.92 (1.54)	3.65 (2.62)	0.51 (0.27)	−2.36 (1.88)	−3.72 (2.53)

Values are in percentages

Standard errors in parenthesis

Asterisks indicate levels of statistical significance: ***$p < 0.01$, **$p < 0.05$, *$p \leq 0.10$

Reference categories are age 31–40 for age, junior high school for education, low-mid income for income, and region 2 for regions

Tertiary-educated individuals are 6.0 and 7.9% less likely to be overweight and obese, and 5.0 and 8.2% more likely to be underweight and in the normal BMI group, respectively, than their cohort with junior high school education. Although low-income earners are 0.5% more likely to be at risk, high-income earners are 3.1% more likely to be overweight than their low-middle income cohort. Similarly, high-income earners have a 2.9% lower probability to be underweight as compared to those in the low-middle income group, *ceteris paribus*.

Individuals with a family history of serious illnesses are more likely to be overweight (2.0%) and obese (3.7%) than those without such backgrounds. These individuals also have a lower propensity to be underweight (1.7%) and normal weight (3.5%). Compared with non-smokers, smokers experience a lower likelihood of being overweight (4.3%) or obese (6.6%), but are more likely to be in the underweight (3.5%), normal (6.5%) and at risk (0.9%) BMI categories.

Ethnic Malays in metropolitan areas (Region 1) are more likely to be overweight (2.0%) and obese (4.2%) than those in non-metropolitan areas (Region 2). Although metropolitan Malays (Region 1) are 3.7% less likely to have a normal weight, they are 1.6% less likely to be underweight than their cohort from non-metropolitan areas (Region 2).

Chinese

The marginal effects of explanatory variables on BMI category probabilities for the Chinese sample are presented in Table 3. Middle-age matured (41–58 years) Chinese are less likely to be overweight (5.7%) or obese (5.3%) than their peers in the 31–40 age group. These individuals also have a higher probability to be underweight (4.3%) or normal weight (6.7%) than those in the 31–40 age bracket. Retirees are 7.3% more likely to have normal weight and 5.3% less likely to be obese compared to individuals ages 31–40, other factors constant.

Ethnic Chinese with primary school education are more likely to be overweight (6.6%) and obese (6.5%) than those with junior high school education. Although primary educated individuals are 8.1% less likely to have normal BMI, these individuals are 4.9% less likely to be underweight than those with junior high school education.

High-income individuals are 6.3% more likely to be overweight and 4.4% less likely to be underweight than their low-middle income counterparts. Individuals with a family history of illnesses are more likely to be overweight (4.4%) and obese (3.9%), and less likely to be in the underweight (3.3%) or normal (5.0%) BMI categories than their cohort without family health conditions.

Table 3 Marginal effects of explanatory variables on BMI category probabilities: Chinese sample

Variable	Under weight	Normal	At risk	Overweight	Obese
Vigorous exercise	0.83 (0.71)	1.29 (1.11)	0.00 (0.06)	−1.11 (0.96)	−1.01 (0.87)
Work hours	0.45 (0.28)	0.70 (0.44)	0.00 (0.03)	−0.60 (0.38)	−0.54 (0.34)
Age ≤30	1.09 (3.29)	1.62 (4.63)	−0.04 (0.23)	−1.44 (4.24)	−1.23 (3.46)
Age 41–58	4.26 (1.97)**	6.71 (3.07)**	0.03 (0.29)	−5.70 (2.61)**	−5.30 (2.47)**
Age ≥59	6.24 (4.40)	7.34 (3.84)*	−0.84 (1.04)	−7.40 (4.59)	−5.33 (2.67)**
Primary	−4.89 (2.11)**	−8.06 (3.57)**	−0.20 (0.39)	6.63 (2.84)**	6.52 (3.02)**
Senior high	2.58 (2.50)	3.73 (3.34)	−0.12 (0.27)	−3.35 (3.15)	−2.83 (2.48)
Tertiary	2.74 (3.42)	3.77 (4.12)	−0.20 (0.48)	−3.49 (4.13)	–2.81 (2.96)
Poverty	−1.67 (2.27)	−2.85 (4.18)	−0.09 (0.30)	2.31 (3.22)	2.30 (3.50)
Low income	1.58 (2.34)	2.34 (3.28)	−0.06 (0.19)	−2.08 (3.01)	−1.78 (2.46)
Up mid income	0.83 (2.76)	1.25 (3.99)	−0.02 (0.15)	−1.10 (3.60)	−0.96 (3.01)
High income	−4.41 (2.12)**	−9.06 (5.56)	−1.03 (1.29)	6.35 (3.11)**	8.15 (5.82)
Male	0.22 (1.78)	0.35 (2.78)	0.00 (0.02)	−0.30 (2.39)	−0.27 (2.16)
Single	0.35 (2.42)	0.53 (3.68)	0.00 (0.06)	−0.46 (3.22)	−0.41 (2.83)
Rural	−2.08 (1.65)	−3.41 (2.81)	−0.06 (0.18)	2.84 (2.28)	2.71 (2.28)
Family history	−3.30 (1.66)**	−5.03 (2.46)**	0.05 (0.22)	4.37 (2.17)**	3.90 (1.90)**
Smoker	−1.16 (2.19)	−1.91 (3.80)	−0.04 (0.17)	1.58 (3.06)	1.51 (3.09)
Region 1	−1.32 (2.23)	−2.19 (3.91)	−0.05 (0.20)	1.81 (3.12)	1.74 (3.20)
Region 3	1.66 (2.02)	2.47 (2.84)	−0.06 (0.17)	−2.19 (2.60)	−1.88 (2.14)

Values are in percentages

Standard errors in parenthesis

Asterisks indicate levels of statistical significance: ***$p < 0.01$, **$p < 0.05$, *$p \leq 0.10$

Reference categories are age 31–40 for age, junior high school for education, low mid income for income, and region 2 for regions

Indians/others

Table 4 illustrates the marginal effects of explanatory variables on BMI category probabilities for individuals of Indian/other ethnicities. Retirees are 6.6% less likely to be obese and 7.2% more likely to have a normal BMI than those age 31–40.

Individuals in the poverty-income bracket have lower probabilities of being overweight (4.4%) and obese (6.6%) than those in the lower-middle income group. This is followed by a higher likelihood of being in the BMI categories of underweight (3.8%) and normal weight (7.0%). The importance of estimation by racial groups is highlighted as the statistical significance of the poverty-income bracket is present only for Indians/others and not ethnic Malays or Chinese.

Rural area residents are more likely to be in the underweight (2.2%) and normal (4.6%) weight groups, and less likely to be overweight (2.6%) or obese (4.6%) than urbanites. Individuals with a family history of serious illnesses are less likely to be in the underweight (2.7%), normal (5.6%), and at-risk (0.5%) weight groups than their counterparts without such history; instead, these individuals are more likely to be overweight (3.2%) and obese (5.6%).

Ethnic Indians/others in metropolitan states (Region 1) are more likely to be overweight (3.7%) and obese (8.4%) than those in non-metropolitan states (Region 2). These individuals are also 3.1% less likely to be underweight while having a 7.8% lower probability of having normal BMI than their cohorts in the non-metropolitan states of Peninsular Malaysia (Region 2), *ceteris paribus*.

Discussion

The results of this study generally corroborate findings by other researchers (Rampal et al. 2007b; Rosnah et al. 2009) that sociodemographic and health-lifestyle factors play a significant role in BMI category probabilities across ethnic groups in Malaysia. This is highlighted by the findings that age groups, education levels, income brackets, history of family illness, and smoking status are significantly associated with body weight status across ethnic groups in Malaysia.

Specifically, our findings substantiate those of other smaller sectoral studies (Chee et al. 2004; Rosnah et al. 2009) that elderly Malays in their middle ages are at a higher risk of being overweight or obese as compared to their younger cohort. Conversely, middle-age matured and retired ethnic

Table 4 Marginal effects of explanatory variables on BMI category probabilities: Indian/other sample

Variable	Under weight	Normal	At risk	Overweight	Obese
Vigorous exercise	0.16 (0.46)	0.33 (0.96)	0.03 (0.08)	−0.19 (0.55)	−0.33 (0.95)
Work hours	0.15 (0.17)	0.31 (0.36)	0.03 (0.03)	−0.18 (0.21)	−0.30 (0.36)
Age ≤30	0.37 (1.71)	0.76 (3.48)	0.06 (0.26)	−0.44 (2.05)	−0.74 (3.39)
Age 41–58	−0.18 (1.24)	−0.38 (2.62)	−0.03 (0.23)	0.22 (1.49)	0.38 (2.59)
Age ≥59	4.39 (3.30)	7.21 (4.20)*	0.03 (0.44)	−5.02 (3.52)	−6.61 (3.59)*
Primary	−0.36 (1.31)	−0.77 (2.76)	−0.07 (0.24)	0.44 (1.58)	0.76 (2.74)
Senior high	0.82 (1.71)	1.66 (3.35)	0.12 (0.21)	−0.98 (2.05)	−1.62 (3.22)
Tertiary	2.25 (2.87)	4.16 (4.67)	0.18 (0.13)	−2.66 (3.31)	−3.93 (4.22)
Poverty	3.79 (1.80)*	6.98 (2.88)*	0.30 (0.22)	−4.44 (2.04)*	−6.63 (2.62)*
Low income	1.13 (1.35)	2.34 (2.74)	0.19 (0.21)	−1.36 (1.62)	−2.30 (2.67)
Up-mid income	−1.29 (2.11)	−2.97 (5.32)	−0.35 (0.80)	1.55 (2.51)	3.06 (5.71)
High income	1.71 (4.81)	3.23 (8.07)	0.16 (0.12)	−2.03 (5.59)	−3.06 (7.35)
Male	0.28 (1.18)	0.60 (2.48)	0.05 (0.21)	−0.34 (1.43)	−0.59 (2.45)
Single	2.54 (1.94)	4.71 (3.13)	0.20 (0.15)	−3.00 (2.22)	−4.45 (2.83)
Rural	2.17 (1.10)*	4.59 (2.30)*	0.41 (0.25)	−2.60 (1.31)*	−4.57 (2.29)*
Family history	−2.65 (1.09)*	−5.59 (2.27)*	−0.50 (0.26)*	3.17 (1.30)*	5.57 (2.25)*
Smoker	2.28 (1.62)	4.38 (2.83)	0.25 (0.15)	−2.71 (1.89)	−4.20 (2.62)
Region 1	−3.13 (1.27)*	−7.75 (3.56)*	−1.14 (0.77)	3.66 (1.39)***	8.36 (4.19)*
Region 3	0.49 (1.28)	1.05 (2.74)	0.09 (0.25)	−0.59 (1.54)	−1.04 (2.73)

Values are in percentages

Standard errors in parenthesis

Asterisks indicate levels of statistical significance: ***$p < 0.01$, **$p < 0.05$, *$p \leq 0.10$

Reference categories are age 31–40 for age, junior high school for education, low-mid income for income, and region 2 for regions

Chinese and retired Indian/other individuals have lower obesity likelihoods and are, instead, more likely to be in the normal BMI category than their younger counterparts. Moreover, the conflicting effects of age categories on body weight status among ethnic Malays, Chinese and Indians/others can only be uncovered by segmented sample estimation that would otherwise be disguised in the pooled sample estimates (see "Appendix Table 5").

The segmented sample estimates highlight two primary sets of outcomes based on the inverse relationship between education levels and prevalence of overweight and obesity. First, we find evidence that less-educated Chinese are more likely to be overweight and obese than their higher educated counterparts. Second, higher educated Malays are less likely to suffer from overweight and obesity issues. These results are in line with the studies conducted in Western Europe (Martinez et al. 2004; Tur et al. 2005), the United States (Freedman et al. 2002), and Asian countries, such as Korea (Yoon et al. 2006), Singapore (Sabanayagam et al. 2007), Thailand (Aekplakorn 2007) and even Malaysia (Chee et al. 2004; Sidik and Rampal 2009). Possible reasons for this outcome are that highly educated individuals are also likely to be more health conscious, have greater access to health information, and have more choice regarding diet and exercise than lower educated individuals.

The results of the present study are also in line with those of Ismail et al. (1995) and Chee et al. (2004) who found a trend of overweight among the middle to high-income urban population in Malaysia. Specifically, affluent Malay and Chinese individuals have a higher propensity to be overweight while Indians/others in poverty-income brackets are more likely to be underweight. These outcomes can be attributed to the unhealthy eating habits and largely sedentary lifestyles which may contribute to overweight and obesity among higher income individuals (Ismail et al. 2002).

Although the literature correlating family health history and body weight status is scant, we find a strong association between family health history and BMI. In particular, individuals of all ethnic backgrounds with adverse family medical backgrounds have a higher probability of being overweight or obese than those without such conditions. These results call attention to the recommendation of the Ministry of Health Malaysia and Academy of Medicine Malaysia in 2003 that clinical practice guidelines on the management and assessment of obesity health risks should include a patient's family history of illnesses. These illnesses include diabetes, hypertension, dyslipidaemia, cardiovascular disease, obesity-related cancer, and thyroid disease (Ministry of Health Malaysia and Academy of Medicine Malaysia 2003).

The effect of smoking status in affecting body weight status is present only for ethnic Malays and not those of Chinese or Indian/other descent. Ethnic Malay smokers are less likely to be overweight or obese, but more likely to be in the normal or even underweight range as compared to non-smokers. This result is consistent with the findings of Rampal et al. (2007b), whereby obesity prevalence was significantly higher among non-smokers as compared to current smokers. This outcome is rationalized by the notion that smokers generally have higher metabolic rates and, on average, consume fewer calories than non-smokers (Chou et al. 2004).

Based on these results, several implications are noted. First, with the primary goal of effectively allocating public resources to ameliorate health disparities in a multi-ethnic society, targeted interventions aimed at different ethnic groups may be necessary. This is in light of the results of the study showing that, in contrast to previous findings by Suzana et al. (2007), the elderly population in Malaysia do not exhibit any underweight tendencies. Instead, among the middle-age matured group, Malays are more likely to be overweight or obese, while ethnic Chinese in the middle-age matured and retiree age groups are more likely to be in the normal BMI category than ethnic Indians/others. As suggested by Rosnah et al. (2009), the greater health risks faced by Malays in this category may be attributed to unhealthy lifestyle and diet. As such, health intervention programs calling for changes in lifestyles and diets in the Malay language-based media (newspapers, TV programs, radio channels) should be considered to more effectively reach out to Malays.

Second, as education is expected to improve an individual's knowledge on health, while improving his/her allocative efficiency in health outcomes, this result suggests further advancement of health education in schools and universities as part of continuing efforts to combat acute weight issues. Recent initiatives at the Malaysian Education Ministry to provide free textbooks and abolish school fees as an important step toward free education for all (The Star 2007) may play a definitive role in the long-term health of Malaysians. Other direct measures to improve public health conditions in Malaysia might include targeting awareness and nutritional programs toward the less-educated among the ethnic Chinese population.

Third, public health officials should take note of the profound relationship between Indians/others in the poverty-income group and a higher likelihood to be undernourished. Although it is important to educate the masses that being underweight is hazardous to general well being, specific food aid programs could be enacted to directly reach out to these underprivileged individuals and such programs could include distribution of food coupons to school children with poorer backgrounds, particularly those of Indian/other descent. Meanwhile, given the higher propensity of affluent Malays and Chinese to be overweight, health intervention messages could be directed at these groups to discourage a diet rich in animal fats and to promote regular exercise and awareness of health issues.

Fourth, as family history of illnesses is a likely factor in overweight and obesity among Malaysians of all ethnic backgrounds, future health educational programs on weight issues should not only target individuals per se but entire groups of immediate family members. This involves publicizing the fact that the causes of overweight and obesity can include an individual's genetic makeup, with occurrences being more common in some families than others, but irrespective of ethnic backgrounds. Furthermore, parents should be informed of the possibility of childhood overweight and obesity problems, especially if their next-of-kin are suffering from the aforementioned string of illnesses.

Last, metropolitan residents of Malay and Indian/other descent are more likely to be overweight or obese than their non-metropolitan cohorts. This suggests that lifestyle differences in the various states in Malaysia may contribute to the increased risk of over nutrition. Contributing factors of this outcome may include a more sedentary lifestyle, lack of exercise, and less healthful diets due to a greater reliance on convenience foods and fast foods among residents in the metropolitan areas of Penang, Selangor and Kuala Lumpur. Given recent migration trends to relocate to larger or metropolitan cities in search of better work opportunities, it may be prudent for policy makers to consider enacting health messages reminding the public, particularly those living in larger cities, of the risks of over-nutrition and its associated health problems.

While this study acts as a catalyst to further research on body weight and health risk patterns in Malaysia, several limitations are acknowledged. First, this study incorporates data from a cross-sectional survey. Hence, inter-temporal occurrences are not taken into consideration. Nevertheless, given current plans to incorporate MyNCDS-1 into the more comprehensive NHMS as well as to increase its data collection frequency in the future, the possibility of a panel data study is a viable option. Second, complete information about the surveyed households is important to enhance the statistical findings. For example, future studies should consider other possible variables, such as individual genetic history, distance to nearest recreational facility, hours of sleep, social networks and others, which are not available due to the secondary nature of the data.

In conclusion, although much future research is needed to address these issues, our results indicate that sociodemographic and health-lifestyle related factors are closely associated with BMI weight categories. As such, the most effective public health intervention to control for body

weight issues in Malaysia could actually be a portfolio of targeted interventions designed to meet the needs of specific sub-populations within the country. This result likely defines a challenge that many other developing nations could also face. Nevertheless, the results of the current study also demonstrate how a population-based survey instrument can assist newly industrialized countries in more effectively directing initial resources and research efforts when attempting to control for BMI weight issues.

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Conflict of interest The authors declare that they have no competing interests.

Appendix

See Table 5.

Table 5 Marginal effects of explanatory variables on BMI category probabilities: pooled sample

Variable	Under weight	Normal	At risk	Over weight	Obese
Vigorous exercise	0.27 (0.26)	0.53 (0.52)	0.06 (0.06)	−0.33 (0.32)	−0.54 (0.52)
Work hours	0.08 (0.09)	0.16 (0.17)	0.02 (0.02)	−0.10 (0.11)	−0.16 (0.18)
Age ≤30	1.57 (1.05)	2.84 (1.76)	0.27 (0.13)*	−1.89 (1.25)	−2.79 (1.68)**
Age 41–58	−1.15 (0.67)*	−2.25 (1.30)*	−0.27 (0.16)*	1.39 (0.81)*	2.28 (1.32)**
Age ≥59	2.22 (1.37)	3.86 (2.10)*	0.31 (0.10)***	−2.66 (1.60)*	−3.73 (1.94)*
Primary	−0.77 (0.72)	−1.52 (1.44)	−0.19 (0.19)	0.94 (0.88)	1.55 (1.47)
Senior high	1.98 (0.89)**	3.64 (1.52)**	0.36 (0.13)***	−2.39 (1.06)**	−3.59 (1.46)**
Tertiary	3.83 (1.50)**	6.16 (1.98)***	0.33 (0.11)***	−4.50 (1.69)***	−5.81 (1.75)***
Poverty	1.79 (0.93)*	3.23 (1.56)**	0.31 (0.12)***	−2.15 (1.11)*	−3.18 (1.48)**
Low income	1.21 (0.70)*	2.32 (1.30)*	0.26 (0.14)	−1.47 (0.84)*	−2.33 (1.29)*
Up-mid income	−0.18 (1.14)	−0.35 (2.28)	−0.04 (0.30)	0.21 (1.38)	0.35 (2.34)
High income	−2.78 (1.16)**	−6.66 (3.38)**	−1.33 (0.94)	3.20 (1.15)***	7.58 (4.33)*
Malay	−0.10 (0.75)	−0.19 (1.47)	−0.02 (0.18)	0.12 (0.91)	0.19 (1.49)
Chinese	3.94 (1.16)***	6.53 (1.62)***	0.42 (0.11)***	−4.65 (1.32)***	−6.25 (1.47)***
Male	0.83 (0.66)	1.61 (1.27)	0.19 (0.15)	−1.01 (0.80)	−1.63 (1.28)
Single	−0.05 (0.81)	−0.10 (1.59)	−0.01 (0.20)	0.06 (0.98)	0.10 (1.62)
Rural	0.11 (0.57)	0.21 (1.12)	0.03 (0.14)	−0.13 (0.69)	−0.21 (1.14)
Family history	−2.18 (0.57)***	−4.21 (1.07)***	−0.50 (0.14)***	2.63 (0.68)***	4.26 (1.07)***
Smoker	2.57 (0.92)***	4.55 (1.47)***	0.40 (0.11)***	−3.08 (1.09)***	−4.44 (1.38)***
Region 1	−2.01 (0.64)***	−4.27 (1.45)***	−0.66 (0.28)**	2.40 (0.74)***	4.54 (1.61)***
Region 3	1.85 (0.85)**	3.39 (1.46)**	0.34 (0.13)***	−2.22 (1.02)**	−3.35 (1.41)**

Values are in percentages

Standard errors in parenthesis

Asterisks indicate levels of statistical significance: ***$p < 0.01$, **$p < 0.05$, *$p \leq 0.10$

Reference categories are age 31–40 for age, junior high school for education, low-mid income for income, and region 2 for regions

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