BODY WEIGHT STATUS OF ADOLESCENTS: A STUDY OF THREE SOUTHEAST ASIAN COUNTRIES

Andrew KG Tan[1], Steven T Yen[2], Leng-Huat Foo[3] and Haibo Liu[4]

[1]School of Social Sciences, Universiti Sains Malaysia, Penang, Malaysia; [2]Department of Agricultural Economics, National Taiwan University, Taipei, Taiwan; [3]School of Health Sciences, Universiti Sains Malaysia, Kelantan, Malaysia; [4]School of Economics and Business, Northeast Normal University, Changchun, Jilin, PR China

Abstract. Underweight, overweight and obesity lead to detrimental health outcomes in adolescents and adulthood. Socio-economic/demographic, dietary-lifestyle and psychosocial-familial factors associated with body mass index (BMI) categories of adolescents were investigated in three Southeast Asian countries, namely, Indonesia, Malaysia and Thailand employing a cross-sectional study based on the World Health Organization's Global School-based Student Health Surveys of adolescents 13-17 years of age. Age- and sex-adjusted BMI status was categorized as underweight, normal weight, overweight, and obese. Ordered probit analysis was performed to examine factors associated with BMI status. Higher likelihoods of overweight and obesity were found among adolescents of both genders in Malaysia and Thailand compared to Indonesia, and higher likelihood of overweight among both groups in Malaysia compared Thailand. Age was negatively associated with overweight and obesity likelihoods among male adolescents in all three countries. Hunger status was correlated with higher underweight and lower overweight/obesity likelihoods among adolescents of both genders in Malaysia and females in Indonesia. Adolescents who exercise regularly experienced higher likelihood of normal BMI in all three countries. Smoking lowered overweight/obesity propensity of male adolescents in Indonesia and Malaysia, while loneliness contributed to propensity of overweight/ obesity among adolescents of both genders in Malaysia. These findings show a need for a portfolio of targeted interventions according to specific adolescent subpopulations within the three target Southeast Asian countries to correct abnormalities in body weight indices detrimental to healthy growth and development.

Keywords: adolescence, body weight index, obesity, overweight, Indonesia, Malaysia, Thailand

Correspondence: Steven T Yen, Department of Agricultural Economics, National Taiwan University, Taipei, Taiwan
E-mail: styen@ntu.edu.tw

INTRODUCTION

Underweight, overweight, and obesity are often precursors to poor health among adolescents. Negative health consequences of adolescence underweight comprise decreased bone mass, scoliosis, muscle weakness, delayed puberty, and increased risk of osteoporosis in adulthood (Pasricha and Biggs, 2010). Potential health problems caused by adolescence overweight and obesity are cardiovascular diseases, hypertension and type-2 diabetes (Daniels, 2006) and such adolescents face greater risks of obesity and chronic diseases in adulthood (Alberga *et al*, 2012).

The 2020 Global Nutrition Report (Development Initiatives, 2020b) points out that global prevalence of children and adolescents (5-19 years of age) with underweight determined from body mass index (BMI) decreased during 2000 and 2016 from 37.0 to 31.6% for boys and from 29.6 to 25.9% for girls, while, on the other hand, prevalence of overweight rose from 10.3 to 19.2% and from 10.3 to 17.5%, respectively. During the same period, prevalence of obesity increased from 3.3 to 7.8% among boys and from 2.5 to 5.6% among girls (Development Initiatives, 2020b).

Based on geographic regions, Europe fares better than the global average as prevalence of adolescence underweight decreased during 2000 and 2016 from 12.9 to 10.3% for boys and from 13.5 to 11.0% for girls, while prevalence of overweight rose from 21.6 to 29.4% and from 18.4 to 24.5% respectively, compared to that of adults of 6.3 to 10.7% among males and 4.2 to 6.7% among females (Development Initiatives, 2020a). Encouraging outcomes were also observed in North America and Oceania with reduction in underweight prevalence similar to the global trend while increase in overweight and obesity prevalence among boys and girls were lower than the global trend. Different patterns were observed in Asia, particularly among countries in the Southeast Asian subregion. While underweight prevalence averaged >30% in 2016, overweight prevalence increased alarmingly from 5.5 to 16.5% among boys and from 5.5 to 13.0% among girls. Obesity prevalence rose from 2.0 to 7.2% among boys and from 1.1 to 4.2% among girls between 2000 and 2016 (Development Initiatives, 2020a).

While several studies have investigated factors associated with adolescent overweight and obesity in Southeast Asia, many are based on small-scale data of selected cities/ districts (Nguyen *et al*, 2013; Su *et al*, 2014; Pham *et al*, 2020). Other than two studies, namely those of Naidu *et al* (2013) and Pengpid and Peltzer (2016), large-scale nationwide studies have been hampered due to lack of comprehensive data. Conclusions from regional studies are limited and ungeneralizable to the country level. Studies among countries cannot be conducted due to lack of common data formats.

Given the high prevalence of underweight and obesity among adolescents in Southeast Asian countries, efforts were made within this population to identify factors associated with BMI categories employing binary logistic/probability models (Tang *et al*, 2010; Pengpid and Peltzer, 2016; Zhu *et al*, 2018). However, information on detailed weight categories is compromised as health and policy implications of correlates of these different weight outcomes (*eg* normal weight, overweight, and obesity) are generally different. This is the major shortcoming of the study by Pengpid and Peltzer (2016), who investigated the binary outcome of overweight or obesity based on the same data source.

This study examined the association of adolescent BMI categories with socio-economic/demographic (age and hunger status), dietary-lifestyle (fruit and vegetable (FV) consumption, physical activity and smoking status), and psychosocial-familial (loneliness, peer support and parental understanding) factors according to gender in three Southeast Asian countries, namely Indonesia, Malaysia, and Thailand. Specific objectives were to investigate the association of BMI with socio-economic/demographic, dietary-lifestyle, and psychosocial-familial factors utilizing large-scale national survey data sets and an ordered (versus binary) probit model.

MATERIALS AND METHODS

Data collection

Data were obtained from the Global School-based Student Health Surveys (GSHS) of Indonesia (961 boys and 1,231 girls) in 2007, Malaysia (11,885 boys and 12,240 girls) in 2012 and Thailand (1,162 boys and 1,305) in 2008 (CDC, 2007; CDC, 2008; CDC, 2012). GSHS is a school-based cross-sectional survey developed by WHO to provide health and social behavioral information of students in secondary schools, 13-17 years of age, who attend Grades 7-11 in Indonesia, Form 1-5 in Malaysia and Mattayom 1-5 in Thailand (MOE Thailand, 2008; UNESCO, 2011; MOE Malaysia, 2019). Standardized scientific sampling process and common school-based methodology were used to obtain representative samples from randomly selected schools in these countries (WHO, 2019). After removing observations with missing information for important variables, the study samples constituted 224,125, 2,467 and 2,192 students from Indonesia, Malaysia and Thailand, respectively. While multiple imputation procedures for missing values are available, these were beyond the scope of the study. Analysis was carried out with the assumption that data are not missing in any non-random way and, as such, the results should be interpreted with caution. No ethical approval was required as GSHS data were anonymized and accessible to the general public.

Outcome variable

Before carrying out the survey, researchers measured the weight (kg) and height (m) of each student; such information was then entered onto the GSHS questionnaire during survey administration (WHO and CDC, 2013). BMI (kg/m2) is categorized into underweight (BMI <-2 standard deviation (SD) from median by age and sex), normal weight (-2 SD ≤ BMI <+1 SD from median by age and sex), overweight (+1 SD ≤ BMI <+2 SD from median by age and sex), and obese (BMI >+2 SD from median by age and sex) (de Onis *et al*, 2007; WHO, 2007). The outcome variable, BMI status, is an ordinal indicator of these categories.

Exposure variables

Exposure variables assumed to be associated with BMI status were age groups (age ≥16), hunger status (Hungry), fruit and vegetable consumption (FV), physical activity status (Physical), smoking status (Smoker), loneliness status (Lonely), peer support (Peer), parental understanding (Parental), and gender (Tang *et al*, 2010; Nguyen *et al*, 2013; Su *et al*, 2014; Pengpid and Peltzer, 2016).

Age groups were divided into two categories, namely, ≤15 years of age (reference) and ≥16 years of age. In GSHS, exposure variables use multi-point response scales and are aggregated into two-point scales. For example, Hungry as a proxy for income and food intake is obtained from response to the question, "During the past 30 days, how often did you go hungry because there was not enough food in your home?". The five-point response scale ranged from 1 = never to 5 = always. Hungry status is then denoted to student responding affirmatively to having gone hungry most (scale 4) or all (scale 5) of the time in the past month due to insufficient food at home. Similarly, a composite binary variable was created to represent FV intake adequacy. From the question, "During the past 30 days, how many times per day did you usually eat fruits (vegetables)?", a respondent who consumed fruits at least twice daily and vegetables at least thrice daily over the past month is considered to have adequate FV intake. Physical denotes an adolescent who exercised ≥60 minutes daily in the past week; Smoker refers to tobacco products usage on ≥1 day(s) in the past month; Lonely to feeling alone most or all the time in the past year; Peer to characterize an adolescent who never or rarely experienced kind and helpful peers in school; and, Parental refers to those having parents/guardians who sometimes/most of the time/always understand the problems or worries of the respondent (WHO and CDC, 2013).

Statistical analysis

Our empirical specification is based on a utility-theoretic framework (Philipson and Posner, 2003). In order to accommodate the ordinal scale of weight category variable (y), ordered probit model was employed as follows (Cameron and Trivedi, 2005):

$$
\begin{aligned}
y &= \text{underweight} && \text{if} \quad -\infty < X^{T}\beta + U \leq 0 \\
&= \text{normal weight} && \text{if} \quad 0 < X^{T}\beta + U \leq r_1 \\
&= \text{overweight} && \text{if} \quad r_1 < X^{T}\beta + U \leq r_2 \\
&= \text{obese} && \text{if} \quad r_2 < X^{T}\beta + U \leq \infty \qquad (1)
\end{aligned}
$$

where X is a vector of exposure variable, β is a conformable parameter vector, and rl and r2 are threshold parameters delineating categories of body weight, along with the fixed thresholds (-∞, 0, ∞). As the dependent variable y contains only categorical information, the disturbance term U is assumed to follow a unit normal distribution, with standard deviation standardized at unity. The probability of each weight category is the defined as difference between two standard normal probabilities. For example, probability of overweight is calculated from the formula:

$$
\Pr(y = \text{overweight}) = F(r_2 - X^{T}\beta) - F(r_1 - X^{T}\beta) \qquad (2)
$$

where F is cumulative distribution function of the unit normal. Probabilities of other weight categories are defined similarly with the pair of thresholds given in each line of equation (1). The likelihood function for an independent sample is the product of all component probabilities defined in (1). Maximum-likelihood estimation and bootstraps for standard errors were carried out by programming in R4.0.5, using the maxLik optimization package (Henningsen and Toomet, 2011). Upon obtaining the parameter estimates, associations of exposure variables, all binary, with the weight category probabilities are quantified by calculating differences in category probabilities. For statistical inference, standard error of association is calculated using paired bootstraps (Greene, 2018).

RESULTS

Statistics of study population

There were more girls than boys in all three countries sampled. The proportions of boys and girls in Malaysia and Thailand reflected both country's population while they differed for Indonesia where the population of boys (51%) are higher than girls (49%) (UIS, 2014). The proportion of adolescents with normal weight was similar in all three countries and among gender, but those in Malaysia and Thailand had a higher proportion of obesity relative to underweight although the opposite was observed in Indonesia. (Fig 1)

The majority of adolescents were ≤15 years of age in all three countries. Between 2-6% of respondents reported hunger most or all the time in the past

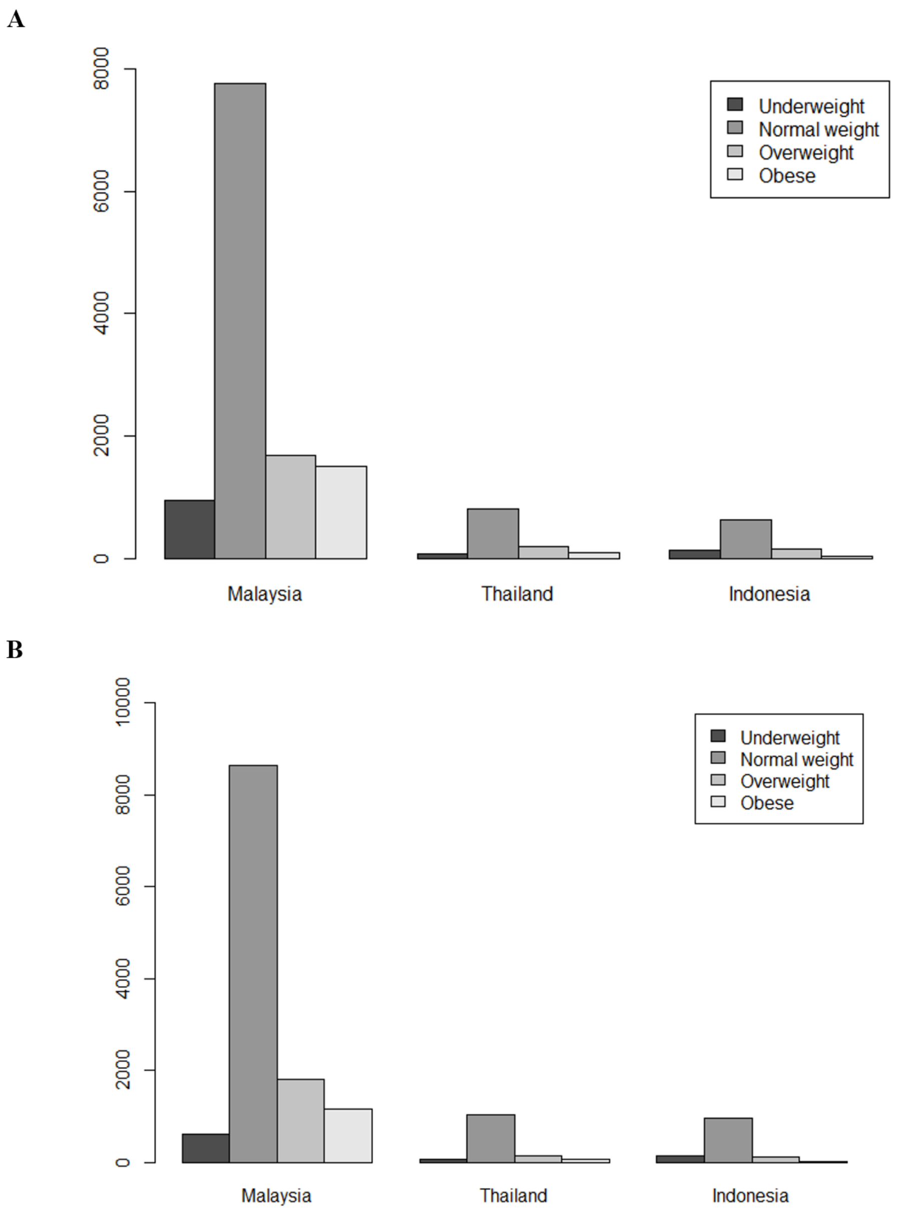

Fig 1 - Frequency distribution of BMI category according to country and gender

A: Male; B: Female

Data are compiled from the Global School-based Student Health Surveys (GSHS) of Indonesia in 2007, Malaysia in 2012 and Thailand in 2008 (CDC, 2007; CDC, 2008; CDC, 2012).

month, with the largest proportion among males (7%) and females (6%) in Indonesia. Proportion of adolescents who consumed adequate fruit and vegetable ranged from 23% (females in Indonesia) to 33% (females in Thailand). Male adolescents from Malaysia and Thailand were more physically active than girls. Proportion of smoking among boys in Indonesia (21%), Malaysia (19%) and Thailand (15%) was higher compared to girls (1-2%).

Between 6-10% of adolescents reported being lonely most or all the time and more boys than girls responded that fellow students were never or rarely kind and helpful. There was no difference in gender of adolescents with understanding parents/guardians in Indonesia and Malaysia but in Thailand there were fewer boys (57%) than girls (68%) in this category (CDC 2007; CDC, 2008; CDC, 2012). Detailed discussions can be obtained from the authors upon request.

Parameter estimates

We initially determined whether to conduct the analysis with a pooled all-country, boy-girl sample, or by country and sex using chi-square tests. Firstly, by estimating the model for the pooled, Indonesia, Malaysia, and Thailand samples, such that each country dummy variables are included in the restricted (pooled sample) model and obtaining maximum log-likelihood values (f_p, f_1, f_2, f_3), the test statistic $2(f_1 + f_2 + f_3 - f_p)$ was chi-square distributed with degrees of freedom equal to the number of additional parameters in segmented-sample estimation. The hypothesis of equal "slope" coefficients was rejected for all three countries ($\chi^2 = 4146.81$, df = 10, p-value < 0.0001). Following the same procedure, the hypothesis of equal slope coefficients was also rejected between genders both by pooling data from all countries and by each individual country (p-value < 0.0001). In summary, statistical tests suggest analysis of each country and by gender for each country. Maximum-likelihood estimates are not presented due to space consideration and are available upon request from the authors. The key results are as follows: (i) all threshold parameter estimates are statistically significant for both boys and girls in all three countries (p-value <0.01), suggesting ability of these thresholds in delineating BMI categories; (ii) all variables are jointly significant (p-value < 0.001 by Wald and likelihood-ratio tests), suggesting explanatory variables are suitable to describe sample variation in BMI categories. The roles of exposure variables can better be explored using marginal effects on BMI category probabilities.

Effects of exposure variables

We first compared probabilities of body weight categories among the three countries. Compared to Indonesia, male adolescents in Malaysia were 6.23 (percentage) points less likely to be underweight, 4.08 points less likely to be normal weight; but 4.44 points more likely to be overweight and 5.88

point more likely to be obese (Table 1). Similar patterns were observed among female adolescents in Malaysia compared to Indonesia, but with higher magnitude, as high as 6.77 points, of being overweight. Between Malaysia and Thailand, boys in Malaysia were 2.68 points less likely to be underweight and 1.12 points more likely to be overweight, with similar results among girls but at higher magnitude, 4.23 and 2.54 points respectively. Overall, higher likelihoods of overweight and obesity were detected among adolescent males and females in Malaysia and Thailand compared to Indonesia, and higher likelihood of overweight adolescents of both genders in Malaysia compared to Thailand.

As our statistical tests favored segmented-sample estimation, we next examined marginal effects of exposure variables on BMI category probabilities according to gender in each country. Boys ≥16 years of age in Malaysia were less likely to be overweight (0.61 point) and obese (1.02 points) but more likely to be underweight (0.74 point) and of normal weight (0.89 point) compared to their younger cohorts (≤15 years of age) (Table 2). Similar outcomes were observed among boys in Thailand and Indonesia.

Hunger is associated with BMI status, albeit with mixed relationships among boys and girls and in individual country. Adolescents in Malaysia and girls in Indonesia with hunger issues displayed higher propensities of being underweight or of normal weight (Table 2). Analysis according to gender revealed a more notable role of hunger among girls compared to boys in Malaysia.

Augmenting role of FV consumption on body weight was noteworthy among adolescents in Malaysia and boys in Thailand, with those consuming adequate FV exhibiting lower underweight likelihood but higher overweight/obese likelihood (Table 2). Adolescents of both genders in Malaysia and Indonesia and adolescent males in Thailand who exercised regularly experienced lower overweight/obesity likelihoods compared to those who were not physically active. Smoking lowers overweight/obesity propensities of boys in Malaysia and Indonesia (Table 2).

Boys and girls in Malaysia facing solitude issues were 1.22 and 1.25 points respectively more likely to be overweight and 2.21 and 1.52 points respectively to be obese, respectively compared to others. Peer issues were significant only among overweight boys in Malaysia (Table 2). However, association between parental understanding and BMI status varied across countries and between genders. Boys with understanding parents/guardians were less likely to be underweight (0.74 point) or of normal weight (0.90 point) but more likely to be overweight (0.61 point) or obese (1.03 points) (Table 2). On the other hand, adolescent females in Thailand with parental empathy were less likely to be overweight or obese.

Table 1

Comparison among adolescents in three Southeast Asian countries of estimated probabilities (in percentage) of body weight categories according to gender

Country	Male		Female	
	Indonesia	Thailand	Indonesia	Thailand
	Probability of underweight			
Thailand	-3.55 (0.50)***		-2.79 (0.37)***	
Malaysia	-6.23 (0.78)***	-2.68 (0.54)***	-7.02 (0.64)***	-4.23 (0.44)***
	Probability of normal weight			
Thailand	-5.87 (1.13)***		-6.92 (1.26)***	
Malaysia	-4.08 (0.27)***	1.78 (1.00)*	-5.75 (0.28)***	1.17 (1.19)
	Probability of overweight			
Thailand	3.32 (0.50)***		4.23 (0.63)***	
Malaysia	4.44 (0.46)***	1.12 (0.38)***	6.77 (0.46)***	2.54 (0.47)***
	Probability of obese			
Thailand	6.10 (1.12)***		5.48 (1.00)***	
Malaysia	5.88 (0.54)***	-0.23 (0.84)	6.00 (0.36)***	0.52 (0.79)

*p-value <0.10; ***p-value <0.01

Number in parenthesis is bootstrapped standard error from 500 replications.

Table 2

Marginal effects on probabilities (in percentage) of body weight categories of adolescents in three Southeast Asian countries

	Malaysia							
	Male (n = 11,885)				Female (n = 12,240)			
Variable	Underweight	Normal weight	Overweight	Obese	Underweight	Normal weight	Overweight	Obese
Age ≥ 16[a]	0.74 (0.33)**	0.89 (0.38)**	-0.61 (0.27)**	-1.02 (0.44)**	-0.27 (0.23)	-0.54 (0.46)	0.37 (0.32)	0.44 (0.37)
Hungry	1.92 (0.79)**	1.91 (0.63)***	-1.48 (0.57)***	-2.34 (0.84)***	3.93 (0.84)***	4.56 (0.52)***	-4.29 (0.74)***	-4.20 (0.60)***
FVb	-1.82 (0.30)***	-2.46 (0.46)***	1.55 (0.27)***	2.73 (0.49)***	-1.32 (0.24)***	-2.93 (0.58)***	1.92 (0.36)***	2.32 (0.46)***
Physical	0.66 (0.38)*	0.77 (0.43)*	-0.54 (0.31)*	-0.90 (0.50)*	0.59 (0.39)	1.08 (0.66)	-0.78 (0.50)	-0.88 (0.55)
Smoker	1.45 (0.42)***	1.60 (0.42)***	-1.16 (0.33)***	-1.89 (0.51)***	0.91 (0.97)	1.57 (1.47)	-1.18 (1.17)	-1.30 (1.25)
Lonely	-1.41 (0.52)***	-2.02 (0.86)**	1.22 (0.47)***	2.21 (0.91)**	-0.85 (0.32)***	-1.91 (0.82)**	1.25 (0.50)**	1.52 (0.64)**
Peer	-0.59 (0.35)*	-0.74 (0.46)	0.49 (0.29)*	0.84 (0.51)	0.14 (0.30)	0.28 (0.58)	-0.19 (0.41)	-0.22 (0.47)
Parental	-0.74 (0.31)**	-0.90 (0.38)**	0.61 (0.26)**	1.03 (0.43)**	0.07 (0.22)	0.14 (0.45)	-0.10 (0.31)	-0.11 (0.36)

Table 2 (cont)

	Thailand							
	Male (n = 1,162)				Female (n = 1,305)			
Variable	Underweight	Normal weight	Overweight	Obese	Underweight	Normal weight	Overweight	Obese
Age ≥ 16	4.02 (2.80)	3.45 (1.42)**	-4.01 (2.26)*	-3.46 (1.73)**	-1.49 (1.78)	-3.49 (5.18)	2.74 (3.46)	2.23 (3.36)
Hungry	3.27 (2.79)	3.09 (1.74)*	-3.38 (2.38)	-2.99 (1.93)	-1.07 (2.02)	-2.22 (4.64)	1.84 (3.41)	1.45 (3.05)
FV	-3.00 (0.85)***	-5.03 (1.76)***	3.91 (1.23)***	4.12 (1.37)***	-0.46 (0.69)	-0.77 (1.20)	0.71 (1.09)	0.52 (0.79)
Physical	2.09 (1.09)*	2.54 (1.22)**	-2.38 (1.20)**	-2.26 (1.10)**	0.11 (1.13)	0.17 (1.74)	-0.16 (1.65)	-0.12 (1.19)
Smoker	0.80 (1.26)	1.06 (1.50)	-0.94 (1.40)	-0.92 (1.34)	-1.20 (2.08)	-2.60 (4.91)	2.12 (3.50)	1.68 (3.27)
Lonely	-1.95 (1.41)	-3.59 (3.28)	2.62 (2.06)	2.92 (2.60)	-0.16 (1.24)	-0.26 (2.15)	0.24 (1.91)	0.18 (1.45)
Peer	-1.56 (0.98)	-2.48 (1.73)	1.98 (1.29)	2.07 (1.41)	0.71 (1.03)	1.02 (1.31)	-1.01 (1.38)	-0.72 (0.94)
Parental	-0.23 (0.92)	-0.33 (1.33)	0.28 (1.13)	0.28 (1.12)	1.83 (0.64)***	3.50 (1.36)**	-3.03 (1.11)***	-2.30 (0.87)***

Table 2 (cont)

	Indonesia							
	Male (n = 961)				Female (n = 1,231)			
Variable	Underweight	Normal weight	Overweight	Obese	Underweight	Normal weight	Overweight	Obese
Age ≥ 16	12.70 (5.98)**	-2.54 (3.11)	-7.45 (2.48)***	-2.72 (0.81)***	-5.34 (2.68)**	-2.11 (2.94)	5.20 (3.52)	2.24 (1.88)
Hungry	0.41 (3.41)	0.08 (0.78)	-0.34 (2.62)	-0.16 (1.21)	7.83 (4.28)*	-2.75 (2.36)	-3.91 (1.68)**	-1.18 (0.50)**
FV	-1.72 (1.85)	-0.43 (0.59)	1.46 (1.61)	0.70 (0.79)	-0.77 (1.58)	0.03 (0.22)	0.54 (1.15)	0.19 (0.43)
Physical	3.90 (2.41)	0.35 (0.38)	-2.96 (1.69)*	-1.29 (0.70)*	5.08 (2.38)**	-1.16 (0.99)	-2.97 (1.21)**	-0.96 (0.38)**
Smoker	4.25 (2.27)*	0.40 (0.41)	-3.24 (1.59)**	-1.41 (0.67)**	-5.38 (6.06)	-2.18 (7.16)	5.28 (6.62)	2.28 (4.86)
Lonely	3.13 (4.38)	0.26 (0.98)	-2.36 (3.01)	-1.03 (1.28)	0.83 (2.30)	-0.08 (0.50)	-0.56 (1.47)	-0.19 (0.51)
Peer	-1.96 (1.85)	-0.51 (0.58)	1.67 (1.59)	0.80 (0.79)	-1.44 (1.80)	0.01 (0.34)	1.05 (1.38)	0.38 (0.54)
Parental	-1.24 (1.83)	-0.24 (0.36)	1.01 (1.47)	0.47 (0.68)	0.74 (1.42)	-0.04 (0.15)	-0.52 (1.01)	-0.19 (0.36)

[a]Years old; bFruit and vegetable
*p-value <0.10; **p-value <0.05; ***p-value < 0.01
Numbers in parenthesis are bootstrapped standard errors from 500 replications.

DISCUSSION

The study utilized large-scale national survey data sets to examine the factors associated with adolescent body weight categories in Malaysia, Thailand, and Indonesia (CDC 2007; CDC, 2008; CDC, 2012). We extended the analysis to include factors associated with all BMI categories using an ordered probit model. As empirical literature suggests sex differences in overweight and obesity (Tang *et al*, 2010; Su *et al*, 2014; Pengpid and Peltzer, 2016; Pham *et al*, 2020), a segmented-sample analysis by country and sex supported by formal statistical tests was employed, which has the advantage of uncovering any differential relationships of the aforementioned factors with BMI categories that would otherwise be masked by use of a pooled sample of both sexes for all countries, as with the study of Pengpid and Peltzer (2016) who investigated boys and girls separately but with pooled data from all countries. Pooling of data from multiple countries can be particularly problematic especially when data were collected at different points in time within 10 years.

The study identified six significant associations. Firstly, our results show an inverse association between body weight and age among adolescent males in Indonesia, Malaysia and Thailand, contrasting with prevailing perceptions of attributing positive trend between BMI status and age to fat accumulation and obesogenic environment in older adolescents (Duncan *et al*, 2011). The negative trend between body weight and age supports the arguments of pre-pubertal growth (Adair, 2008), parental control on dietary habits (Tang *et al*, 2010), and lack of physical activity due to pressures of study (Yen *et al*, 2010) among younger adolescents. Studies have also shown a higher likelihood of older adolescents in trying to lose weight (Yost *et al*, 2010). It is therefore suggested that health awareness programs on the importance of proper nutritional practices to maintain appropriate body weight of high school children be promoted in the three study countries. This includes monitoring younger adolescents in lower secondary (junior high) schools for overweight/obesity, and older adolescents in upper secondary (senior high) schools should be screened for underweight tendencies. Public health authorities should also be mindful that malnutrition may be occurring primarily among boys of all age ranges.

Secondly, results on hunger due to food shortage at home as a proxy for household income and food intake showed adolescents in Malaysia and adolescent females in Indonesia with hunger issues were less likely to be overweight/obese and more likely to be underweight than those without such issues. These outcomes contradict findings from developed countries where adolescent overweight/obesity is concentrated among poorer households (Klein-Platat *et al*, 2003; Boumtje *et al*, 2005). Instead, our findings echo those from less industrialized countries where prevalence of underweight is found among low income families, which often suffer from some form of food insecurity issues (Pérez-Cueto *et al*, 2005; Tang *et al*, 2010).

Because adolescent underweight could lead to a myriad of chronic diseases (Dong *et al*, 2018), policy measures to provide free and healthy foods should be considered to improve dietary intake of underprivileged adolescents facing food insecurity. Short term measures such as food subsidies, cash rebates, and food coupons should be considered to improve dietary intake and alleviate burden of low-income households from hunger issues (MacAuslan and Attah, 2015). Particular attention should be focused on girls from low-income families in Malaysia and Indonesia given their higher propensities to be underweight.

Thirdly, our findings show regular physical activity lowered overweight/obesity likelihoods and even raises normal weight propensities among adolescents in all three study countries, confirming the affirmative role of physical activity on body weight status among adolescents in Malaysia (Su *et al*, 2014) and among adults in USA (Yen, 2012) and Malaysia (Tan *et al*, 2016). It is interesting to note that while studies have found a positive association between human development index (HDI) (UNDP, 2019) and prevalence of obesity (Khazaei *et al*, 2020) and physical inactivity (Dumith *et al*, 2011), our findings show active physical activity participation was effective in reducing adolescence overweight/obesity prevalence even within countries with relatively high HDIs, such as Indonesia (0.707), Malaysia (0.804) and Thailand (0.765) (UNDP, 2019). Government authorities should, therefore, take notice from the present study to embark on programs promoting physical education among adolescents as such policies serve as early intervention "no-regrets" strategies generating net social benefits irrespective of a country's HDI (Tan *et al*, 2019).

Fourthly, findings that smoking status is associated with underweight likelihood of boys in Indonesia and Malaysia support studies on a negative association between smoking status and body weight categories within the adult population (Tan *et al*, 2013; Plurphanswat and Rodu, 2014). Cigarette smoking may suppress appetite or raise metabolism rates (Chou *et al*, 2004), leading to lower BMI and overweight/obese likelihood among smokers. Nevertheless, it should be emphasized that although smoking may be a possible alternative to achieve weight loss goals, it would be naïve to exploit such a notion in public awareness and educational programs. In fact, the list of negative health effects from smoking far outweigh health risks associated with elevated BMI (Tan *et al*, 2019). Health authorities in these countries should therefore be cognizant that while smoking related disorders (heart and respiratory diseases, and lung and related cancers) may pose as a health burden within its adolescence community, other health issues associated with adolescence underweight (delayed puberty, osteoporosis and scoliosis) should not be ruled out (Pasricha and Biggs, 2010).

Fifthly, psychosocial factors of loneliness and (lack of) peer support were important factors impacting BMI status only among Malaysian adolescents, where boys lacking peer support were 0.49 point more likely to be overweight compared to girls (although obesity likelihood was unaffected). These results support previous literature reporting adolescents facing loneliness and peer pressure often experience inappropriate coping behavior and eating disorders resulting in unhealthy body weight issues. These individuals often spend significant amounts of time partaking in sedentary activities and consuming junk food (Goosby *et al*, 2013), thus elevating their likelihoods of unhealthy BMI values. Awareness programs should be promulgated among Malaysian adolescents facing social exclusion and low self-esteem so as to avoid experiencing far-reaching health ramifications, including unhealthy body weight issues (Levine, 2012).

Lastly, despite the important role of parental understanding on adolescent well-being (Williams and Mummery, 2011), unhealthy BMI values may still arise from empathetic parenting styles. This is characterized by the elevated BMI values of adolescent males in Malaysia and underweight issues of girls in Thailand even with the support of understanding parents. This is not surprising as studies have shown that among the different parenting styles (*eg* authoritative, authoritarian, permissive, and neglectful), in addition to understanding an adolescent's problems and worries, an authoritative style will result in healthy adolescent weight outcome (Berge *et al*, 2010).

The study suffered from several limitations. Firstly, we note that adolescents in Malaysia and boys in Thailand with adequate FV can be associated with higher likelihoods of overweight/obesity. While healthy consumption is defined as consuming fruits two or more times and vegetables three or more times daily, "times per day" could be associated with meal frequency, resulting in elevated body weight; future surveys should consider alternative measures of FV intake. Secondly, omission of traditional wealth variables (eg income) was a shortcoming but such information was unavailable in the GSHS, and in the absence of these data, we used hunger status as a proxy for income and food intake (Pengpid and Peltzer, 2016). Additional variables (*eg* parents' education level, household size, urbanicity, and pubertal status) may offer further insights. Thirdly, there was absence of verification of weight-height and lifestyle factors in self-reported health surveys. Fourthly, as surveys were carried out in different years from 2003 to 2013, results should be interpreted with care given that changes in health care practices could have occurred in the Southeast Asian region within this period. Further studies might also consider potential endogeneity of physical activity in investigation of body weight (Tan *et al*, 2016). Fifthly, observations with missing information were omitted from the analysis, and randomness of missing information should be explored in further studies and imputation (Rubin, 1987) might also be considered to compensate for the missing data.

In conclusion, as negative health consequences of malnutrition in adolescents can carry into adulthood, strategies aimed at preventing unhealthy body mass indices should start at early childhood. Because socio-economic/demographic, dietary-lifestyle and psychosocial-familial factors are associated with adolescent BMI categories, albeit with different outcomes across countries and genders, interventions should support balanced diet, regular physical activity, healthy lifestyle, and psychosocial-familial development to ensure optimal adolescent BMI values. There is no "one size fits all" approach to address malnutrition among adolescents in Indonesia, Malaysia and Thailand. The most effective public health intervention to ameliorate adolescent body weight issues should consist of a portfolio of systemic and targeted interventions designed to address the health burdens of specific gender within various country settings.

ACKNOWLEDGEMENTS

The authors thank the Universiti Sains Malaysia for financial support (grant no. 1001/PSOSIAL/8016054).

REFERENCES

Adair LS. Child and adolescent obesity: epidemiology and developmental perspectives. *Physiol Behav* 2008; 94: 8-16.

Alberga AS, Sigal RJ, Goldfield G, Prud'homme D, Kenny GP. Overweight and obese teenagers: why is adolescence a critical period? *Pediatr Obes* 2012; 7: 261-73.

Berge JM, Wall M, Loth K, Neumark-Sztainer D. Parenting style as a predictor of adolescent weight and weight-related behaviors. *J Adolesc Health* 2010; 46: 331-8.

Boumtje PI, Huang CL, Lee JY, Lin BH. Dietary habits, demographics, and the development of overweight and obesity among children in the United States. *Food Policy* 2005; 30: 115-28.

Cameron AC, Trivedi PK. Microeconometrics: Methods and applications. Cambridge, UK: Cambridge University Press; 2005.

Centers for Disease Control and Prevention (CDC). Global School-based Student Health Survey (GSHS): Indonesia, 2007 [cited 2020 Nov 07]. Available from: URL: https://www.who.int/ncds/surveillance/gshs/GSHS_Country_Report_Indonesia_2007.pdf

Centers for Disease Control and Prevention (CDC). Global School-based Student Health Survey (GSHS): Malaysia, 2012 [cited 2020 Nov 07]. Available from: URL: https://www.cdc.gov/gshs/countries/westpacific/malaysia.htm

Centers for Disease Control and Prevention (CDC). Global School-based Student Health Survey (GSHS): Thailand, 2008 [cited 2020 Nov 07]. Available from: URL: https://www.who.int/ncds/surveillance/gshs/GSHS_FINAL_Report_Thailand_2008.pdf

Chou SY, Grossman M, Saffer H. An economic analysis of adult obesity: results from the Behavioral Risk Factor Surveillance System. *J Health Econ* 2004; 23: 565-87.

Daniels SR. The consequences of childhood overweight and obesity. *Future Child* 2006; 16: 47- 67.

de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Heal Organ* 2007; 85: 660-7.

Development Initiatives. Country Nutrition Profiles, 2020a [cited 2020 Nov 07]. Available from: URL: https://globalnutritionreport.org/resources/nutrition-profiles/

Development Initiatives. Global Nutrition Report, 2020b [cited 2020 Nov 07]. Available from: URL:https://globalnutritionreport.org/documents/566/2020_Global_Nutrition_Report_2hrssKo.pdf

Dong Y, Zou Z, Yang Z, *et al*. Prevalence of excess body weight and underweight among 26 Chinese ethnic minority children and adolescents in 2014: a cross-sectional observational study. *BMC Public Health* 2018; 18: 562.

Dumith SC, Hallal PC, Reis RS, Kohl HW 3rd. Worldwide prevalence of physical inactivity and its association with human development index in 76 countries. *Prev Med* 2011; 53: 24-8.

Duncan S, Duncan EK, Fernandes RA, *et al*. Modifiable risk factors for overweight and obesity in children and adolescents from Sao Paulo, Brazil. *BMC Public Health* 2011; 11: 585.

Goosby BJ, Bellatorre A, Walsemann KM, Cheadle JE. Adolescent loneliness and health in early adulthood. *Sociol Inq* 2013; 83: 505-36.

Greene WH. Econometric analysis. 8th ed. New York: Pearson; 2018.

Henningsen A, Toomet O. maxLik: A package for maximum likelihood estimation in R. *Comput Stat* 2011; 26: 443-58.

Khazaei Z, Sohrabivafa M, Darvishi I, Naemi H, Goodarzi E. Relation between obesity prevalence and the human development index and its components: an updated study on the Asian population. *J Public Health* 2020; 28: 323-9.

Klein-Platat C, Wagner A, Haan MC, Arveiler D, Schlienger JL, Simon C. Prevalence and sociodemographic determinants of overweight in young French adolescents. *Diabetes Metab Res Rev* 2003; 19: 153-8.

Levine MP. Loneliness and eating disorders. *J Psychol* 2012; 146: 243-57.

MacAuslan I, Attah R. Food stamps for food security: the impact of a targeted social assistance programme in Mongolia. *J Poverty Soc Justice* 2015; 23: 121-34.

Ministry of Education Malaysia (MOE Malaysia). Introduction to the secondary education in Malaysia, 2019 [cited 2020 Nov 07]. Available from: URL: https://www.moe.gov.my/en/education/

secondary-school/pengenalan-2 [in Malay]

Ministry of Education Thailand (MOE Thailand). Towards a learning society in Thailand: an introduction to education in Thailand, 2008 [cited 2020 Nov 07]. Available from: URL: https://www.bic.moe.go.th/images/stories/book/ed-eng-series/intro-ed08.pdf

Naidu BM, Mahmud SZ, Ambak R, *et al*. Overweight among primary school-age children in Malaysia. *Asia Pac J Clin Nutr* 2013; 22: 408-15.

Nguyen PVN, Hong TK, Hoang T, Nguyen DT, Robert AR. High prevalence of overweight among adolescents in Ho Chi Minh City, Vietnam. *BMC Public Health* 2013; 13: 141.

Pasricha S-R, Biggs BA. Undernutrition among children in South and South-East Asia. *J Paediatr Child Health* 2010; 46: 497-503.

Pengpid S, Peltzer K. Overweight, obesity and associated factors among 13-15 years old students in the Association of Southeast Asian Nations Member Countries, 2007-2014. *Southeast Asian J Trop Med Public Health* 2016; 47: 250-62.

Pérez-Cueto A, Almanza M, Kolsteren PW. Female gender and wealth are associated to overweight among adolescents in La Paz, Bolivia. *Eur J Clin Nutr* 2005; 59: 82-7.

Pham NK, Sepehri A, Le TM, Tran VT. Correlates of body mass index among primary school children in Ho Chi Minh City, Vietnam. *Public Health* 2020; 181: 65-72.

Philipson TJ, Posner RA. The long-run growth in obesity as a function of technological change. *Perspect Biol Med* 2003; 46 (3 Suppl): S87-107.

Plurphanswat N, Rodu B. The association of smoking and demographic characteristics on body mass index and obesity among adults in the U.S., 1999-2012. *BMC Obes* 2014; 1: 18.

Rubin DB. Multiple imputation for nonresponse in surveys. New York: John Wiley & Sons Inc; 1987.

Su TT, Sim PY, Nahar AM, *et al*. Association between self-reported physical activity and indicators of body composition in Malaysian adolescents. *Prev Med* 2014; 67: 100-5.

Tan AKG, Wang Y, Yen ST, Feisul MI. Physical activity and bodyweight among adults in Malaysia. *Appl Econ Perspect Policy* 2016; 38: 318-33.

Tan AKG, Yen ST, Fang X, Chiang FS. Body weight and physical activity of adolescents in Malaysia. *Int Health* 2019; 11: 150-8.

Tan AKG, Yen ST, Feisul MI. The association between smoking and body mass index: Results from a national sample of Malaysian adults. *J Public Health* 2013; 21: 403-12.

Tang KH, Nguyen HH, Dibley MJ, Sibbritt DW, Phan NT, Tran TM. Factors associated with adolescent overweight/obesity in Ho Chi Minh City. *Int J Pediatr Obes* 2010; 5: 396- 403.

United Nations Development Programme (UNDP). Human development report 2019. Beyond income, beyond averages, beyond today: inequalities in human development in the 21st century, 2019 [cited 2020 Nov 7]. Available from: URL: http://hdr.undp.org/sites/default/files/hdr2019.pdf

United Nations Educational Scientific and Cultural Organization (UNESCO). World data on education, 7th ed, 2010-11, 2011 [cited 2020 Nov 7]. Available from: URL: http://www.ibe.unesco.org/fileadmin/user_upload/Publications/WDE/2010/pdf-versions/Indonesia.pdf

United Nations Educational Scientific and Cultural Organization Institute for Statistics (UIS). UIS.STAT, 2014 [cited 2020 Nov 07]. Available from: URL: http://data.uis.unesco.org/Index.aspx

Williams SL, Mummery WK. Links between adolescent physical activity, body mass index, and adolescent and parent characteristics. *Health Educ Behav* 2011; 38: 510-20.

World Health Organization (WHO). Global School-based Student Health Survey (GSHS) purpose and methodology, 2019 [cited 2020 Nov 07]. Available from: URL: https://www.who.int/ncds/surveillance/gshs/methodology/en/

World Health Organization. Growth reference data for 5-19 years, 2007 [cited 2020 Nov 07]. Available from: URL: https://www.who.int/tools/growth-reference-data-for-5to19-years

World Health Organization (WHO) and Centers for Disease Control and Prevention (CDC). Global School-based Student Health Survey: 2013 GSHS Data User's Guide, 2013 [cited 2020 Nov 07]. Available from: URL: https://www.cdc.gov/gshs/pdf/gshs-data-users-guide.pdf

Yen CF, Hsiao RC, Yen JY, *et al*. Body weight statuses and their sociodemographic correlates among adolescents in southern Taiwan: results using two sets of cutoff references. *J Adolesc Health* 2010; 46: 62-9.

Yen ST. Gender differences, physical activity and body weight. *Appl Econ* 2012; 44: 3921-34.

Yost J, Krainovich-Miller B, Budin W, Norman R. Assessing weight perception accuracy to promote weight loss among U.S. female adolescents: a secondary analysis. *BMC Public Health* 2010; 10: 465.

Zhu X, Haegele JA, Tang Y, Wu X. Prevalence and demographic correlates of overweight, physical activity, and screen time among school-aged children in urban China: the Shanghai study. *Asia Pac J Public Health* 2018; 30: 118-27.