The double burden of malnutrition in Vietnamese school-aged children and adolescents: a rapid shift over a decade in Ho Chi Minh City

Thi My Thien Mai1,2 · Ngoc Oanh Pham1 · Thi Minh Hanh Tran3 · Peter Baker4 · Danielle Gallegos2 · Thi Ngoc Diep Do2 · Jolieke C. van der Pols2 · Susan J. Jordan4,5

ARTICLE

Epidemiology

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Abstract

Background/objectives Vietnam is undergoing a nutrition transition, which is leading to marked shifts in body size at the population level, but up-to-date data are lacking. We therefore quantified the prevalence of undernutrition (stunting and thinness) and overnutrition (overweight, obesity, and abdominal obesity) in school-aged children in Ho Chi Minh City (HCMc), Vietnam, and compared this with previous estimates.

Subjects/methods A cross-sectional survey of 10,949 children (6–18 years old) from 30 schools in HCMc, Vietnam in 2014–2015 was used to ascertain the nutritional status of children and adolescents. Different international classification systems (WHO, IOTF, IOTF for Asian children) were used to assess the prevalence of under and overnutrition. Comparisons were made with previous surveys in HCMc.

Results Regardless of definitions used, the prevalence of overnutrition was high, particularly in primary school children (20–30% were overweight, 20–30% were obese, and 50% had abdominal obesity), in boys, and urban children. Undernutrition was more prevalent in high-school children (8% were stunted, and 6–18% were thin, versus 2 and 2–9% in primary children, respectively), and in rural areas. Comparisons with previous surveys indicated substantial increases in overnutrition and decreased in undernutrition since 2009 in all age groups.

Conclusions Overnutrition is increasingly common in school-aged children and adolescents in HCMc, while over and undernutrition continue to coexist. These findings highlight an urgent need for greater efforts to control malnutrition in children in HCMc.

Introduction

Both under and overnutrition among children and adolescents have negative short-term impacts on physical and mental health, as well as potential adverse consequences in adulthood, including increased risk of noncommunicable diseases [1, 2]. Recently, rapid socioeconomic development in many low-to-middle income countries has led to shifts in lifestyles toward higher consumption of energy-dense, nutrient-poor foods, and adoption of increasingly sedentary lifestyles [3]. These shifts, known as the “nutrition transition”, are changing the profile of health outcomes in these countries, particularly by increasing the prevalence of overweight, obesity [4], and noncommunicable diseases [3].

Vietnam is a lower-middle-income country, which is undergoing nutrition transition [5]. However, because the target population in the National Survey on Nutrition in Vietnam was children under 5 years old and women of
reproductive age [6], there is no national-level data about the nutritional status of school-aged children. One study of the nutritional status of school-aged children in Vietnam from the South East Asian Nutrition Survey study indicated the coexistence of under and overnutrition in Vietnamese children, but it was limited to children from 5 to 12 years old [7]. Also, to our knowledge, no study has captured the change in nutritional status in school-aged children across the whole age range. Thus, additional data on the nutritional status of school-aged children in Vietnam are needed.

Ho Chi Minh City (HCMc) is the leading city in Vietnam in terms of total population, density of population, population growth, and foreign direct investment projects [8]. Furthermore, the city is home to nearly nine million citizens, accounting for ~10% of the total population in Vietnam and a third of the urban population [9, 10]. Thus, HCMc provides the best opportunity to study the advanced nutrition transition underway in urban Vietnam. Previous studies indicated an increase in overweight and obesity and a decrease in underweight and stunting in school-aged children in HCMc [11]. However, no data showing how the nutritional status of school-aged children in HCMc has changed since 2009. In addition, while evidence indicates that for Asian adults [12] lower body mass index (BMI) cut points are required to define overweight, obesity, and cardio-metabolic risk [13], there is no consensus on the best indicator to use to ascertain overweight and obesity for children in this region. Thus, we have used several different international criteria to assess the prevalence of stunting, thinness, overweight, obesity, and abdominal obesity in school-aged children in HCMc from the survey in 2014–2015 to comprehensively evaluate the change in nutritional status in this population.

Subjects and methods

Study design and study population

The current study used data from the Survey of Nutritional Status, in which between October 2014 and January 2015, data were collected from school-aged children in HCMC, Vietnam, using a two-stage cluster sampling design with stratification by school level, location, and sex. In Vietnam, most primary school children are aged 6–11 years old; those in secondary school are aged 11–15 years, and those in high school are aged 15–18 years old. The sample size was calculated for each school level based on the prevalence of thinness, overweight and obesity, stunting, and means of height-for-age in children from 6 to 18 years old from a previous survey, and the highest value of the sample size was used for data collection. As a result, this survey aimed to include 6042 primary school children, 2812 secondary school children, and 2046 high-school children to estimate means of height from the equation \( n = Z_{(1−α/2)}^2 \delta^2 \) (Z = 1.96, \( \delta \) standard deviation of height-for-age as observed in the 2009 survey, d: 0.5 cm) and design effect = 2. The number of schools for each school level was calculated from the sample size needed for nutritional status assessments, the number of grades, and the average number of students in each school level. Also, around 80% of school-aged children in HCMC live in urban districts. Thus, 30 schools (11 primary—9 urban and 2 rural; 10 secondary—8 urban and 2 rural; and 9 high schools—8 urban and 1 rural) were selected using probability proportion to size sampling according to the number of students in each school and the total number of students in each stratum. Then, students were chosen from the list of students in each school, using systematic random sampling from the list of students stratified by sex and ordered by class. In total, 500 students were selected from each primary school, 300 from each secondary school, and 250 from each high school. The selected children and their parents were sent information sheets and consent forms to complete before data collection. Children were excluded from the study if they had disorders that could affect growth, such as growth hormone dysfunction or severe scoliosis. To facilitate comparisons with previous surveys (2002/2004 and 2009), only children aged 6–18 years were included in the analysis. Therefore, after excluding 122 participants who were under 6, and 1 participant with extreme BMI (>40), 10,494 students were included in the analysis.

Anthropometric measurements and definitions

Trained health officers from the HCMC Nutrition Center took all anthropometric measurements (once for each child) using the standard protocol [14]. A team leader checked all anthropometric values by after each measurement. A second measurement was taken if the child had an extreme anthropometric value based on WHO Growth Standard for children 5–19 years old. The average value of the two measurements or a third value (if the difference was >2 cm) was used in this case. Weight scales and height boards were standardized before the data collection day. Weight was measured to the nearest 0.1 kg using electronic scales (TANITA–HD313). Height and waist circumference were measured to the nearest 0.1 cm; height using wooden height boards and waist circumference using nonelastic tape measures against the skin at the midpoint between the lower costal border and the top of the iliocrest at the end of expiration. The circumference at the umbilicus was used if the anatomical landmarks could not be identified. Children wore light clothes and no shoes during measurement. BMI was defined as weight in kg divided by height in meters squared (m²).
Undernutrition

Stunting was defined as a height-for-age Z-score $<-2$ SD (standard deviation) using the WHO growth standard for children and adolescents [15]. Thinness was defined by BMI-for-age Z-score $<-2$ SD (WHO) [15] and by age and sex-specific BMI cut points that correspond to BMI values at 18 years old of $<18.5$ kg/m$^2$ (International Obesity Task Force (IOTF)) [16].

Overnutrition

According to WHO, in children aged 5–19 years old, overweight is defined by BMI-for-age Z-score $>1$ SD (WHO) [15]. However, to assess the prevalence of overweight without obesity, the BMI-for-age Z-score $>1$ SD and $\leq +2$ SD was used to define children with overweight. In addition, the age and sex-specific BMI cut points that correspond to BMI values at 18 years old of $\geq 25$ kg/m$^2$ to $<30$ kg/m$^2$ (IOTF) [16] and of $\geq 23$ kg/m$^2$ to $<27$ kg/m$^2$ (IOTF for Asian children) were also used to define overweight [17]. Obesity was defined by BMI-for-age Z-score $>2$ SD (WHO) [15], by age and sex-specific BMI cut points that correspond to BMI values at 18 years old of $\geq 30$ kg/m$^2$ (IOTF) [16] and of $\geq 27$ kg/m$^2$ (IOTF for Asian children) [17]. Abdominal obesity was defined as waist circumference $\geq 90$th percentile by sex and age—using a reference population of Hong Kong Chinese children [18], as well as a reference population of children from the United States (US) [19] for comparison.

Analysis

All analyses were conducted using Stata version 12 (College Station, TX 77845, USA). Summary prevalence estimates of all nutritional status indicators were weighted, using the svy prefix in Stata. The weight for each school was calculated based on two-stages sampling with the probability of selecting children from each school. The data were analyzed by school level (primary, secondary, and high school) as a proxy indicator for the age group. Prevalence estimates were weighted for the sampling fractions and presented with 95% confidence intervals. A Pearson’s chi-squared test was used to test differences in proportions between boys and girls, and children from urban versus rural districts. A $p$ value $<0.05$ was considered statistically significant.

This study used the dataset from the Survey of Nutritional Status in School-aged children in HCMc (Number of approval: 404/QĐ-TTDD dated 09/09/2014). These analyses were approved by the School of Public Health Human Research Ethics Committee, The University of Queensland (TM20122016).

Results

Overall, of 10,949 subjects, 50.6% were boys, and 80.6% were from urban areas. The distribution by school level was 51.2% primary, 31.9% secondary, and 16.9% high school. Mean age (SD) of children in primary, secondary and high school was 7.9 (±1.4), 12.3 (±1.2), and 15.9 (±0.9) years old (Table 1).

Prevalence estimates of under and overnutrition are presented in Table 2. Overnutrition was more prevalent (20–50%) than undernutrition (2–20%) in school-aged children in HCMc. The prevalence of overweight and obesity was the highest in primary school children (WHO definition: 24.3 and 26.9%, respectively), while the prevalence of stunting and thinness was the highest in high-school children (WHO definition: 7.9 and 6.0%, respectively). We also found that the prevalence of overweight was higher than obesity in older children (those in secondary and high school), whereas the prevalence of overweight and obesity was similar in primary school children. The estimates of obesity prevalence were lower using international definitions than using the Asian-specific definition, particularly for children in high school (5.2%)

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**Table 1** Characteristics of participating school-aged children in Ho Chi Minh City during the school year 2014–2015.

| Characteristics | Primary school | Secondary school | High school |
|----------------|---------------|-----------------|-------------|
|                | N or mean     | % or SD         | N or mean   | % or SD         | N or mean | % or SD |
| Age in years (range) | 7.9 (6–13) | 1.4 | 12.3 (10–17) | 1.2 | 15.9 (14–18) | 0.9 |       |
| Sex            |               |                 |             |                 |           |       |
| Male           | 2986          | 50.5            | 1496        | 50.0            | 1059      | 51.8  |
| Female         | 2926          | 49.5            | 1497        | 50.0            | 985       | 48.2  |
| Location       |               |                 |             |                 |           |       |
| Urban          | 4837          | 79.3            | 2396        | 80.5            | 1810      | 85.0  |
| Rural          | 1075          | 20.7            | 597         | 19.5            | 234       | 15.0  |
| Total (row%)   | 5912          | 51.2            | 2993        | 31.9            | 2044      | 16.9  |

*Weighted prevalence and mean.
Table 2 Nutritional status of school-aged children in Ho Chi Minh City by school level using different definitions of over and undernutrition.

| Nutritional statusa | Primary school (n = 5912) | Secondary school (n = 2993) | High school (n = 2044) |
|---------------------|---------------------------|-----------------------------|------------------------|
|                     | n  | %  | 95% CI | n  | %  | 95% CI | n  | %  | 95% CI |
| Stuntingb           | 134| 2.4| 1.1, 3.6 | 115| 3.8| 2.1, 5.6 | 160| 7.9| 6.3, 9.5 |
| Thinness            |    |    |         |    |    |         |    |    |         |
| IOTFc               | 535| 9.3| 6.4, 12.2 | 372| 12.4| 8.0, 16.7| 365| 18.3| 13.5, 23.2|
| WHOd                | 125| 2.2| 1.4, 2.9 | 140| 4.6| 2.3, 7.0 | 120| 6.0| 3.8, 8.3 |
| Overweight          |    |    |         |    |    |         |    |    |         |
| IOTFc               | 1642| 27.5| 23.9, 31.1 | 688| 23.0| 19.0, 27.1| 282| 13.6| 10.7, 16.5 |
| IOTF_Asiae          | 1540| 25.8| 23.6, 28.1 | 838| 28.0| 24.4, 31.7| 422| 20.5| 17.4, 23.6 |
| WHOd                | 1448| 24.3| 21.8, 26.8 | 703| 23.5| 20.0, 27.1| 290| 14.0| 11.3, 16.7 |
| Obesity             |    |    |         |    |    |         |    |    |         |
| IOTFc               | 959 | 16.0| 13.4, 18.7 | 178| 5.9| 4.7, 7.3 | 83 | 4.0| 3.1, 4.9 |
| IOTF_Asiae          | 1857| 31.0| 26.2, 35.8 | 505| 16.9| 13.8, 20.0| 210| 10.1| 7.6, 12.6 |
| WHOd                | 1610| 26.9| 22.7, 31.1 | 360| 12.1| 9.8, 14.2| 109| 5.2| 4.1, 6.4 |
| Abdominal obesity   |    |    |         |    |    |         |    |    |         |
| Chinese referencef | 2738| 45.7| 39.6, 51.9 | 1264| 42.3| 36.4, 48.2| 692| 33.7| 29.5, 37.9 |
| US referenceg      | 1362| 22.7| 18.7, 26.7 | 354| 11.9| 9.7, 14.0| 184| 8.9| 7.4, 10.4 |

aEstimates are weighted: % (weighted prevalence and 95% confidence interval).
bWHO: stunting (height-for-age Z-score < −2 SD).
cIOTF: specific BMI-for-age and sex cut points corresponded to BMI at 18 years old: thinness (BMI < 18.5 kg/m²), overweight (BMI ≥ 25 and < 30 kg/m²), and obesity (BMI ≥ 30 kg/m²).
dWHO: thinness (BMI-for-age Z-score < −2 SD), overweight (BMI-for-age Z-score > +1 SD and ≤ +2 SD), obesity (BMI-for-age Z-score > +2 SD).
eIOTF_Asia: specific BMI-for-age and sex cut points corresponded to BMI at 18 years old: overweight (BMI ≥ 23 and <27 kg/m²), obesity (BMI ≥ 27 kg/m²).
fSpecific waist circumference for age and sex ≥90th percentile of waist circumference reference from Chinese Hong Kong children (6–18 years old).
gSpecific waist circumference for age and sex ≥90th percentile of waist circumference reference from US children (2–18 years old).

(WHO) and 4.0% (IOTF) versus 10.1% (IOTF for Asian) or for abdominal obesity 7.4% (US reference) versus 33.7% (Chinese reference).

The characteristics of children with under and overnutrition are presented in Table 3. The prevalence of stunting was significantly higher in children in primary and secondary school from rural compared with urban districts (p < 0.001), and girls in high school compared with boys in high school (p < 0.001). Similarly, the prevalence of thinness was higher in children from rural compared with urban districts (p < 0.001 and p < 0.01), but lower in girls in high school compared with boys in high school (p < 0.001). Overweight and obesity (general and abdominal) in primary and secondary students were significantly more prevalent in urban versus rural districts (p < 0.001). The prevalence of overweight and obesity was generally higher in boys than in girls, whereas the prevalence of abdominal obesity was higher in girls than in boys in primary and secondary school (p < 0.001 and p < 0.05).

The distribution of BMI-for-age Z-scores and height-for-age Z-scores relative to the WHO standard is presented in Fig. 1. Overall, BMI-for-age Z-score and height-for-age Z-score in children from the survey in 2014–2015 appeared to decrease with age. The mean of BMI-for-age in this survey started lower than the average BMI of WHO population at 14 years old, while the mean of height-for-age started lower the average height of WHO population at the earlier age (10-year-old).

Figure 2 shows the comparison of findings from the current 2014 survey with previous surveys carried out in similar representative samples of school-aged children in HCMCs. The prevalence of overweight and obesity was two to four times higher, whereas the prevalence of stunting and thinness was two to three times lower in the present survey compared with the 2002/2004 survey. The prevalence estimates for children in the same birth cohort remained quite consistent across over 12 years (marked by bold numbers in Fig. 2).
The nutritional status of school-aged children and adolescents in HCMC in 2014/2015 was characterized by a very high prevalence of overnutrition, regardless of defining criteria. The prevalence of overnutrition increased notably since the 2009 survey. There was also substantial coexistence of undernutrition, particularly in high school students. Overnutrition was more prevalent in boys and urban children, whereas undernutrition was more common in rural areas, in high school boys (thinness), and in high school girls (stunting).

Our prevalence estimates for overweight and obesity are two to three times higher than those from other studies from urban areas in low and middle countries in South East Asian region such as Thailand [20] and Indonesia [21] in 2011–2014, whereas the prevalence of thinness (WHO) and stunting among children in our study was two to five times lower than children in urban areas these countries [20, 21].

The prevalence of abdominal obesity in our study was around three times higher than in a study of suburban
Malaysian school children that also used the Asian 90th percentile cut point [22]. Thus, overweight and obesity are a severe problem in school-aged children in HCMc.

The utility of different international criteria to evaluate the prevalence of thinness, overweight, obesity, and abdominal obesity indicated that the size of problem depends heavily on the criteria used. The prevalence of overweight, obesity, and abdominal obesity was higher with the tailored ethnic criteria (IOTF criteria for Asians and Asian waist circumference references) than with the international criteria (WHO, US’s waist circumference reference). Although the validity of international indicators has not been examined in Vietnamese children, other studies in Asian children have shown that the use of specific ethnicity criteria would provide more reliable data on the nutritional status of children [23] as children in Asia probably have a slower BMI increase from adolescence to adulthood than other ethnicities [24]. Thus, it is necessary to further develop and validate specific ethnic criteria to accurately estimate the prevalence of overweight and obesity in children.

The prevalence of overweight and obesity was higher in primary school children, and this pattern was the same in three surveys (Fig. 2). The data from a longitudinal study in China over a 20 year period [25] also indicated that the prevalence of overweight and obesity in the younger age group (6–12 years old) was higher and increased faster compared with the older age group (13–17 years old). Although the data are not available to explain this disparity, this trend may reflect substantial changes in younger children’s behaviors such as food consumption and physical activity and changes in environments and opportunities for children to practice proper nutrition and physical activities. Thus, the identification and monitoring of contributing factors to childhood overweight and obesity are necessary to control this problem.

In addition to the high prevalence of overweight and obesity in primary school children, stunting also remained common in high school children, particularly in girls. From 10 years of age, children in HCMc did not reach the average height of the WHO reference population. We do not have data on puberty timing in the survey participants, but our results (Supplement Figure) show that children’s average height still increases continuously from 10 to 14 years old, and then starts to plateau from 14 years of age onwards. It is suggested that apart from the first 1000 days period, puberty may also be a crucial window for interventions to help children catch up their height growth [26]. Thus, appropriate interventions for school-aged children before and during puberty could improve children’s height and may help to reduce the impact of stunting in developing countries. However, it should be noted that these interventions should consider guidelines for double-duty action to avoid unexpected consequences of the intervention, for example, increase body weight in the intervention to reduce stunting [27].

The higher prevalence of overweight and obesity in boys is consistent with findings in children in Vietnam [28] and other Southeast Asian studies [7, 20]. This might be explained by Vietnamese cultural perceptions that girls should be thin, and boys should be big and muscular [29], which may lead to differences in diet and physical activity between boys and girls when they develop an awareness of body image. However, we did not have the data required to

![Fig. 2 The nutritional status of school-aged children and adolescents across three surveys in Ho Chi Minh City using WHO definitions. The bold numbers in the graph the nutritional status indicate approximately the same birth cohort, i.e., 6–7-year-old children in primary school in 2002 would be 13–14 years old in 2009 and therefore in secondary school in 2009, and 18–19 years old in 2014 and therefore in high school in 2014 if they continued to study. The primary school includes five grades, secondary school includes four grades, and high school consists of three grades. Thus, after 5 years (the interval between surveys), most children have moved to a higher school level. For the 2002/2004 survey, data from primary and secondary schools were collected in 2002, data from high school were collected in 2004.](image-url)
ascertain the drivers of this difference. Future research should address this shortcoming.

Urban and rural disparities have been found previously in research on nutritional status in Vietnamese children [28]. These disparities are probably attributable to differences in food quality, physical activity environment, food advertisements, and socioeconomic status [2]. In HCMc, one explanation could be the urban–rural income gap. In 2004, this gap was ~US$25 per capita per month, but the gap doubled by 2009 and tripled by 2014 [30]. Food prices also increased significantly during this period disproportionately affecting rural dwellers and urban poor [31]. These groups may have more difficulty in accessing quality foods, while those with higher income are likely to have access to a variety of foods. Although the income disparity and the increase in food prices could partly explain the rural–urban differences we have observed, additional research is needed to definitively determine the factors underlying this gap.

The substantial increase in overweight and obesity over the examined 12-year period suggests that children in HCMc are moving quickly through the nutrition transition and Vietnam is unlikely to meet the WHO target “control the increase in obesity in children by 2025.” Data have shown that from 1999 to 2012 Vietnam had amongst the highest increases in processed food and sugar-sweetened beverage consumption [32]. Such foods are more accessible in urban areas where there are more supermarkets and greater affordability for those with higher incomes [32, 33]. Children from urban areas also eat out of home more frequently, and much of the energy consumed in these environments is attributable to fat and sugar [34]. Also, due to the high and increasing population density in HCMc, there is less space for physical activity. The proportion of fifth graders in HCMc who met physical activity recommendations is low (18%) [35]. Thus, future assessments of nutritional status in school-aged children should be undertaken alongside the evaluation of contributing factors to develop intervention programs to control factors that contribute to the development of childhood obesity in urban Vietnam.

Strengths of this study include the large sample size, the representative study population, and the use of standardized measurements of anthropometric indicators. However, there were also several limitations. Enrollment in school is high in urban areas in Vietnamese children aged 7–15 years old (95.6%), but this figure was lower for those 16–23 years old (44.9%) [36]. Thus, a smaller proportion of HCMc children attending high school compared with primary and secondary schools indicates that our prevalence estimates for older children may not be entirely representative of all in this age group. Also, the relatively smaller sample of rural children, as well as the selection of only one high school from rural areas may have influenced the representativeness for rural students. However, it was suggested that irrespective of having a proportion of clusters with one observation, the estimations with large number of subjects in that cluster (n = 500) would be more accurate compared with the estimation with a small number of subjects in the cluster (n = 50) [37]. Although there was only one high school in the rural district, 234 students from this high school were included in the survey suggesting our estimates are likely to be reasonably representative. Finally, the survey did not obtain information on participants’ socioeconomic or pubertal status, key factors influencing nutrition status [2]. Thus, variation in children’s nutritional status according to socioeconomic status and the influence of puberty could not be assessed in the evaluation of children’s physical growth.

Our study reflects the nutritional status of school-aged children in HCMc, the largest city in Vietnam. Thus, the results may not generalize to other parts of the country. Results from other studies in urban areas of Vietnam such as primary children in Hai Phong city in 2012 (20%) [38] and in urban areas in Vietnam from the South East Asian Nutrition Survey in 2011 (30%) [7] indicated a lower prevalence of overweight and obesity compared with our estimates in primary school children. Nevertheless, the results from the current and past surveys are likely indicative of changes in anthropometric characteristics over time that will probably also increasingly affect the rest of the country. Thus, unless action is taken to reverse this trend, Vietnam as a whole faces an alarming increase in the prevalence of overnutrition in children.

All international reference populations for children and adolescents have shortcomings for nutritional assessment, particularly for evaluating obesity [39]. Lower BMI cut points may be needed to identify body fatness, and chronic disease risks among Asians [12, 13, 40]. However, a consensus on optimal indicators for these conditions is not well established for children in Southeast Asia. Thus, we used the IOTF unofficial BMI cut points for Asian children, and a Chinese reference population for children’s waist circumference, which is currently the best available criteria for evaluating the nutritional status of HCMc children. The higher prevalence of overnutrition using ethnicity-specific compared with international definitions suggests that the prevalence of overnutrition in Asian children has been underestimated in studies using international definitions. Notwithstanding differences in estimates with different criteria, all estimates from our study indicate that the prevalence of overnutrition in children in HCMc is very high.

Overall, this study demonstrates a high prevalence of overnutrition, particularly in primary school children, and the coexistence of undernutrition in high school children, in HCMc, Vietnam. Future research should focus on establishing the etiology of childhood obesity and identifying effective interventions to control this epidemic. Stunting and thinness are being addressed as indicated by the lower
rates of undernutrition in primary school children, but actions should also focus on optimizing growth in secondary and high school children to maximize the outcomes for the next generation of children. Given the possible underestimation of overweight and obesity in children using standard international criteria, future research should focus on establishing optimal definitions for overweight and obesity in Asian children.

**Code availability**

The analysis code for main results in Tables 2 and 3 was presented in the Supplementary documents.

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**Author contributions** MTMT analyzed data, interpreted results, generated tables of results, and wrote the first draft of the paper, PNO collected data, DTND designed the survey and collected data, DTND and GD interpreted results. MTMT, JSI, vdPJC and BP contributed to the analysis plan. All authors contributed to the interpretation of results and writing of the paper.

**Compliance with ethical standards**

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Ethics Committee of Ho Chi Minh City Nutrition Center. Written informed consents were obtained from all subjects. The secondary analysis was approved by the School of Public Health Ethics Committee, The University of Queensland (TM20122016).

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