British Journal of Nutrition (2020), 123, 1043–1055
doi:10.1017/S0007114520000203

British Journal of Nutrition

The utility of anthopometric indicators to identify cardiovascular risk factors in Vietnamese children

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(Submitted 7 June 2019 – Final revision received 21 December 2019 – Accepted 6 January 2020 – First published online 22 January 2020)

Abstract

BMI, waist circumference (WC) and waist-to-height ratio (WHtR) can be used for discriminating children and adolescents at risk of CVD. However, consensus on how to use these anthropometric indicators is lacking for children and adolescents in Asia. Discrete criteria are promoted internationally, but continuous variables could be used. Data from a survey of 10 949 Vietnamese school-aged children (6–18 years) were used to evaluate the performance of anthropometric indicators to identify elevated blood pressure (BP), dyslipidaemia or at least three cardiovascular risk factors (CVRF). Weight, height, WC and BP were measured using standardised protocols; 1009 participants who had blood lipids were analysed. AUC was used to assess the performance, and the Youden index to identify optimal cut-offs. The prevalence of elevated BP, dyslipidaemia and CVRF was 26·5, 49·3 and 12·2 %, respectively. BMI, WC and WHtR had low capacity to identify elevated BP and dyslipidaemia (AUC range 0·61–0·66) but moderate capacity to identify CVRF (0·72–0·74). Optimal BMIZ cut-offs to identify elevated BP, dyslipidaemia and CVRF were 0·40, 1·01 and 1·1 SD; for WC *z*-score, they were 0·06, 0·49 and 0·62 SD; for WHtR, optimal cut-offs were close to 0·5. A BMIZ cut-off of 1·0 SD and a WHtR cut-off of 0·5 would, therefore, be useful criteria to identify Vietnamese children who are likely to have CVRF. However, further validation of these criteria in other studies of Asian children and adolescents is needed.

Key words: Anthropometric indicators: Waist-to-height ratio: Weight status: Optimal cut-offs: Children and adolescents: Cardiovascular risk factors: Vietnam

Childhood obesity is associated with increased risk of obesity in adulthood and with increased cardiovascular risk factors (CVRF) in children[1,2] and adults[3]. The prevalence of obesity in children has increased rapidly, particularly in low- and middle-income countries[4]. In Ho Chi Minh City (HCMC), the largest city in Vietnam, a lower to middle-income country, the prevalence of overweight and obesity in schoolchildren (6–18 years old) increased from 12 % in 2002, to 22 % in 2009 and to 41 % in 2014[5,6]. CVD are a leading cause of death for adults in Vietnam[7]. Thus, early detection of childhood obesity and concomitant CVRF is needed to inform public health strategies and prevent increases in the burden of CVD in Vietnam and similar countries in the South-East Asian region.

Anthropometric indicators such as BMI, waist circumference (WC) and waist-to-height ratio (WHtR) can be used as an accurate and cost-effective method for discriminating variations in overweight, obesity and CVD risk in children and adolescents[8]. WC is commonly used as an abdominal obesity indicator, which has shown additional benefits to BMI for prediction of cardiometabolic risk factors in children[9]. WHtR is a simple indicator that only requires a tape measure for assessment and is less influenced by age, sex and ethnicity than BMI. It has previously been found to be useful but not better than WC and BMI for identification of CVRF in an international sample of children[10].

Binary cut-offs rather than continuous variables have been promoted most commonly for CVD risk prediction[11,12]. However, the most optimal cut-offs to be used for this purpose, in particular in children and adolescents of different ethnicities, are not well established[13]. A cut-off of 0·5 for WHtR is generally recommended for identification of children at increased risk of CVD[14], whereas WHtR cut-offs of 0·44 (boys) and 0·43 (girls) are recommended for Korean children[15]. It is unclear which

Abbreviations: BMIZ, BMI *z*-score; BP, blood pressure; CVRF, cardiovascular risk factor; HCMC, Ho Chi Minh City; WC, waist circumference; WCZ, waist circumference *z*-score; WHtR, waist-to-height ratio.

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cut-off is suitable for Vietnamese children[10]. In addition, a BMIZ of 2·0 SD is the cut-off used globally to identify children with obesity. However, this cut-off is not necessarily optimal to identify body fatness or health outcomes in specific ethnicities. Asian children tend to have higher TAG levels, insulin resistance and CVD incidence at a lower BMI cut-off compared with their non-Asian counterparts[16]. Furthermore, consideration of anthropometric indicators as continuous variables rather than dichotomised criteria may have additional benefits. The performance of BMI, WC and WHtR in the identification of two specific CVD risk factors, elevated blood pressure (BP) and dyslipidaemia, is therefore evaluated in a large survey of children and adolescents in Vietnam. Optimal cut-offs are identified and compared with commonly used cut-offs, and the usefulness of discrete compared with continuous anthropometric indicators for this purpose is considered.

Methodology

Study population

Data from the Survey of Nutritional Status Among School-aged Children conducted by the HCMC Nutrition Center funded by the Department of Health, HCMC, Vietnam, was used in the present study[6]. The primary objectives of this survey were to estimate the prevalence of stunting, thinness and overweight, to estimate the prevalence of hypertension, to estimate the mean height of children in each age, to estimate the prevalence of lipid disorder and the prevalence of Fe deficiency in school-aged children in primary, secondary and high school in HCMC, Vietnam. The sample size for data collection was selected from the largest sample size requirement for each objective. The largest sample size of 10 900 students was from the estimation of mean height for each age group from 6 to 18 years in school-aged children in HCMC. This estimation was calculated from the standard deviation of height for age from the nutritional survey in school-aged children in HCMC in 2009 with 95 % CI, a marginal error of 0·5 (cm) and a design effect of 2·0. The sample size of 950 children for sub-group of children with blood test was calculated from the estimation of the prevalence of Fe deficiency in each school level from the prevalence of Fe deficiency in each school level from a previous survey, with 95 % CI and the marginal error of 5 % and a design effect of 2·0.

Between October 2014 and January 2015, data were collected from school-aged children in HCMC using a two-stage cluster sampling design, with stratification by school level, location and sex. Sample size for each school level was calculated based on nutritional status distributions from a previous survey. All schools in HCMC were categorised by school level (primary, secondary and high school) and location (urban and rural). Probability-proportion-to-size sampling was used to select schools from these school categories, and for selection of students within the schools[6]. Approximately, 20 % of students in HCMC live in rural districts within the city boundaries[17]. A total of thirty schools were selected: eleven primary schools including nine urban and two rural; ten secondary schools including eight urban and two rural and nine high schools including eight urban and one rural. Students were selected from each school's student list stratified by sex and selected from each grade using systematic random sampling. In total, 500 students were selected from each primary school, 300 from each secondary school and 250 from each high school. For a blood lipid test, fifty students were selected at random per school in seven primary schools, and in six secondary schools, and ninety students per school in five high schools. All children and their parents provided informed written consent prior to data collection. Children with disorders affecting their ability to be accurately weighed and measured such as severe scoliosis, and urgent medical conditions such as high fever or diarrhoea, were excluded from the study before data collection. Ethics was approved by the Scientific Committee at Ho Chi Minh City Nutrition Centre (approval number: 404/QD-TTDD). The secondary analyses received an ethics exemption from the Queensland University of Technology Office of Research Ethics and Integrity (approval number: 1800000880).

Anthropometric measurements

Height, weight and WC were measured by trained health officers using standardised WHO guidelines[18]. Children wore light clothes and no shoes during measurement. Weight was measured to the nearest 0·1 kg using electronic scales (HD313; TANITA). Height was measured using a wooden stadiometer and WC using non-elastic tape-measures against the skin at the midpoint between the lower costal border and the top of the iliac crest at the end of expiration, to the nearest 0·1 cm. The circumference at the umbilicus was used if the anatomical landmarks could not be identified. BMI was calculated as weight (kg) divided by height squared (m^2). WHtR was calculated as WC (cm) divided by height (cm).

Cardiovascular risk factors

Obesity, elevated BP and dyslipidaemia are CVRF in children[19,20]. In the present study, anthropometric indicators were used to identify obesity; thus, we did not include obesity as one of CVRF in the analysis. Overweight was defined as age–sex-specific BMI z-score (BMIZ) > 1·0 SD, and obesity was defined as age–sex-specific BMIZ > 2·0 SD[15]. All subjects had BP measured in the morning, seated in a quiet room after 10 min rest, on the right arm using electronic sphygmomanometer (HEM-7121; OMRON) with the appropriate cuff-size according to the arm circumference[21]. BP was measured for a second time after an additional 10 min rest. If the first BP reading was abnormal (≥120/80 mmHg), the second reading was used. Elevated BP was defined as systolic BP and/or diastolic BP ≥90th percentile for sex, height and age (6–12 years) and ≥120/80 mmHg (≥13 years)[22]. Blood tests for the concentration of total cholesterol, HDL, LDL and TAG were performed in a sub-group of 1009 children after 8 h of fasting. Dyslipidaemia was identified as having one of following: high cholesterol (total cholesterol ≥ 5·18 mmol/l); hypertriacylglycerolaemia (TAG ≥ 1·13 mmol/l (6–9 year) or ≥1·47 mmol/l (10–18 years); low HDL (HDL < 0·91 mmol/l) or high LDL (LDL ≥ 3·37 mmol/l)[23]. The summary measure 'combined cardiovascular risk factors' (CVRF) was created to indicate children who had at least three out of five cardiovascular disorders including elevated BP, high

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total cholesterol, hypertriacylglycerolaemia, low HDL and high LDL.

Statistical analysis

Analyses were performed using the 'svy' prefix in survey analysis in Stata package version 15.1 (StataCorp) to account for the two-stage cluster sampling design. The 'weight' value in survey analysis was used separately for the total sample of 10 949 subjects and the sub-sample of 1009 subjects due to the different method of sampling for the sub-sample. These values were calculated from the total number of children in each school, total number of children in each stratum, number of school in each strata and sample size for each school. General characteristics were presented as mean or prevalence and standard errors. The differences in general characteristics between boys and girls were tested using two-sided independent *t* test in survey analysis. $P<0{\cdot}04$ was used to indicate statistical significance. To avoid the influence of age and sex on BMI, BMIZ were used, derived from the mean and standard deviations of the WHO reference population, using WHO Anthro-plus[15]. WC *z*-scores (WCZ) were derived from the mean and standard deviations of the study population.

Receiver-operating characteristic analysis was used to evaluate the capacity of anthropometric indicators to identify elevated BP, dyslipidaemia and the combined CVRF. Predicted probabilities were derived, and receiver-operating characteristic analysis was carried out in Stata using the 'roctab' command, treating the anthropometric variables as continuous variables. AUC with 95 % CI was reported with higher values of AUC indicating a higher capacity of prediction, AUC = 1·0 indicates perfect prediction[24] and AUC > 0·5 indicates a capacity to discriminate a health outcome. This capacity could be classified as follows: $0{\cdot}5 < \text{AUC} < 0{\cdot}7$ for less accurate, $0{\cdot}7 \leq \text{AUC} < 0{\cdot}9$ for moderately accurate and $\text{AUC} \geq 0{\cdot}9$ for highly accurate[25]. The present study was able to detect an AUC of 0·6 with 90 % power and a significance level of 0·05 in all sub-group analysis. In addition, the performance of the capacity to identify elevated BP, dyslipidaemia and combined CVRF is presented as the OR of having these outcomes for every increase in one unit of the anthropometric indicator (1·0 SD increase in BMIZ and WCZ and 0·1 increase in WHtR). These were derived from a logistic regression model adjusted for age and sex when appropriate.

Differences in AUC were analysed with the command 'roccomp' in Stata, using algorithm suggested by DeLong[26] to evaluate the equality of AUC between WHtR, BMIZ and WCZ to identify CVD risk factors, and the differences by sex or age group. The significant difference was identified by the χ^2 test with $P<0{\cdot}04$. To facilitate comparisons between different age groups, children aged 6 to 9 years were defined as children and children aged 10 to 18 years were defined as adolescents[27]. Due to the relatively small number of children in age- and sex-specific sub-groups with CVRF in the sample with blood lipid data, all analyses by sex were conducted for all health outcomes, and analyses by age were conducted for elevated BP only. The receiver-operating characteristic regression analysis with univariate logistic regression models were used to calculate the Youden index from sensitivity and specificity at each cut-off. The optimal cut-off for anthropometric indicators was defined based on the maximum Youden index (J value = sensitivity + specificity − 1)[28].

The probability of having the outcome at a certain cut-off was calculated from the logit model of anthropometric indicators (as dichotomised variables) and health outcomes. The OR were calculated from logistic model of anthropometric indicators and health outcomes at each specific anthropometric cut-off, adjusted for age and sex and no adjustments. Odds and 95 % CI were reported with the statistical significance being considered $P<0{\cdot}04$ using Bonferroni correction for six random tests.

Results

In total, 10 949 subjects were included in the analyses, 50·6 % were male and mean age was 10·7 (SD 3·4) years (range 6–18 years). Analyses that considered blood lipids were based on the sub-sample of 1009 children (48·2 % male) who had blood lipid data. The prevalence of elevated BP, dyslipidaemia and the combined CVRF was 26·5, 49·3 and 12·2 %, respectively (Table 1). All anthropometric indicators, except WCZ and BP profiles, were different between boys and girls. The prevalence of abnormal lipids was not different between boys and girls. Elevated BP, overweight and obesity were more common among boys than girls (31·2 *v.* 21·6 %, 48·2 *v.* 33·1 % and 26·8 *v.* 10·0 %, respectively). Dyslipidaemia and combined CVRF were common in children than adolescents (59·5 *v.* 42·1 % and 16·7 *v.* 9·0 %, respectively)

The performance of anthropometric indicators to identify elevated BP, dyslipidaemia and combined CVRF is presented in Table 2 and Figs. 1–3. Overall, all anthropometric indicators had capacity in identifying elevated BP, dyslipidaemia and combined CVRF. For the identification of elevated BP, WCZ (AUC 0·64) performed better ($P<0{\cdot}04$) than BMIZ (AUC 0·63) and WHtR (AUC 0·61). All indicators performed better for identifying elevated BP in adolescents (AUC 0·64–0·66) than in children (AUC 0·61–0·62) ($P<0{\cdot}001$). Similarly, the OR of having elevated BP in adolescents ranges from 1·69 to 2·45, whereas these ratios in children range from 1·33 to 1·97 (Table 2). For the identification of dyslipidaemia, BMIZ (AUC 0·64) performed similarly to WHtR (AUC 0·66) but performed better than WCZ (AUC 0·62) ($P<0{\cdot}04$) (Table 2). For identification of children and adolescents who had at least three CVRF, all indicators had a moderately accurate capacity (AUC range 0·72–0·74). The OR for having dyslipidaemia associated with a unit increase in anthropometric indicators ranged from 1·35 to 2·24, while these OR for combined CVRF ranged from 2·06 to 4·52 (Table 2).

Optimal cut-offs for each anthropometric indicator are presented in Tables 3 and 4. The optimal cut-offs for BMIZ and WCZ to identify elevated BP (Table 3) were 0·4 and 0·06 SD, whereas these cut-offs to identify dyslipidaemia or combined CVRF (Table 4) were 1·01 and 1·10 SD for BMIZ and 0·45 and 0·62 SD for WCZ. In contrast, optimal WHtR cut-offs for all CVRF considered ranged from 0·47 to 0·50 (Tables 3 and 4). The sensitivity and specificity for each of the optimal anthropometric cut-offs were higher than 50·0 %, except for the optimal

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Table 1. Characteristics of school-aged children and adolescents in Ho Chi Minh City, Vietnam (2014–2015)
(Mean values with their standard errors; numbers and percentages)

	Total				Boys				Girls			
Variables	*n*	Mean	%	SE	*n*	Mean	%	SE	*n*	Mean	%	SE
Age (years)	10 949	10·7		0·6	5541	10·7		0·6	5408	10·7		0·6
Weight (kg)*	10 949	40·5		1·9	5541	42·3		2·1	5408	38·5		1·7
Height (cm)*	10 949	142·2		2·6	5541	143·5		3·0	5408	140·8		2·3
BMI (kg/m^2)*	10 949	19·4		0·2	5541	19·9		0·2	5408	18·9		0·3
WC (cm)*	10 945	67·4		0·9	5539	69·2		1·0	5406	65·5		0·8
WHtR*	10 945	0·5		0·0	5539	0·5		0·0	5406	0·5		0·0
BMI *z*-score (SD)*	10 949	0·8		0·1	5541	1·0		0·1	5408	0·5		0·1
Overweight*	10 949		40·8	0·0	5541		48·2	0·0	5408		33·1	0·0
Obesity*	10 949		18·8	0·0	5541		26·8	0·0	5408		10·0	0·0
WC *z*-score (SD)	10 945	−0·0		0·1	5539	−0·0		0·1	5406	−0·0		0·1
SBP (mmHg)*	10 936	103·7		1·3	5537	105·8		1·5	5399	101·5		1·0
DBP (mmHg)*	10 937	65·8		0·7	5537	66·2		0·7	5400	65·4		0·7
Elevated blood pressure*	10 936		26·5	0·0	5537		31·2	0·0	5399		21·6	0·0
Children*	4808		22·5†	0·0	2448		24·5†	0·0	2360		20·4	0·0
Adolescents*	6141		29·3	0·0	3093		36·1	0·0	3048		22·5	0·0
Total cholesterol (mmol/l)	1009	4·7		0·1	486	4·7		0·1	523	4·8		0·1
LDL-cholesterol (mmol/l)	1009	1·4		0·0	486	1·4		0·0	523	1·4		0·0
HDL-cholesterol (mmol/l)	1009	2·8		0·1	486	2·8		0·1	523	2·8		0·1
TAG (mmol/l)	1009	1·3		0·0	486	1·2		0·1	523	1·3		0·0
High cholesterol	1009		26·3	0·0	486		25·3	0·0	523		27·3	0·0
High LDL	1009		18·0	0·0	486		18·5	0·0	523		17·5	0·0
Low HDL	1009		2·7	0·0	486		2·9	0·0	523		2·6	0·0
Hypertriacylglycerolaemia	1009		34·5	0·0	486		33·9	0·0	523		35·2	0·0
Dyslipidaemia	1009		49·3	0·0	486		49·3	0·1	523		49·3	0·0
Children	254		59·5†	0·0	128		58·9†	0·0	126		60·0†	0·0
Adolescents	755		42·1	0·0	358		42·2	0·0	397		42·0	0·0
CVRF	1009		12·2	0·0	486		12·3	0·0	523		12·1	0·0
Children	254		16·7†	0·0	128		16·9†	0·0	126		16·6†	0·0
Adolescents	755		9·0	0·0	358		8·9	0·0	397		9·0	0·0

WC, waist circumference; WHtR, waist-to-height ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; CVRF, cardiovascular risk factor.
* *P* <0·001 for the difference of mean or prevalence between boys and girls.
† *P* <0·04 for the difference of the prevalence between children and adolescents.

Table 2. Performance of anthropometric indicators to identify elevated blood pressure, dyslipidaemia, and combined cardiovascular risk factors in school-aged children and adolescents in Ho Chi Minh City, Vietnam
(Areas under the curve or odds ratios and 95 % confidence intervals)

	BMIZ		WCZ		WHtR		BMIZ		WCZ		WHtR	
	AUC	95 % CI	AUC	95 % CI	AUC	95 % CI	OR*	95 % CI	OR*	95 % CI	OR*	95 % CI
Elevated blood pressure												
Total (*n* 10 949)	0·63	0·62, 0·64	0·64†	0·63, 0·65	0·61	0·60, 0·63	1·50	1·39,1·62	1·68	1·53, 1·85	2·22	1·97, 2·50
Children												
Total (*n* 4808)	0·62‡	0·60, 0·64	0·61	0·59, 0·62	0·61†	0·59, 0·63	1·33	1·20,1·47	1·45	1·24, 1·71	1·92	1·52, 2·43
Boys (*n* 2448)	0·63	0·60, 0·66	0·63§	0·60, 0·65	0·63§	0·61, 0·66	1·34	1·23, 1·46	1·56	1·37, 1·79	2·05	1·62, 2·59
Girls (*n* 2360)	0·60‡	0·57, 0·63	0·58	0·55, 0·61	0·58	0·56, 0·61	1·38	1·14, 1·52	1·34	1·08, 1·66	1·77	1·33, 2·37
Adolescents												
Total (*n* 6141)	0·66‡‖	0·65, 0·68	0·66‖¶	0·65, 0·68	0·64**	0·63, 0·66	1·69	1·58, 1·82	1·88	1·73, 2·01	2·45	2·19, 2·75
Boys (*n* 3093)	0·65	0·63, 0·67	0·69‡†§	0·67, 0·71	0·64	0·62, 0·66	1·78	1·65, 1·91	2·11	1·93, 2·29	2·75	2·42, 3·11
Girls (*n* 3048)	0·66¶	0·64, 0·69	0·64	0·62, 0·67	0·63	0·60, 0·65	1·68	1·52, 1·85	1·68	1·55, 1·83	2·43	2·11, 2·78
Dyslipidaemia												
Total (*n* 1009)	0·64‡	0·61, 0·68	0·62	0·58, 0·65	0·66†	0·62, 0·69	1·35	1·19, 1·53	1·54	1·30, 1·84	2·24	1·78, 2·86
Boys (*n* 486)	0·64	0·58, 0·69	0·61	0·56, 0·66	0·65†	0·60, 0·70	1·26	1·07, 1·48	1·43	1·14, 1·79	1·84	1·30, 2·60
Girls (*n* 523)	0·65‡	0·61, 0·70	0·62	0·57, 0·67	0·66†	0·62, 0·71	1·49	1·28, 1·73	1·67	1·30, 2·12	3·07	1·96, 4·80
Combined cardiovascular risk factors												
Total (*n* 1001)	0·73	0·68, 0·78	0·72	0·66, 0·77	0·74	0·70, 0·79	2·06	1·67, 2·53	2·35	1·97, 2·81	4·52	3·27, 6·24
Boys (*n* 485)	0·73	0·65, 0·79	0·71†¶	0·64, 0·78	0·75	0·69, 0·82	1·80	1·43, 2·27	2·17	1·63, 2·89	3·92	2·53, 6·08
Girls (*n* 523)	0·76	0·68, 0·83	0·73	0·65, 0·81	0·75	0·69, 0·83	2·45	1·66, 3·61	2·44	1·71, 3·49	5·35	2·69, 10·64

BMIZ, BMI *z*-score; WCZ, waist circumference *z*-score; WHtR, waist-to-height ratio.
* OR for 1·0 unit increase (1 SD for BMIZ and WCZ and 0·1 for WHtR) using logistic regression adjusted for age and sex when it is appropriate in survey analysis.
† *P* <0·04 for the difference between WCZ and WHtR.
‡ *P* < 0·05 for the difference in AUC between BMIZ and WCZ.
§ *P* < 0·001 for the difference between boys and girls.
‖ *P* < 0·001 for the difference between children and adolescents.
¶ *P* <0·04 for the difference between BMIZ and WHtR.
** *P* < 0·04 for the difference between children and adolescents.

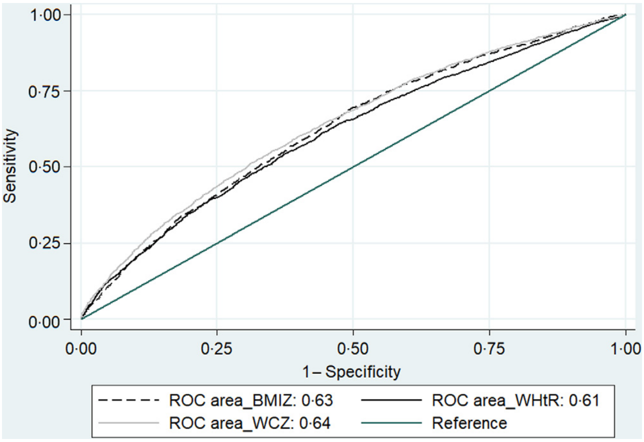

Fig. 1. AUC of anthropometric indicators to identify elevated blood pressure in school-aged children in Ho Chi Minh City, Vietnam. ROC, receiver-operating characteristic; BMIZ, BMI *z*-score; WHtR, waist-to-height ratio; WCZ, waist circumference *z*-score.

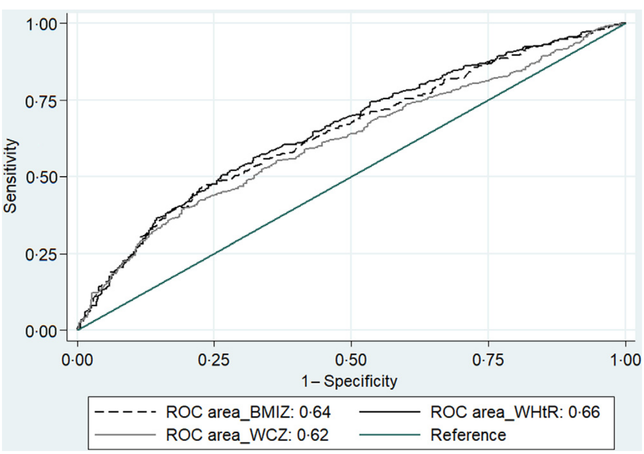

Fig. 2. AUC of anthropometric indicators to identify dyslipidaemia in school-aged children in Ho Chi Minh City, Vietnam. ROC, receiver-operating characteristic; BMIZ, BMI *z*-score; WHtR, waist-to-height ratio; WCZ, waist circumference *z*-score.

BMIZ cut-off (sensitivity 47·2 %) and optimal WCZ cut-off (sensitivity 39·7 %) to identify dyslipidaemia, and some sex-specific sub-groups. All optimal cut-offs for identification of the combined CVRF in children and adolescents provided a high specificity (>70·0 %) (Table 4).

Anthropometric cut-offs for BP varied by age and sex. To identify elevated BP, younger boys had a higher cut-off than older boys for all anthropometric indicators (Table 3). In addition, the optimal WCZ cut-offs for boys to identify elevated BP were lower than the mean WC of the population (−0·12 SD in children and −0·22 SD in adolescent). To identify dyslipidaemia and combined CVRF, BMIZ cut-offs for boys were higher than those for girls, and this finding was similar in younger age groups to identify elevated BP. The optimal cut-offs for WHtR had a smaller variation by age group and sex (0·44–0·51) compared with other indicators WCZ (−0·22 to 0·62 SD) and BMIZ (0·40–1·96 SD) (Tables 3 and 4).

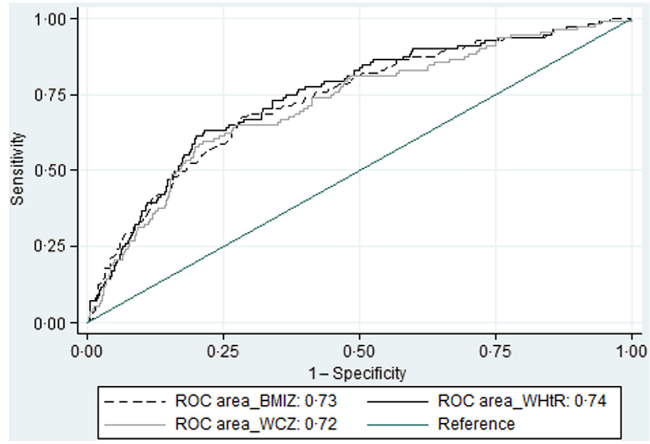

Fig. 3. AUC of anthropometric indicators to identify at least three cardiovascular risk factors in school-aged children in Ho Chi Minh City, Vietnam. ROC, receiver-operating characteristic; BMIZ, BMI *z*-score; WHtR, waist-to-height ratio; WCZ, waist circumference *z*-score.

The probability of having CVRF above the anthropometric cut-offs, as well as OR for those above *v.* below the cut-off, is presented in Table 5, comparing optimal cut-offs identified from our survey *v.* those commonly used. The differences in probability of having CVRF between the commonly recommended >1·0 SD BMIZ cut-off and the optimal BMIZ cut-off were small for all the three CVD risk factor outcomes considered (0·281 *v.* 0·244, 0·528 *v.* 0·529, 0·118 *v.* 0·125, respectively) (Table 5). This was also the case for the different WHtR cut-offs. The optimal BMIZ cut-offs and the recommended BMIZ cut-off of 1·0 SD also showed comparable OR, sensitivity and specificity. At a BMIZ cut-off of 2·0 SD, the OR were higher than those for the optimal or 1·0 SD cut-offs, but the 2·0 SD cut-off had lower sensitivity (28·6 %) than the 1·0 SD cut-off (54·4 %). At the WHtR cut-off of 0·5, the OR for having elevated BP, dyslipidaemia or the combined CVRF were comparable to those for the BMIZ cut-off of 1·0 SD. However, the OR of having elevated BP at the optimal WHtR cut-off of 0·48 was higher (OR 3·74; 95 % CI 2·88, 4·85) compared with the 0·50 WHtR cut-off (OR 2·29; 95 % CI 2·01, 2·67).

The relationship between the anthropometric variables considered as *continuous* variables and the probability of having CVRF is illustrated in Figs. 4–6. Based on the shape of the probability curve, the probability of having elevated BP or dyslipidaemia did not change markedly (approaching linearity) with each increase in BMIZ, WCZ and WHtR cut-offs (Figs. 4 and 5). In contrast, the probability of having CVRF had a greater variation (approaching a u-curve) with each increase in BMIZ, WCZ and WHtR cut-offs that are central in the distribution and lie closer to the optimal cut-points (Fig. 6).

Discussion

Our results showed that one in three, one in two, and more than one in ten children in urban Vietnam had elevated BP, dyslipidaemia and at least two CVRF, respectively. BMIZ, WCZ and WHtR had capacity to identify Vietnamese children and adolescents who have elevated BP, dyslipidaemia or at least three

Table 3. Optimal cut-offs of anthropometric indicators to identify elevated blood pressure in school-aged children and adolescents in Ho Chi Minh City, Vietnam

Indicators	Optimal cut-off	AUC	Sensitivity (%)	Specificity (%)	*J* value
Total					
BMIZ	0·40	0·63	69·4	50·1	0·196
WCZ	0·06	0·64	59·0	61·1	0·200
WHtR	0·48	0·61	54·3	62·6	0·170
Children (6–9 years old)					
Total					
BMIZ	1·88	0·62	46·2	72·7	0·189
WCZ	0·22	0·61	53·2	63·4	0·166
WHtR	0·49	0·61	59·1	57·9	0·170
Boys					
BMIZ	1·96	0·63	57·7	64·0	0·216
WCZ	−0·12	0·63	53·1	22·7	0·203
WHtR	0·51	0·63	58·0	62·2	0·202
Girls					
BMIZ	0·40	0·60	71·1	43·0	0·142
WCZ	0·20	0·58	49·9	63·0	0·129
WHtR	0·48	0·58	58·1	55·0	0·131
Adolescents (10–18 years old)					
Total					
BMIZ	0·45	0·66	64·4	61·6	0·259
WCZ	0·28	0·66	52·1	71·1	0·232
WHtR	0·46	0·64	58·1	63·7	0·218
Boys					
BMIZ	0·03	0·65	75·2	48·4	0·237
WCZ	−0·22	0·69	69·6	57·7	0·273
WHtR	0·46	0·64	59·7	62·0	0·217
Girls					
BMIZ	0·45	0·66	61·3	65·3	0·265
WCZ	0·29	0·64	51·3	69·9	0·212
WHtR	0·46	0·63	54·8	65·5	0·203

BMIZ, BMI *z*-score; WCZ, waist circumference *z*-score; WHtR, waist-to-height ratio.
J value (Youden index) = sensitivity + specificity − 1.

CVRF. Overall, all anthropometric indicators had moderate and comparable capacity to identify at least three CVRF. The indicator that performed best for identification of elevated BP was WCZ, though BMIZ performed almost equally well. BMIZ and WHtR performed relatively better than WCZ for identification of dyslipidaemia.

Overall, our AUC values were comparable with those reported in a meta-analysis of children and adolescents from thirty studies which included four studies from China (in which AUC 0·64–0·68 for hypertension, 0·67–0·7 for dyslipidaemia and >0·7 for at least three morbidities)[10]. The performance of anthropometric indicators in our study, when evaluated as AUC achieved to identify elevated BP, was lower than reported to identify hypertension in recent studies in Malaysian and Chinese children (AUC around 0·60 in our study *v*. AUC around 0·70 in the other two studies)[29,30].

Elevated blood pressure

According to the WHO, raised BP is a leading risk factor noncommunicable diseases, including CVD, in Vietnam[7]. The prevalence of hypertension in Vietnamese adults in 2015 was 23·1 % (males) and 14·9 % (females). There are no known national BP data for children and adolescents. The prevalence of elevated BP in our survey was 29·3 % (adolescents), whereas in a study of 693 in high schoolchildren in HCMC in 2007 showed that this prevalence was 21·5 %[31]. Our result indicated that the prevalence of elevated BP in adolescents was higher than in children. Also, similar to other studies, the prevalence of elevated BP was higher in boys than in girls[31,32], particularly in adolescents.

Regarding the capacity to identify elevated BP, we found that BMIZ and WCZ performed better than WHtR ($P < 0·04$) in predicting elevated BP. This finding is consistent with recent studies in children (7–15 years old) in Tianjin, China[30], and adolescents (12–17 years old) in Sarawak, Malaysia[29], and with a previous meta-analysis of studies in children and adolescents[33]. However, in another study of children (6–10 years old) in Guangzhou, China, Liang (2015) found that WC was the best indicator to identify elevated BP[34]. In contrast, a study from the Chinese National Survey on Student's Constitution and Health in children (7–17 years old) suggested that BMIZ had a better performance to identify elevated BP compared with WCZ, WHtR *z*-score, waist-to-hip ratio *z*-score and skinfold thickness *z*-score[32]. Collectively, the current evidence indicates that WHtR is less useful than BMIZ and WCZ for identification of elevated BP.

The optimal BMIZ cut-off in children was 1·88 SD, whereas the optimal cut-off in adolescents was 0·45 SD. This contradiction may reflect the difference in the relative relationship between BMIZ and elevated BP. In adolescents, the prevalence of elevated BP and the OR of having elevated BP were higher than in children (29·3 *v*. 22·5 % and 1·69 *v*. 1·33 %, respectively). Due to the higher prevalence of elevated BP in adolescents, the

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Table 4. Optimal cut-offs of anthropometric indicators to identify dyslipidaemia and combined cardiovascular risk factors in school-aged children and adolescents in Ho Chi Minh City, Vietnam

	Cut-off	AUC	Sensitivity (%)	Specificity (%)	*J* value
Dyslipidaemia					
Total					
BMIZ	1·01	0·64	47·2	76·8	0·239
WCZ	0·49	0·62	39·7	80·6	0·203
WHtR	0·47	0·66	56·3	67·8	0·242
Boys					
BMIZ	1·39	0·64	45·5	75·8	0·213
WCZ	0·47	0·61	71·2	46·8	0·179
WHtR	0·44	0·65	76·6	45·3	0·218
Girls					
BMIZ	1·00	0·65	41·1	86·8	0·279
WCZ	0·26	0·62	46·2	77·7	0·239
WHtR	0·47	0·66	47·5	80·1	0·276
Combined cardiovascular risk factors					
Total					
BMIZ	1·10	0·73	67·9	71·6	0·394
WCZ	0·62	0·72	58·9	79·7	0·387
WHtR	0·50	0·74	63·7	78·5	0·423
Boys					
BMIZ	1·57	0·71	62·5	74·9	0·373
WCZ	0·41	0·72	62·5	70·6	0·331
WHtR	0·50	0·75	71·8	71·8	0·432
Girls					
BMIZ	1·09	0·76	64·9	80·5	0·454
WCZ	0·53	0·73	66·7	79·2	0·459
WHtR	0·47	0·75	70·2	73·0	0·431

BMIZ, BMI *z*-score; WCZ, waist circumference *z*-score; WHtR, waist-to-height ratio.

prediction of elevated BP in the total population was influenced by the relative relationship between BMIZ and elevated BP in adolescents. This may explain the low optimal BMIZ cut-off in total population (0·4 SD) compared with the optimal cut-offs for children (1·98 SD).

Adolescents had an increased risk of elevated BP even when their BMIZ was within the healthy range. Thus, screening for elevated BP in adolescents should not be limited to children with overweight or obesity according to the current definition (WHO 2006). Given the high prevalence of hypertension in Vietnamese adults (18·9 %)[35], and the evidence for an increased risk of developing CVD in adulthood for children with elevated BP[36], it may be beneficial to consider the lower BMIZ cut-off of 0·4 SD for the detection of Vietnamese children and adolescents likely to have elevated BP. However, the suggestion of BMIZ of 0·4 SD cut-off to identify elevated BP may not be practical in the context of the relatively high prevalence of children with overweight and obesity at the BMIZ cut-off of 1·0 SD. It would likely lead to a large burden on the health system due to increased management of children at risk of elevated BP. At the BMIZ cut-off of 1·0 SD, children are even more likely at risk of elevated BP. Measuring BP is cheap and non-invasive technique, so BP screening could be recommended in children and adolescents[22] by using an electronic sphygmomanometer.

Dyslipidaemia and combined cardiovascular risk

Dyslipidaemia is common among school-aged children in HCMC, particularly in those aged 6–9 years. The prevalence of dyslipidaemia in our survey (49·3 %) was higher than in school-aged children (6–18 years old) in Bejing, China, in 2014 (28·9 %)[37]. Dyslipidaemia is strongly associated with BMI, breakfast skipping[38], screen time and lack of physical activity[39]. Although we were not able to take these covariates into consideration, our prediction models were adjusted for age and sex. In addition to the higher prevalence of dyslipidaemia in children compared with adolescents, the prevalence of combined CVRF also showed a similar trend (16·7 *v.* 9·0 %). When considering the prevalence of dyslipidaemia and combined CVRF in the context of the nutrition transition, there are indications that children in urban Vietnam are moving to stage four of the nutrition transition process[40]. Thus, the prevention of CVRF should be prioritised from an early age.

For the identification of dyslipidaemia and combined CVRF, our results indicated that although BMIZ and WHtR had higher capacity than WCZ to detect dyslipidaemia, all anthropometric indicators had a comparable capacity to identify combined CVRF. This is in agreement with the finding from Lo and colleagues' meta-analysis[10], with a recent study of Korean adolescents (10–19 years old) (AUC for BMI percentile, WC percentile, WHtR 0·68–0·69)[41], and with a cohort study of Chilean children[42]. Therefore, it is highly likely that all three anthropometric indicators are useful for the identification of Vietnamese children and adolescents with dyslipidaemia and combined CVRF.

Utility of BMI

BMIZ had moderate capacity to identify combined CVRF but was less accurate for identification of elevated BP and dyslipidaemia. The optimal BMIZ cut-off of 0·4 SD had the higher capacity to detect children with elevated BP than using BMIZ cut-offs of 1·0 and 2·0 SD, which are the criteria recommended by WHO for identification of overweight and obesity in children[15]. However, the optimal cut-offs for identification of dyslipidaemia and combined CVRF were close to 1·0 SD and therefore more consistent with the recommendation from WHO to use 1·0 SD (BMI 25 kg/m^2 at 19 years old) as a cut-off for overweight[15]. Given that the sensitivity and specificity of the 1·0 SD BMIZ cut-off to identify combined CVRF were acceptable and similar to the optimal cut-off of 1·10 SD, continued promotion of the use of the 1·0 SD BMIZ cut-off would help focus on the increased risk of CVRF in addition to the identification of overweight in school-aged children and adolescents.

In urban Vietnam, given the high prevalence of dyslipidaemia and CVRF, particularly in children (6–9 years old), these risk factors should be detected early to prevent the future morbidity. However, currently, universal screening for CVD in children and adolescents is not widely recommended and practised[43]. Thus, based on the performance of BMIZ, this indicator with a suggested cut-off of 1·0 SD could be promoted as a screening tool to identify CVRF. Children with a BMIZ cut-off more than 1·0 SD would be at 5 times higher odds of having at least three CVRF than those with BMIZ 1·0 SD or less.

Utility of waist circumference z-scores

Regarding the utility of WCZ, our results showed that the optimal cut-off was 0·06 SD for the prediction of elevated BP, 0·49 SD for the prediction of dyslipidaemia and 0·62 SD for the prediction of

Table 5. Probability of having risk factor and the OR of each risk factor for suggested and optimal BMI *z*-score (BMIZ) and waist-to-height ratio (WHtR) cut-offs
(Odds ratios and 95 % confidence intervals; percentages)

	BMIZ									WHtR					
Risk factors	Optimal cut-off*	%		>1·0 SD	%		>2·0 SD	%		Optimal cut-off†	%		>0·50	%	
Elevated blood pressure															
Probability	0·244			0·281			0·350			0·264			0·290		
Crude															
OR			2·32			2·11			2·63			2·66			2·02
95 % CI			1·89, 2·84			1·78, 2·50			2·14, 3·24			1·89, 3·73			1·75, 2·32
Adjusted															
OR			2·72			2·49			3·19			3·74			2·29
95 % CI			2·29, 3·24			2·17, 2·86			2·61, 3·89			2·88, 4·85			2·01, 2·67
P‡	0·048			0·000			0·014			0·085			0·017		
Sensitivity		69·4			54·4			28·6			54·3			44·5	
Specificity		50·1			63·4			84·4			62·6			71·3	
Dyslipidaemia															
Probability	0·529			0·528			0·607			0·493			0·560		
Crude															
OR			2·58			2·53			2·93			2·49			2·79
95 % CI			1·83, 3·63			1·78, 3·59			1·92, 4·47			1·70, 3·65			2·08, 3·75
Adjusted															
OR			2·39			2·34			2·39			2·33			2·68
95 % CI			1·80, 3·16			1·75, 3·12			1·73, 3·31			1·66, 3·27			2·09, 3·44
P‡	0·326			0·487			0·008			0·416			0·038		
Sensitivity		47·2			47·4			20·1			56·3			37·1	
Specificity		76·8			75·7			91·5			67·8			83·7	
Combined cardiovascular risk factors															
Probability	0·125			0·118			0·205			0·155			0·155		
Crude															
OR			5·48			4·14			7·25			5·88			5·88
95 % CI			3·64, 8·24			3·45, 7·67			4·20, 12·50			3·96, 8·73			3·96, 8·73
Adjusted															
OR			5·53			5·14			6·89			5·92			5·92
95 % CI			3·72, 8·22			3·48, 7·58			3·94, 12·04			4·03, 8·67			4·04, 8·67
P‡	0·939			0·800			0·000			0·732			0·732		
Sensitivity		67·9			69·0			35·4			63·7			63·7	
Specificity		71·6			69·5			89·0			78·5			78·5	

* Optimal BMIZ cut-offs to identify elevated blood pressure, dyslipidaemia and combined cardiovascular risk factors were 0·4, 1·01 and 1·10 SD, respectively.
† Optimal WHtR cut-offs to identify elevated blood pressure, dyslipidaemia and combined cardiovascular risk factors were 0·48, 0·47 and 0·5, respectively.
‡ *P* value of goodness of fit for logistics models adjusted for age and sex. Crude OR was generated from the logistic model of health outcome and anthropometric indicators, adjusted OR was the logistic model adjusted for age and sex, and all models were analysed using 'svy' prefix.

British Journal of Nutrition

https://doi.org/10.1017/S0007114520000203 Published online by Cambridge University Press

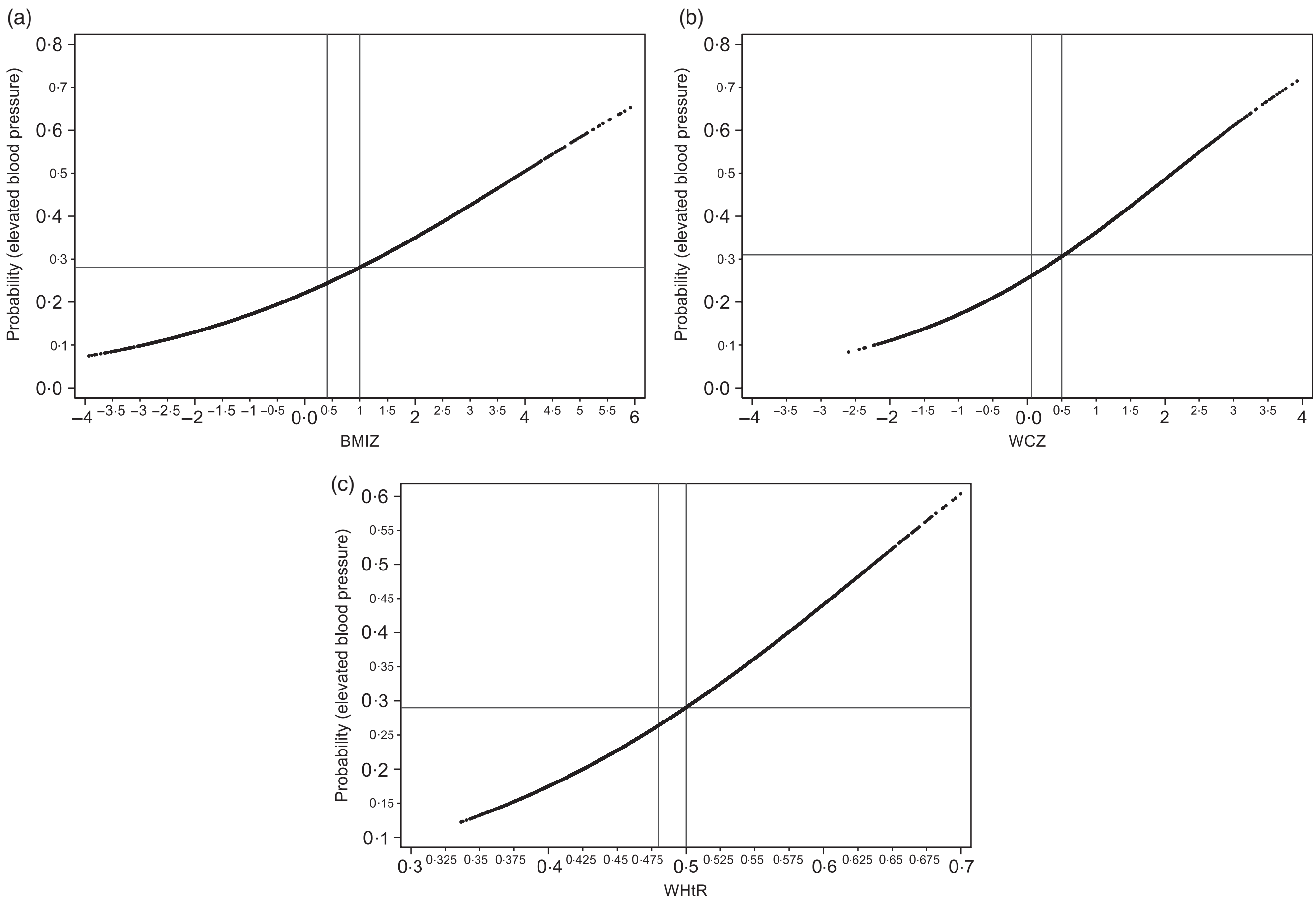

Fig. 4. Probability of having elevated blood pressure among children and adolescents by recommended and optimal anthropometric cut-offs. (a) By BMI *z*-score (BMIZ) cut-offs. (b) By waist circumference *z*-score (WCZ) cut-offs. (c) By waist-to-height ratio (WHtR) cut-offs. Recommended cut-offs: BMIZ (1·0 SD), WCZ (0·5 SD), WHtR (0·5). Optimal cut-offs: BMIZ (0·4 SD), WCZ (0·06 SD), WHtR (0·48).

combined CVRF. The sensitivity of this WCZ cut-off for identification of dyslipidaemia was low (39·7 %), and age- and sex-specific WC cut-offs were not available. Thus, this indicator should not yet be considered as a screening tool for CVRF in Vietnamese children, until more evidence is gathered. WCZ was the best indicator to identify elevated BP, particularly in boys. Notably, boys were identified with high risk of elevated pressure even at cut-offs that were lower than the mean WC of the current population. This is likely due to the currently, on average, significantly higher WC in Vietnamese boys and also reflects the fact that abdominal obesity was highly associated with elevated BP in Vietnamese children, particularly in boys. Given the sensitivity of WC in determining elevated BP in children, the establishment of age- and sex-specific WC cut-offs will enhance the identification of risk screening in Vietnamese children.

Utility of waist-to-height ratio

Regarding the utility of WHtR, results from our study suggest that children with high WHtR had approximately 6-fold increased odds of having combined CVRF compared with those with lower WHtR. Sensitivity for the WHtR optimal cut-offs was low but acceptable (>50·0 %) but lower for the 0·5 cut-off. A study in Korean children also reported a very low sensitivity (27·8 %) for the WHtR 0·5 cut-off in the identification of at least two cardiometabolic risk factors[41]. The evidence thus suggests that the use of WHtR 0·44 for boys and WHtR 0·43 for girls, instead of the universal 0·5 cut-off, would be optimal for screening of CVD risk factors in Korean children[41]. However, in our study, the optimal cut-off to identify combined CVRF was 0·5, which is the same as the suggested WHtR cut-off. In addition, the AUC (0·74), sensitivity (63·7 %) and specificity (78·5 %) were acceptable. From a practical point of view, the message 'keep your waist a half of your height' is easy to communicate to the community[44]. Thus, a WHtR cut-off of 0·5 could be recommended as a screening tool for the CVRF in urban children in Vietnam.

A preference for discrete anthropometric indicators or continuous variables for the purpose of identifying young people who are likely to carry CVD risk factors was also considered. The results suggest that there were small differences in the probability of having a risk factor between the optimal cut-offs and the commonly suggested cut-offs and that the probability of carrying risk factors changed at a more or less constant rate in particular for elevated BP and dyslipidaemia. Although the use of specific cut-offs might result in misclassification of diseases[45], from a practical point of view, the use of complex prediction

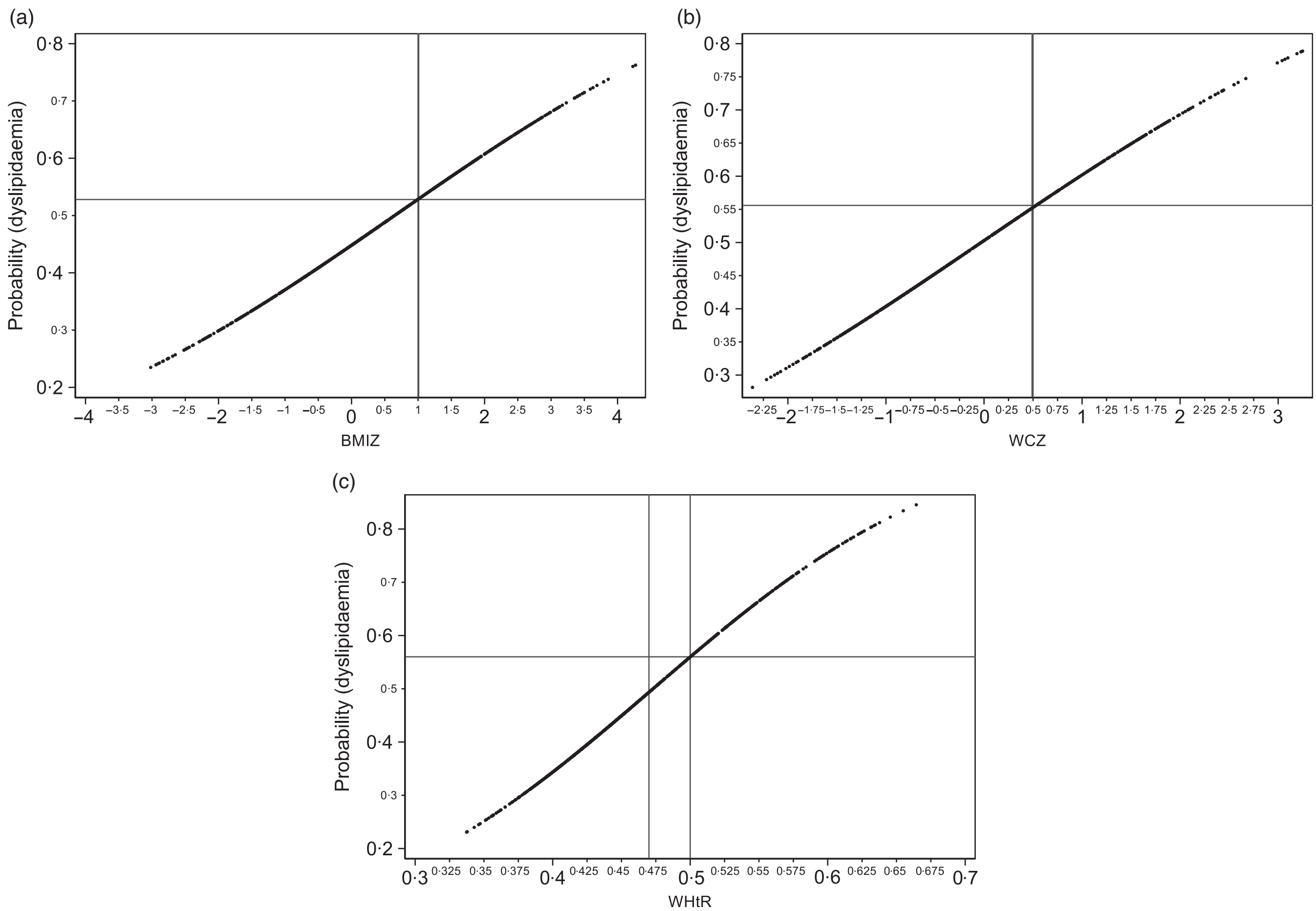

Fig. 5. Probability of having dyslipidaemia among children and adolescents by recommended and optimal anthropometric cut-offs. (a) By BMI *z*-score (BMIZ) cut-offs. (b) By waist circumference *z*-score (WCZ) cut-offs. (c) By waist-to-height ratio (WHtR) cut-offs. Recommended cut-offs: BMIZ (1·0 SD), WCZ (0·5 SD), WHtR (0·5). Optimal cut-offs: BMIZ (1·01 SD), WCZ (0·49 SD), WHtR (0·47).

models using continuous variables may not be feasible in some low-resource settings, particularly in low- and low–middle-income countries. This could lead to delays in screening individuals with a high risk of disease in low-resource settings. Therefore, discrete cut-offs rather than continuous variables to identify CVRF in children would appear to be more useful in low-resource settings such as Vietnam. However, there still remains a need for ongoing validation of the optimal discrete anthropometric cut-offs for identification of Asian children at high risk of cardiovascular risk factors[43]. Given the benefit of intervening early in life to reduce the risk of CVD in adulthood, interventions that promote healthy eating and physical activity should be prioritised rather than waiting for the validation of cut-offs for risk[46].

The present study has a number of strengths. The results were derived from a large and representative sample of children and adolescents in HCMC, Vietnam and included blood lipid data from approximately one-thousand subjects. Blood samples can be difficult to collect in school-aged children especially in lower to middle-income countries. The present study does, however, have some limitations. It is a cross-sectional study, and thus, the results cannot provide strong evidence of the predictive capacity of anthropometric indicators to identify elevated BP, dyslipidaemia and combined CVRF – longitudinal data would provide stronger evidence. Although a second reading of abnormal BP reduces measurement error, one measurement of BP cannot eliminate the possibility of 'white-coat' hypertension in the elevated BP group. However, regardless of the cause of hypertension, this group is still at higher risk of CVD and mortality than the normotensive BP group[47,48]. The pubertal stage of children in the present study was unavailable and therefore could not be analysed in regard to its association with anthropometric indicators and health outcomes. In addition, data on dietary intake and physical activity were unavailable, so prediction models could not be adjusted for these factors. Finally, for the development of predictive criteria, the population for tool development should not be the same as the population used for tool validation. However, due to the relatively smaller number of observations in the lipid profile data, we were not able to do this. Thus, it is necessary to validate the capacity of optimal cut-offs identified by our analyses in another sample of children and adolescents in Vietnam and to examine to what extent these cut-offs provide the same predictive capacity in different groups of Vietnamese children.

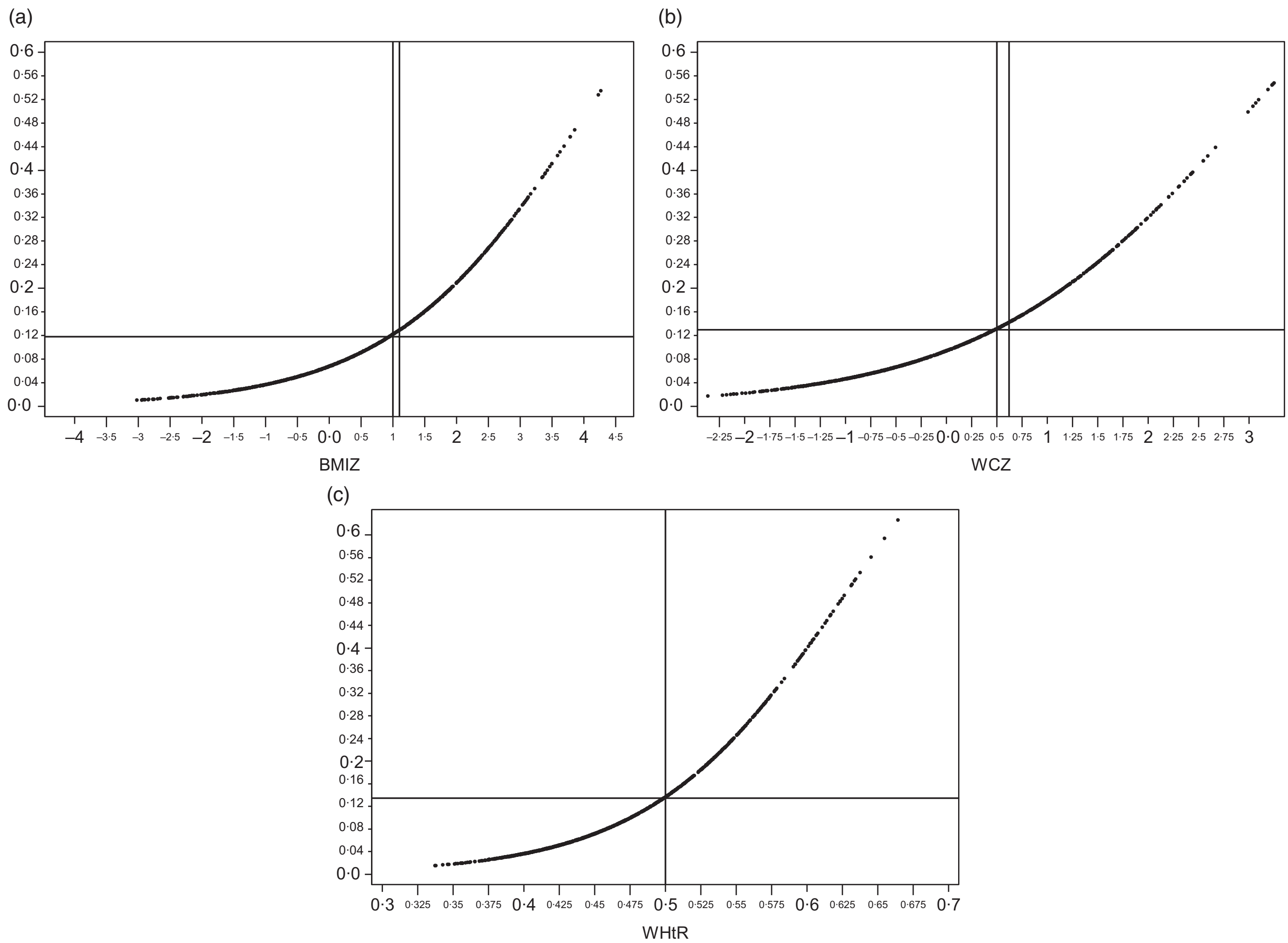

Fig. 6. Probability of having combined cardiovascular risk factors among children and adolescents by recommended and optimal anthropometric cut-offs. (a) By BMI *z*-score (BMIZ) cut-offs. (b) By waist circumference *z*-score (WCZ) cut-offs. (c) By waist-to-height ratio (WHtR) cut-offs. Recommended cut-offs: BMIZ (1·0 SD), WCZ (0·5 SD), WHtR (0·5). Optimal cut-offs: BMIZ (1·1 SD), WCZ (0·62 SD), WHtR (0·5).

In conclusion, the results indicated that all anthropometric indicators had power to discriminate the elevated BP, dyslipidaemia and combined CVRF in school-aged children and adolescents in HCMC, Vietnam. Discrete anthropometric indicators such as a BMIZ cut-off of 1·0 SD and the WHtR cut-off of 0·5 SD could be considered as a screening tool for CVRF in this setting, the additional utility of continuous variables appeared minimal. However, further research in other study populations should be done to confirm the validity of these cut-offs in other settings. Consensus regarding the optimal anthropometric cut-offs to identify children at high risk of CVD in Asian populations should eventually be established.

Acknowledgements

The authors would like to thank Dr Tran Thi Minh Hanh, Dr Pham Ngoc Oanh, Dr Vu Quynh Hoa, Dr Phan Nguyen Thanh Binh and staff at the HCMC Nutrition Centre for conducting the survey of nutritional status of school-aged children in HCMC in the school year 2014–2015. The authors would especially like to thank Dr Do Thi Ngoc Diep, the former Director of HCMC Nutrition Centre, for permission to use this dataset for the present analyses. The authors also acknowledge the technical support from Dr Signe Bruun at the Hans Christian Andersen Children's Hospital, Denmark and her colleges for helping to apply elevated BP criteria in our study, based on the new Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents.

T. M. T. M. and J. C. v. d. P. formulated the research questions and scope of the manuscript, T. M. H. T. designed the survey of Nutritional Status Among School-Aged Children, T. M. T. M. carried out the analyses, J. C. v. d. P. contributed to the analysis plan, L. J. assisted with the statistical analyses, T. M. T. M. wrote the first draft of manuscript, J. C. v. d. P., D. G., L. J., Q. C. T. and T. M. H. T. contributed to interpretation of the result. All authors contributed to writing the final draft of manuscript.

This work was supported by the Australian Government Research Training Program, and QUT HDR Tuition Fee Scholarship to T. M. T. M. for the programme Doctor of Philosophy at Queensland University of Technology, Brisbane, Australia.

The authors declare that there are no conflicts of interest.

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