MICROSOFT® OFFICE EXCEL-BASED WORKSHEET PROGRAM FOR RAPID CALCULATION OF WEIGHT-FOR-AGE (WA) AND HEIGHT-FOR-AGE (HA) Z-SCORES IN THAI PEDIATRIC POPULATION (THAI-Z)

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Abstract. Weight-for-age and height-for-age z-scores (WAZ and HAZ) are commonly used anthropometric tools for assessing a child's growth, development, and nutritional status. These parameters are also widely used in research studies to compare the effects of management, medications, and disease progression on height and weight in studied children, as these scores can minimize variation caused by ethnicity and genetic background. To calculate these scores, exact weight and height measurements must be manually calculated using a formula to adjust for age (month and year) and gender (boy or girl) within the same study population. In this study, we set forth to develop a user-friendly Microsoft® Excel-based program (*THAI-Z*) for calculating WAZ and HAZ using normative reference data obtained from the National Growth References for Children Under 20 Years of Age (1999), Ministry of Public Health, Thailand. The results using data from 400 Thai pediatric thalassemic patients and 381 normal Thai children to calculate HAZ and WAZ found 100% accuracy using the *THAI-Z* program, as compared to 99.68% from manual calculation. Moreover, manual calculation required more time than *THAI-Z* program to achieve measurement of HAZ and WAZ (11.3 *vs* 5.4 seconds per sample, respectively).This program can be used in both routine clinical evaluation and clinical research settings not only in Thailand, but also in neighboring Southeast Asian countries where children have anthropometric measurements similar to those of Thai children.

Keywords: weight-for-age, height-for-age, z-scores, growth, Thai children and adolescents

INTRODUCTION

Weight-for-age and height-for-age are commonly used anthropometric tools to assess child growth and nutritional status problems, including malnutrition (*eg*, stunting, wasting, and underweight) and over-nutrition (*eg*, overweight and obesity) (WHO, 1995; Wang and Chen, 2012). These tools can be used on an individual basis to evaluate and follow each child in a routine pediatric clinic setting to determine growth and development. A lower or declining weight-for-age and/or height-for-age from a standard growth curve indicates a failure to thrive or a growth abnormality, and this should prompt an investigation to identify the cause. In developing countries, poor nutritional sup-

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port is the major cause of low weight-for-age (protein-energy malnutrition, underweight) and low height-for-age (chronic malnutrition, stunting) (WHO, 1995; Dijkhuizen *et al*, 2008). Low weight-for-height is indicative of acute malnutrition or wasting. However, these anthropometric parameters may not be easily applicable to a research setting, since the data is individual and it varies by gender, age, and ethnicity (Wang and Chen, 2012).

Another way to express the difference between an individual child's weight (or height) and the average weight (height) of comparable children (same age and gender) within the reference population is by using weight-for-age and height-for-age z-scores (WAZ and HAZ) (Wang and Chen, 2012). These calculated parameters have certain advantages and they are widely used to present research study and survey results. A z-score indicates how many standard deviations a value is from the mean. Data with a high z-score or standard deviation will be widely dispersed and values among individuals will vary widely. Therefore, using normative reference data from any given population, one can determine how much the weight or height of each individual will deviate from the 'norm' or average of children within the same gender and age group (Wang and Chen, 2012). In addition, z-scores can be used to compare data among different populations using the same criteria (Butte *et al*, 2007; de Onis, 2007). For example, absence of acute protein-energy malnutrition (*ie*, normal nutritional status) is defined as having a weight-for-height z-score of -2.0 or greater. A weight-for-height z-score of -3.0 to <-2.0 is the cut-off for moderate acute protein-energy malnutrition, while a weight-for-height z-score <-3.0 indicates severe acute protein-energy malnutrition. WAZ and HAZ scores are commonly used in studies and surveys of nutritional status in pediatric population to evaluate the incidence of protein-calorie malnutrition (Panpanich *et al*, 2000; Nopchinda *et al*, 2002; Thurlow *et al*, 2006). These z-scores can also be used to determine growth and development in children in different clinical settings and in chronic illness, such as low-birth-weight infant (Jaruratanasirikul *et al*, 1999), failure to thrive (Jaruratanasirikul *et al*, 2000), renal tubular disease (Pirojsakul *et al*, 2011), congenital heart disease (Ratanachu-Ek and Pongdara, 2011), asthma (Visitsunthorn *et al*, 2002), thalassemia (Tienboon *et al*, 1996), HIV infection and the effects of anti-retroviral therapy (Briand *et al*, 2006; Aurpibul *et al*, 2009), chronic infestation of intestinal parasites (Egger *et al*, 1990; Janoff *et al*, 1990),and obesity and over-nutrition (Langendijk *et al*, 2003; Yamborisut *et al*, 2008). WAZ and HAZ are normally manually calculated using standard anthropometric measurement normative reference data for each population. However, this method is time-consuming and vulnerable to miscalculation when used in daily clinical practice or in a research setting.

There are currently several web-based tools available for calculating these parameters, such as WHO AnthroPlus software (http://www.who.int/growthref/tools/en/), which was developed using data from the WHO database (de Onis *et al*, 2007). However, the references for these programs were derived from regional growth reference data (Brazil, Ghana, India, Norway, Oman, and the USA).There is currently no standard growth pattern data specific to Southeast Asian population (including Thailand) in the WHO database. This limitation was addressed earlier (Wang *et al*, 2006). Apart from different genetic background, variation in environmental factors including socioeconomic status, health, and nutrition were considered as the main determinants underlying population differences in child and adolescent growth (Wang *et al*, 2006). To develop our population-specific tool (*THAI-Z* program) to calculate WAZ and HAZ in Thai children, we generated a user-friendly, Microsoft® Excel-based worksheet program using standard growth data obtained from the National Growth

References for Children Under 20 Years of Age, Ministry of Public Health, Thailand (Anonymous, 1999). Details about the development of *THAI-Z* program and its use in both clinical and research settings are described herein.

MATERIALS AND METHODS

A z-score is calculated by dividing the difference between the measured value (x) and the mean (μ) by the standard deviation (σ), as follows:

$$Z = \frac{x - \mu}{\sigma}$$

This worksheet-based program was developed using a Microsoft® Office Excel 2003 workbook. The program uses normative reference data for Thai people aged 1 day to 19 years old derived from the latest national growth references for weight, height, and nutritional index developed in 1999 by the Ministry of Public Health, Thailand (Anonymous, 1999). This database was generated using anthropometric data from 47,297 Thai individuals (22,496 males and 24,801 females) from 5 different regions of Thailand (Table 1).

This normative data was collected from normal children with no inter-current illness, as determined by clinical examination; no history of chronic illness or diseases, such as heart, renal, blood, or liver diseases; and no history of chronic diarrhea or malnutrition. All infant data was collected from singletons with full-term gestation (38-40 weeks) and a birth weight of 2,500-4,000 grams. Individuals with neurologic abnormalities, such as blindness, deafness, and mental retardation, were excluded. This normative reference booklet (Fig 1) can be accessed or downloaded from the Bureau of Nutrition, Department of Health, Ministry of Public Health Thailand website (http://nutrition.anamai.moph.go.th).

To develop the Excel worksheet for calculating HAZ and WAZ, all normative data from the aforementioned normative reference data booklet was recorded into four different worksheets of an Excel workbook. The first, second, third, and fourth worksheets were used for calculation of male WAZ, female WAZ, male HAZ, and female HAZ, respectively. Each worksheet contains the following 5 columns: age, input

Table 1
Number of population recruited for Thailand's National Growth Reference (1999) by geographic region and the provinces surveyed within each region.

Geographic regions	Males	Females	Total
Central	2,715	3,355	6,070
Ayutthaya, Saraburi, Chon Buri, Rayong, Ratchaburi			
Northeastern	6,949	7,519	14,468
Nakhon Ratchasima, Khon Kaen, Udon Thani, Ubon Ratchathani			
North	3,333	4,229	7,562
Nakhon Sawan, Phitsanulok, Lampang, Chiang Mai			
South	3,120	3,858	6,978
Songkhla, Yala			
Bangkok	6,379	5,840	12,219
Total	22,496	24,801	47,297

box for weight in kilograms or height/length in centimeters, median, standard deviation, and z-score result. *THAI-Z* program will be freely available on an open access basis via a link on this journal's website.

RESULTS

Two sets of data (one Thai girl and one Thai boy) were used to illustrate the process and the practicality of use of our *THAI-Z* program (Figs 2 and 3). The calculated HAZ and WAZ from *THAI-Z* for both individuals were compatible with the expected percentile for height and weight compared to the standard growth curve for Thai children. For example, the height of 135 cm and weight of 33 kg from an 8-year-old Thai girl were plotted against the standard growth curve for Thai girls, which showed the height to be in the 97th percentile (P97) and the weight in the 90th percentile (P90) (Fig 2A). A calculated z-score for height (HAZ = +1.96) can be easily achieved (Fig 2B) by adding the height in cm into the height box on the line that corresponds to the child's age, and likewise for the calculated z-score for weight (WAZ = +1.57), as shown in Fig 2C.

Similarly, the height of 135 cm and weight of 33 kg from a 8-year-old Thai boy were plotted against the standard growth curve for Thai boys, which showed the height and weight to both be in the 90th percentile (P90) (Fig 3A). Again, a calculated z-score for height (HAZ = +1.85) can be easily performed by inputting the height in cm into the height box on the line that corresponds with the child's age (Fig 3B). Finally, using the same methodology, a z-score for weight (WAZ = +1.65) can be simply calculated after the exact weight was added into the weight box on the line that correctly corresponds with the child's age (Fig 3C). For all tests, the calculated z-score values were found to be consistent with the results of manual calculation.

To validate the accuracy and efficacy of our

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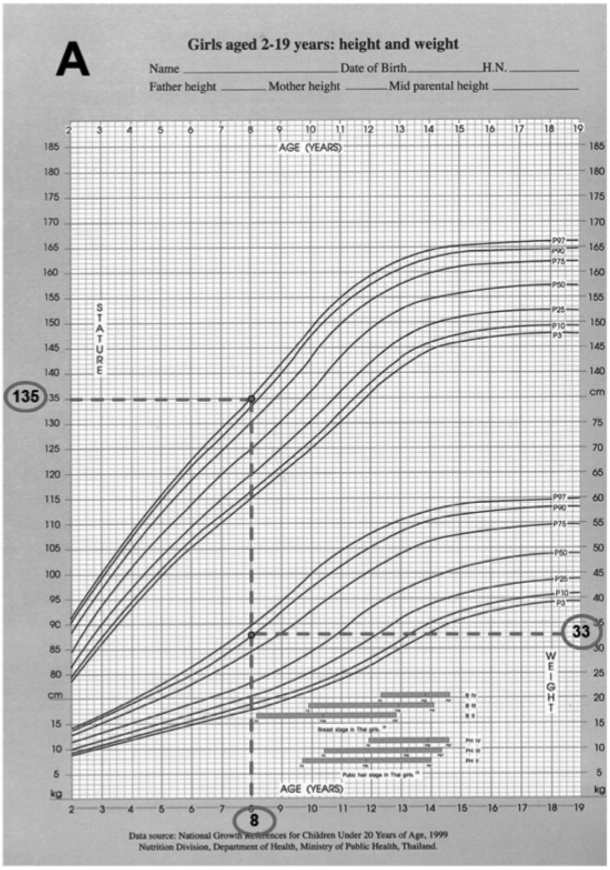
TABLE 3. HEIGHT BY AGE : BOYS

อายุ			PERCENTILES																	STANDARD DEVIATIONS						
ปี	เดือน	N	P3	P5	P10	P15	P20	P25	P30	P40	P50	P60	P70	P75	P80	P85	P90	P95	P97	-3SD	-2SD	-1SD	MEDIAN	+1SD	+2SD	+3SD
4	0	88	94.3	94.6	95.5	96.3	97.1	97.9	98.8	100.4	102.0	103.7	105.3	106.1	106.9	107.8	108.6	109.4	109.7	89.7	93.8	97.9	102.0	106.1	110.2	114.3
4	1	86	94.8	95.2	96.0	96.8	97.6	98.5	99.3	100.9	102.6	104.2	105.9	106.7	107.5	108.3	109.2	110.0	110.3	90.3	94.4	98.5	102.6	106.7	110.8	114.9
4	2	92	95.4	95.7	96.5	97.3	98.2	99.0	99.8	101.4	103.1	104.8	106.4	107.3	108.1	108.9	109.8	110.6	110.9	90.8	94.9	99.0	103.1	107.3	111.4	115.6
4	3	93	95.9	96.2	97.1	97.9	98.7	99.5	100.3	102.0	103.6	105.3	107.0	107.8	108.7	109.5	110.3	111.2	111.5	91.3	95.4	99.5	103.6	107.8	112.0	116.2
4	4	84	96.4	96.8	97.6	98.4	99.2	100.0	100.9	102.5	104.1	105.8	107.5	108.4	109.2	110.1	110.9	111.8	112.1	91.9	96.0	100.0	104.1	108.4	112.6	116.9
4	5	102	97.0	97.3	98.1	98.9	99.8	100.6	101.4	103.0	104.7	106.4	108.1	108.9	109.8	110.7	111.5	112.4	112.7	92.4	96.5	100.6	104.7	108.9	113.2	117.5
4	6	96	97.4	97.7	98.6	99.4	100.2	101.0	101.9	103.5	105.2	106.9	108.6	109.5	110.4	111.2	112.1	113.0	113.3	92.8	96.9	101.0	105.2	109.5	113.8	118.2
4	7	94	98.0	98.4	99.2	100.0	100.8	101.6	102.4	104.1	105.7	107.5	109.2	110.1	110.9	111.8	112.7	113.6	113.9	93.5	97.6	101.6	105.7	110.1	114.4	118.8
4	8	89	98.5	98.8	99.7	100.5	101.3	102.1	102.9	104.6	106.2	108.0	109.7	110.6	111.5	112.4	113.3	114.1	114.5	93.9	98.0	102.1	106.2	110.6	115.0	119.4
4	9	86	99.0	99.3	100.2	101.0	101.8	102.6	103.5	105.1	106.8	108.5	110.3	111.2	112.1	113.0	113.8	114.7	115.1	94.4	98.5	102.6	106.8	111.2	115.6	120.0
4	10	100	99.5	99.8	100.7	101.5	102.3	103.1	104.0	105.6	107.3	109.1	110.8	111.7	112.6	113.5	114.4	115.3	115.6	94.9	99.0	103.1	107.3	111.7	116.2	120.6
4	11	82	100.0	100.3	101.2	102.0	102.8	103.7	104.5	106.2	107.8	109.6	111.4	112.3	113.2	114.1	115.0	115.8	116.2	95.3	99.5	103.7	107.8	112.3	116.7	121.2
5	0	84	100.4	100.7	101.6	102.4	103.3	104.1	105.0	106.7	108.3	110.1	111.9	112.8	113.7	114.6	115.5	116.4	116.8	95.7	99.9	104.1	108.3	112.8	117.3	121.8
5	1	96	100.9	101.2	102.1	102.9	103.8	104.6	105.5	107.2	108.9	110.7	112.5	113.4	114.2	115.1	116.0	116.9	117.3	96.2	100.4	104.6	108.9	113.3	117.8	122.3
5	2	82	101.4	101.7	102.6	103.4	104.3	105.1	106.0	107.7	109.4	111.2	113.0	113.9	114.8	115.7	116.6	117.5	117.8	96.6	100.9	105.1	109.4	113.9	118.4	122.9
5	3	97	101.9	102.2	103.1	103.9	104.8	105.6	106.5	108.2	109.9	111.7	113.5	114.4	115.3	116.2	117.1	118.0	118.4	97.1	101.4	105.6	109.9	114.4	118.9	123.4
5	4	97	102.3	102.6	103.5	104.4	105.2	106.1	107.0	108.7	110.4	112.2	114.0	114.9	115.8	116.7	117.6	118.5	118.9	97.5	101.8	106.1	110.4	114.9	119.4	123.9
5	5	90	102.8	103.1	104.0	104.9	105.7	106.6	107.5	109.2	110.9	112.7	114.5	115.4	116.3	117.2	118.1	119.1	119.4	98.0	102.3	106.6	110.9	115.4	120.0	124.5
5	6	89	103.3	103.6	104.5	105.4	106.2	107.1	108.0	109.7	111.4	113.2	115.0	116.0	116.9	117.8	118.7	119.6	119.9	98.5	102.8	107.1	111.4	116.0	120.5	125.0
5	7	85	103.7	104.1	104.9	105.8	106.7	107.6	108.4	110.2	111.9	113.7	115.6	116.5	117.4	118.3	119.2	120.1	120.5	98.8	103.2	107.6	111.9	116.5	121.0	125.5
5	8	80	104.2	104.6	105.5	106.3	107.2	108.1	108.9	110.7	112.4	114.2	116.1	117.0	117.9	118.8	119.7	120.6	121.0	99.4	103.7	108.1	112.4	117.0	121.5	126.1
5	9	101	104.6	105.0	105.8	106.7	107.6	108.5	109.4	111.1	112.9	114.7	116.6	117.5	118.4	119.3	120.2	121.1	121.5	99.6	104.1	108.5	112.9	117.5	122.0	126.6
5	10	77	105.1	105.5	106.4	107.2	108.1	109.0	109.9	111.6	113.4	115.2	117.1	118.0	118.9	119.8	120.7	121.7	122.0	100.2	104.6	109.0	113.4	118.0	122.6	127.2
5	11	86	105.5	105.9	106.8	107.7	108.6	109.5	110.3	112.1	113.9	115.7	117.6	118.5	119.4	120.3	121.3	122.2	122.5	100.6	105.0	109.5	113.9	118.5	123.1	127.7

Fig 1– Normative reference data for weight, height, and nutritional index for child and adolescent Thai population (age 1 day-19 years) published by the Ministry of Public Health, Thailand. **Left panel:** Front page of the reference book; **Right panel:** An example of normative data for height in Thai boys aged 4-5 years showing age, number of individuals, P3-P97 (P=percentile), median, and median ±1SD, ±2SD, and ±3SD. SD, standard deviation.



B Height-for-age z-scores in Thai girls

Height/length-for-age Z-scores (Thai girls, 1-8 years old)					
Age		Height/Length (cm)	Median	SD	Z-score
year	month				
7	11		124.3	5.1	-24.37
8	0	135	124.8	5.2	1.96
8	1		125.3	5.2	-24.10
8	2		125.8	5.2	-24.19
8	3		126.2	5.3	-23.81
8	4		126.7	5.3	-23.91
8	5		127.1	5.4	-23.54

C Weight-for-age z-scores in Thai girls

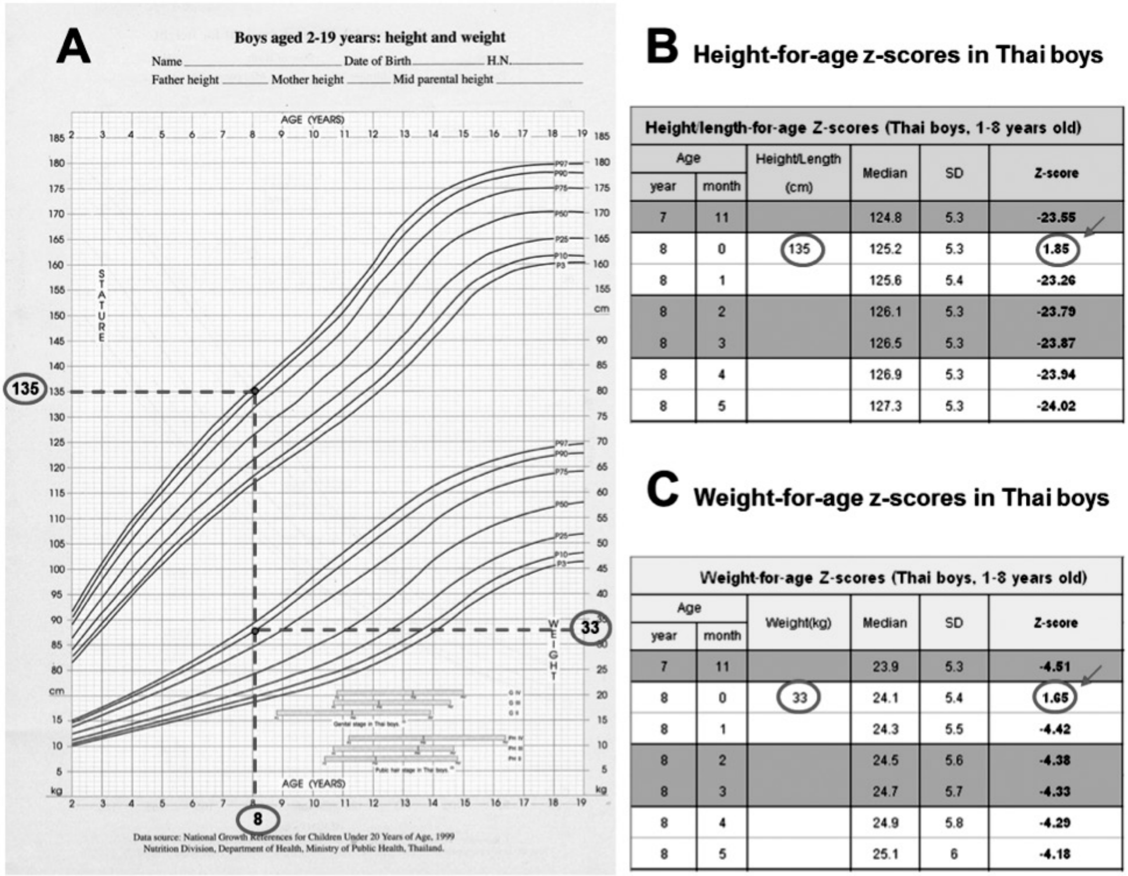
Weight-for-age Z-scores (Thai girls, 1-8 years old)					
Age		Weight(kg)	Median	SD	Z-score
year	month				
7	11		23.4	5.9	-3.97
8	0	33	23.6	6	1.57
8	1		23.8	6.1	-3.90
8	2		24	6.2	-3.87
8	3		24.2	6.3	-3.84
8	4		24.5	6.4	-3.83
8	5		24.7	6.5	-3.80

Fig 2– (A) Demonstration of how the *THAI-Z* program works in an 8-year-old Thai girl with (B) height of 135 centimeters (cm) and (C) body weight of 33 kilograms (kg). SD, standard deviation.

program, we used data from 400 Thai pediatric thalassemic patients and 381 normal Thai children to calculate the HAZ and WAZ. We then compared that data to results from manual calculation that was performed using data from Thailand's national growth reference table and a calculator. We calculated height and weight data from 781 individuals that ranged in age from 1 to 20 years. In addition, our dataset included data of both normal and abnormal growth and development due to chronic disease (thalassemia disease; β-thalassemia, Hb H disease, and Hb E/β-thalassemia). The results of our comparative analysis revealed 100% accuracy from the *THAI-Z* program, compared to 99.68% accuracy from manual calculation (Table 2). Moreover, manual calculation required more time than *THAI-Z* program to achieve measurement of HAZ and WAZ (11.3 *vs* 5.4 seconds per sample, respectively) (Table 2). These results confirm that the *THAI-Z* program is more simple, more accurate, and less time-consuming to use than manual calculation.

DISCUSSION

The *THAI-Z* program has been extensively tested in routine clinical practice and in several clinical research studies conducted at our center. For example, *THAI-Z* was used in growth and height studies in the development of Thailand's first normative reference data for bone mineral density (BMD) (Nakavachara *et al*, 2014) and in



Height/length-for-age Z-scores (Thai boys, 1-8 years old)

Age year	Age month	Height/Length (cm)	Median	SD	Z-score
7	11		124.8	5.3	-23.55
8	0	135	125.2	5.3	1.85
8	1		125.6	5.4	-23.26
8	2		126.1	5.3	-23.79
8	3		126.5	5.3	-23.87
8	4		126.9	5.3	-23.94
8	5		127.3	5.3	-24.02

Weight-for-age Z-scores (Thai boys, 1-8 years old)

Age year	Age month	Weight(kg)	Median	SD	Z-score
7	11		23.9	5.3	-4.51
8	0	33	24.1	5.4	1.65
8	1		24.3	5.5	-4.42
8	2		24.5	5.6	-4.38
8	3		24.7	5.7	-4.33
8	4		24.9	5.8	-4.29
8	5		25.1	6	-4.18

Fig 3– (A) Demonstration of how the *THAI-Z* program works in an 8-year-old Thai boy with (B) height of 135 centimeters (cm) and (C) body weight of 33 kilograms (kg). SD, standard deviation.

Table 2
Accuracy and efficacy of *THAI-Z* program compared to manual calculation using data from 400 pediatric thalassemic Thai patients and 381 normal Thai children.

Method	Error (%)		Average error (%)	Total time spent (minutes)		Average total time spent/ sample (seconds)
	Thalassemic patients (*n*=400)	Normal children (*n*=381)		Thalassemic patients (*n*=400)	Normal children (*n*=381)	
Manual calculation for HAZ and WAZ	2/800 (0.25)	3/762 (0.39)	0.32	153	142	11.3
THAI-Z program for HAZ and WAZ	0/800 (0)	0/762 (0)	0	73	68	5.4

HAZ, height-for-age z-score; WAZ, weight-for-age z-score.

several endocrinology studies, including vitamin D levels (Nakavachara and Viprakasit, 2013a) and adrenal function and pubertal development in HbE/β thalassemia (Nakavachara and Viprakasit, 2013b).

In addition to being a simple and beneficial tool for clinical evaluation among pediatricians and research scientists in Thailand, *THAI-Z* may also be useful for physicians and researchers in neighboring countries like Lao PDR, Cambodia, Vietnam, Malaysia, and Myanmar. In addition to sharing geopolitical borders and a comparable level of health and socioeconomic development with Thailand, people in these countries also share a similar genetic background that results in similar anthropometric measurements. Moreover, some of these countries do not currently have normative reference data for their populations. As such, the *THAI-Z* program may have more practical usefulness than comparing their data with normative reference data for Caucasian population or with the WHO database, which does not have normative reference data for Southeast Asians as a subset of Asians.

The main limitation of our study is our normative reference data used was nearly 20 year old since it was surveyed and published in 1999. Due to significant improvement in our public health, socioeconomic status, household income and nutritional supports in Thailand during the last two decades, it is highly possible that our current normative data for height and weight of Thai children and adolescent in 2017 must be different from the previous survey. This limitation has also been observed earlier that different WAZ and HAZ could be calculated when two normative dataset from 1977 and 2007 were used (de Onis *et al*, 2007). Nevertheless, our program could be easily 'upgraded' when a new normative data of Thai population would become available.

In summary, we have successfully developed a user-friendly Microsoft® Excel-based program for calculating WAZ and HAZ in Thai children and adolescents. *THAI-Z* program is more accurate and faster than the manual height and weight measurement method. In addition to the associated benefits of use in Thai population, *THAI-Z* could facilitate clinical evaluation and clinical research regarding growth development among normal children and those with underlying disease conditions in other pediatric populations in Southeast Asia.

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CONFLICTS OF INTEREST

All authors declare no conflicts of interest.

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