

# Implications of using World Health Organization growth reference (2007) for identifying growth problems in Hong Kong children aged 6 to 18 years

CME

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**Objective** To evaluate the implications of replacing Hong Kong's 1993 growth references (HK1993) with the World Health Organization's 2007 references (WHO2007) for children aged 6 to 18 years.

**Design** Cross-sectional study.

**Setting** Thirty-six randomly selected primary and secondary schools in Hong Kong.

**Participants** A total of 14 842 children and adolescents aged 6 to 18 years in Hong Kong during 2005/06.

**Main outcome measures** Creation of age-specific z-scores for height, weight, and body mass index relative to HK1993 and WHO2007 references.

**Results** Use of WHO2007 instead of HK1993 could classify an additional 1.4% children aged 6 to 10 years and 2.8% children aged 11 to 18 years as having a short stature. Using WHO2007, respective proportions that could be classified as underweight and obese increased by 3.5% and 2.1% among children aged 6 to 10 years, and 5.5% and 1.6% among children aged 11 to 18 years.

**Conclusions** Use of WHO2007 could increase clinical workload and patient and parent anxiety by 'over-diagnosing' short stature and underweight. Although WHO2007 may have a role in international comparative research, retention of HK1993 would seem appropriate from a clinical perspective.

## Introduction

An appropriate growth chart is an essential tool for the screening, surveillance, and monitoring of children's growth, since abnormal growth may be an early sign of significant illness.<sup>1</sup> On 27 April 2006, the World Health Organization (WHO) launched new Child Growth Standards (CGS) for children aged 0-5 years based on the growth of optimally (breastfed) infants from six countries ([www.who.int/childgrowth](http://www.who.int/childgrowth)). The WHO suggested that Ministries of Health, national paediatric associations and other policy-makers decide whether to officially adopt these new standards for their respective populations. In 2007, WHO published revised growth reference curves for the age-group 5-19 years (WHO2007).<sup>2</sup> The sample for 5-19 years was pooled from two United States datasets. The first and second datasets were from the Health Examination Survey Cycle II (6-11 years) and Cycle III (12-17 years). These data were collected during the period 1963-74. These references were reconstructed to be in accordance with the WHO CGS (0-5 years) for preschool children and with body mass index (BMI) cut-offs for adults.<sup>3</sup>

Primary health care providers are alerted to the possibility of health problems in children who are 'too thin', 'too short', 'too tall', and 'too fat'. The new WHO CGS (0-5 years) were developed in recognition that exclusively breastfed infants tend to be thinner than formula-fed infants, and since existing standards had been developed with data from predominantly formula-fed infants, there was considered a risk of over-diagnosing 'failure to thrive' in breastfed infants. A number of other limitations in the references for older children and adolescents have also been highlighted.<sup>4</sup> In particular, WHO growth references for both 0-5 years and 5-19 years assume that there are no genetic differences in the growth of different ethnic populations and that the references are universally applicable.

Hong Kong's current growth references for children aged 0-18 years were developed from data collected in 1993 (HK1993).<sup>5,6</sup> These references are widely used in Hong Kong

### Key words

Child development; Growth; Puberty;  
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to assess child growth in clinical practice, public health programmes and research. In virtually all populations, secular changes in body size in terms of height and weight, and also BMI, have been noted over generations.<sup>7</sup> In 2005/06 we conducted a growth survey of children aged 6-18 years using the same methodology as the 1993 study to assess these secular trends in height, weight and BMI.<sup>8</sup> The resulting data demonstrated an increase in the prevalence of obesity in both boys and girls, but not in the final height. We suggested that the decision on whether Hong Kong should continue using the current HK1993 growth reference charts for children aged 6-18 years or whether to adopt the new WHO2007 references for children aged 5-19 years (weight references only available for children 5-10 years) would require further comparisons and discussions with stakeholders.

We now assess the potential implications of replacing HK1993 with WHO2007 in Hong Kong children aged 6-18 years.

## Methods

### HK1993 data

The 1993 growth survey included 24 509 children from birth to 18 years. These data were used to develop Hong Kong's current growth charts for weight, height, weight-for-age, weight-for-height and BMI ( $\text{kg}/\text{m}^2$ ).<sup>5-7</sup> In addition, these data formed part of the dataset used to develop international BMI cut-offs.<sup>9</sup>

### HK2005/06 data

During the 2005/06 school year, a cross-sectional survey of 14 842 children and adolescents aged 6-18 years from Hong Kong's 18 districts was undertaken. All subjects in this study were apparently healthy children. Details of the study methods have been reported elsewhere.<sup>8</sup>

### WHO2007 data

The z-scores of the WHO2007 charts were calculated with the LMS values downloaded from the WHO website (<http://www.who.int/growthref/>). The Box-Cox power exponential (BCPE)<sup>10</sup> method was used in the construction of WHO2007,<sup>2</sup> which is similar to the LMS method used for HK1993. The WHO2007 charts only contain data on weight for ages 6-10 years, whereas data for height and BMI are available for ages 6-18 years.

### Statistical analysis

The z-score (z) for a given measurement (X) was calculated as:  $z = ((X/M)^L - 1)/(L * S)$  if  $L \neq 0$  or  $z = \log(X/M)/S$  if  $L = 0$ ; L (Box-Cox power to transform the data

## 使用2007年世界衛生組織學齡兒童和青少年生長參考標準來為香港六歲至十八歲人士分析發育問題的影響

**目的** 探討使用2007年世界衛生組織學齡兒童和青少年生長參考標準 (WHO2007) 代替1993年香港生長參考標準 (HK1993) 來為六歲至十八歲兒童和青少年分析生長發育問題所帶來的影響。

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**安排** 香港隨機抽樣的36間中學及小學。

**參與者** 2005/06年期間共14842位六歲至十八歲兒童和青少年。

**主要結果測量** 根據HK1993及WHO2007生長參考標準來制定高度、重量及身體質量指數的年齡別Z分值。

**結果** 如果使用WHO2007生長參考標準來代替HK1993，會分別為六至十歲兒童及十一至十八歲青少年兩個組別多界定以下指數：身材矮小分別多出1.4%及2.8%；體重過輕分別多出3.5%及5.5%；過胖分別多出2.1%及1.6%。

**結論** 使用WHO2007生長參考標準可能會過度診斷身材矮小及體重過輕的兒童。這樣不但會增加醫療服務的重擔，更引發兒童及家長憂慮。雖然WHO2007生長參考標準在國際比較研究中佔一席位，但從臨床角度去分析，繼續使用HK1993生長參考標準會更為適合。

that follow a normal distribution), M (median) and S (coefficient of variation).<sup>11</sup>

Comparisons were undertaken to estimate the prevalence of shortness, underweight, and overweight in the HK 2005/06 children aged 6-18 years, using either the WHO2007 or the HK1993 growth charts and the common percentile cut-off values as used in Hong Kong (3rd, 97th) or recommended by WHO expert committee (5th, 95th).<sup>12</sup> A child was classified as stunted if the height z-score was below -1.6 (5th centile) and as underweight if the weight z-score or BMI z-score were below -1.6 (5th centile). A further category of height and BMI below the 3rd centile was also examined, since this reflects current guidelines for referral from Hong Kong Department of Health's primary medical care facilities (KH Mak, personal communication). Meanwhile, a child was classified as obese if the BMI z-score was above 1.6 (95th centile). The BMI and height-age z-score curves by gender from -1.6 to 1.6 were created for the comparison between WHO2007 and HK1993. To determine the secular trends between 1993 and 2005/06, the height-age z-score curves by gender derived from the HK2005/06 data were also compared with the WHO2007 growth reference. The study was approved by the Joint Chinese University of Hong Kong – New Territories East Cluster Clinical Research Ethics Committee.

## Results

The 2005/06 dataset was used to generate a comparison table for BMI and height status using either the HK1993- or WHO2007-derived references (Table).

### Body mass index comparisons

If HK1993 were to be replaced by WHO2007, 3.5% of children aged 6-10 years and 5.5% of those aged 11-18 years would be reclassified as low BMI (underweight) and 2.1% of children aged 6-10 years and 1.6% of those aged 11-18 years as obese (Table). If the 3rd percentile is used as a more stringent criterion for referral to hospital for further investigation and management of underweight, an extra 2.5% and 3.6% of the children aged 6-10 years and 11-18 years, respectively, would be identified by the WHO2007 references.

### Height comparisons

If HK1993 were to be replaced by WHO2007, 1.4% of children aged 6-10 years and 2.8% of those aged 11-18 years would be reclassified as having short stature (Table). Using the 3rd percentile as the cut-off, an extra 0.7% and 1.6% of the children aged 6-10 years and 11-18 years would be referred to the hospital as having short stature, respectively, using WHO2007 references.

### Z-score curves

The BMI-for-age z-scores calculated from HK1993 were generally more widely distributed than those derived from WHO2007 with the differences being more pronounced in the upper curves, particularly for boys (Fig 1). The height-for-age z-scores calculated from HK1993 showed a distinct fall-off compared to

those derived from WHO2007 from around the age of 12 years for both boys and girls (Fig 2a and 2b). The height-for-age z-scores calculated for HK2005/06 showed a similar pattern to those for HK1993 with a fall-off from 12 years, although for younger children the HK2005/06 curves more closely matched WHO2007 (Fig 2c and 2d).

## Discussion

If Hong Kong were to replace its HK1993 references with WHO2007, approximately 5% of children currently considered normal weight could be identified as underweight, and 1.4% of children aged 6-10 years and 2.8% of those aged 11-18 years who are currently considered normal height would be classified as short. Assuming a birth cohort of 50 000, this could represent as many as 2500 additional referrals for investigation of underweight and 1000 for short stature. These findings have important policy implications, particularly because these differences could be due to environmental and/or genetic factors.<sup>4,13</sup>

WHO2007 references are based on data collected in the United States during the 1970s, two decades prior to collection of data to develop HK1993 references.<sup>2</sup> Although WHO tried to identify existing growth datasets from various countries, after further review, even the most promising studies showed great heterogeneity in methods and data quality, sample size, age categories, socioeconomic status of participating children, and various other factors critical to growth curve construction.<sup>2</sup> Although some have argued for universal growth references, this highlights likely ethnic and socioeconomic differences. Therefore the key question for clinicians in Hong Kong to address is whether these additional

TABLE. Comparison of the estimated prevalence of shortness, underweight, and overweight in the HK 2005/06 data for children aged 6-18 years, using either the WHO2007 or the HK1993 growth charts, with the commonly used percentile cut-off values in Hong Kong and that recommended by World Health Organization\*

Age-group (years)	Chart	Percentile cut-off	Short stature Height-for-age (%)	Underweight BMI-for-age (%)	Obese BMI-for-age (%)
6-10 years					
	WHO2007	5th/95th	3.2	5.9	14.5
	HK1993	5th/95th	1.8	2.4	12.4
	WHO2007	3rd/97th	1.7	3.8	11.8
	HK1993	3rd/97th	1.0	1.3	7.4
11-18 years					
	WHO2007	5th/95th	5.7	9.0	10.0
	HK1993	5th/95th	2.9	3.5	8.4
	WHO2007	3rd/97th	3.3	5.8	6.3
	HK1993	3rd/97th	1.7	2.2	4.6

\* Cut-offs for short stature and underweight are 5th or 3rd percentile; cut-off for obese is 95th or 97th percentile; BMI denotes body mass index

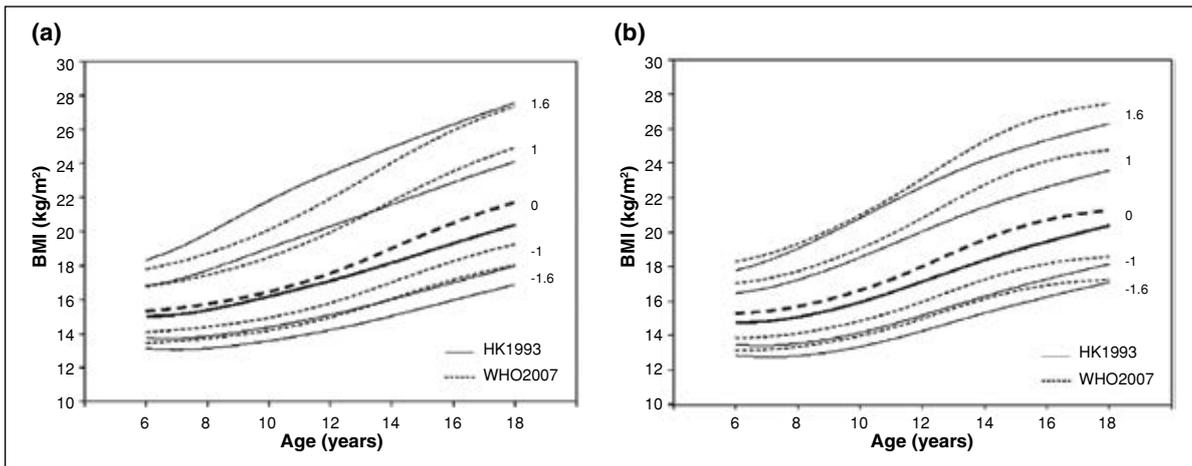


FIG 1. Comparison of body mass index (BMI)-for-age z-score curves: (a) HKI1993 vs WHO2007 for boys, and (b) HKI1993 vs WHO2007 for girls

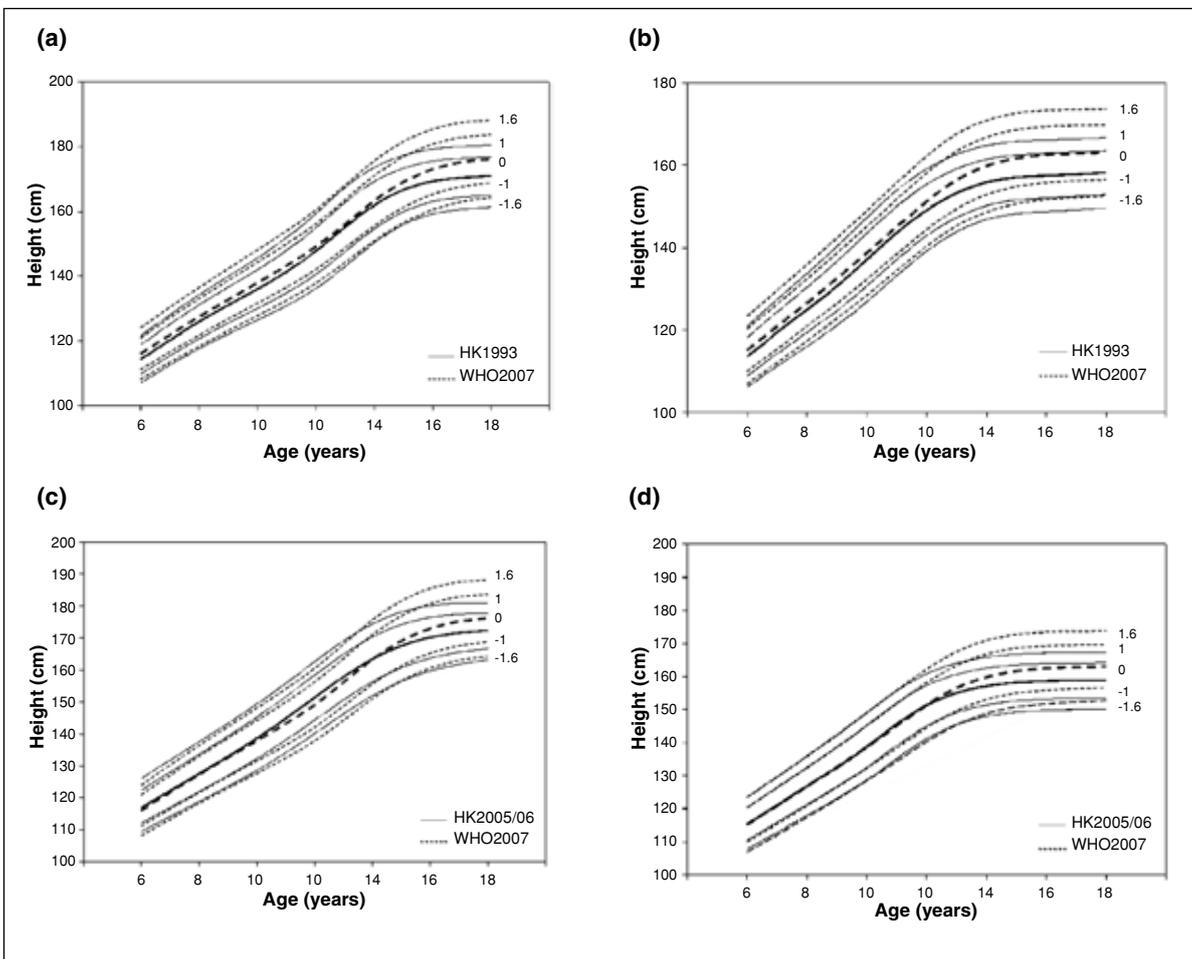


FIG 2. Comparison of height-for-age z-score curves: (a) HKI1993 vs WHO2007 for boys, (b) HKI1993 vs WHO2007 for girls, (c) HK2005/06 vs WHO2007 for boys, and (d) HK2005/06 vs WHO2007 for girls

'underweight' and/or 'short' children identified by WHO2007 are normal healthy genetically smaller children, or whether they reflect nutritional or other factors negatively impacting growth. Given Hong Kong's ranking among the top 20 most affluent nations, and given its impressively low infant and under-5 mortality rates, the argument that these

are healthy well-nourished genetically smaller children seems more persuasive, although difficult to prove. Retaining HK1993 for clinical use might underestimate obesity relative to WHO2007 in younger boys and overestimate it in older girls (Fig 1). In practice, however, referral for assessment of overweight only occurs in more extreme cases, that

is, at BMIs well above the cut-offs. Likewise retention of HK1993 could result in more older children being considered 'too tall'. Since being tall is often viewed positively, it is likely that referral will only occur in more extreme cases when clinical syndromes or medical conditions are suspected. Sex maturation could account for disparities between the WHO and Hong Kong z-score curves, which were larger among the older adolescents. We did not document pubertal development in our study, but a previous study reported that Hong Kong Chinese adolescents experienced menarche at 12.1 (1.2) years for girls and the first nocturnal ejaculation at 13.0 (1.7) years for boys,<sup>14</sup> of which the figures are similar to WHO data.<sup>15</sup>

Application of an international growth references to a specific population can lead to underestimation or overestimation of the real growth.<sup>16</sup> The Growth Reference Review Group in the United Kingdom recommended that local growth references should be changed only when shown to be no longer reliable for use at any specific age.<sup>17</sup> A similar conclusion was reached in Hong Kong regarding the use of WHO CGS (0-5 years).<sup>16</sup> The latter study utilised data from a Hong Kong birth cohort of 8327 predominantly formula-fed infants born in April and May 1997, and concluded that Hong Kong Chinese toddlers were, on average, shorter than the new WHO CGS (0-5 years). This appeared contrary to the WHO study group's conclusion that there was a striking similarity in length/height among different populations. The Hong Kong authors concluded that a universal infant growth standard may not be appropriate across all populations. Another study concluded that using WHO2007 references could increase the number of children considered to be in need of closer surveillance or intervention, especially among adolescents,<sup>13</sup> and that these differences may relate to genetic factors.<sup>4,13</sup> If WHO2007 references were to be used in China, there could be an increase in the prevalence of short stature and underweight with 5.8 million children co-affected with both conditions.<sup>18</sup>

Despite these reservations about WHO2007, there may still be a role for these references in research involving international comparisons of growth. The International Obesity Task Force's (IOTF) proposed cut-offs to define obesity have been widely used around the world. A number of studies have

determined the differences in the estimation of the prevalence of overweight and obesity in children and adolescents, based on these two international references (WHO2007 and IOTF) and found a significantly lower prevalence of obesity using IOTF cut-offs.<sup>18-21</sup> As yet there appears to be no consensus as to whether WHO2007 or the IOTF cut-offs should be used for international comparative studies in assessing overweight and obesity.

The strengths of this study include the availability of a large representative dataset to evaluate the two references developed from different data.<sup>8</sup> A possible limitation is that we determined the differences between WHO2007 and HK1993 references with the HK2005/06 dataset using a z-score calculation method and software provided on the WHO website (<http://www.who.int/growthref/>). Although the WHO2007 and HK1993 growth references were constructed with different methods (LMS method<sup>11</sup> was used for HK1993 and BCPE<sup>10</sup> for WHO2007), we do not consider this to have impacted our findings.

## Conclusions

Use of WHO2007 in Hong Kong could increase clinical workload and patient and parent anxiety by identifying additional 'underweight' and/or 'short' children. Whether these are normal healthy genetically smaller children or whether they reflect adverse environmental factors is arguable, but given Hong Kong's affluence the former argument seems more convincing. However further study with clinical data is required to determine the utility of HK1993, WHO2007, and HK2005/06 to positively and negatively predict medically significant growth problems in Hong Kong children. Although WHO2007 may have a role in international comparative research, for the time being at least, retention of HK1993 would seem appropriate for clinical use in Hong Kong.

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