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**AUTHOR QUERIES**

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Malaysian growth centiles for children under six years old

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Abstract

Background: Growth references are useful for the screening, assessment and monitoring of individual children as well as for evaluating various growth promoting interventions that could possibly affect a child in early life.

Aim: To determine the growth centiles of Malaysian children and to establish contemporary cross-sectional growth reference charts for height and weight from birth to 6 years of age based on a representative sample of children from Malaysia.

Methods: Gender- and age-specific centile curves for height and weight were derived using the Cole’s LMS method. Data for this study were retrieved from Malaysian government health clinics using a two-stage stratified random sampling technique. Assessment of nutritional status was done with the SD scores (Z-scores) of WHO 2006 standards.

Results: Boys were found to be taller and heavier than girls in this study. The median length of Malaysian children was higher than the WHO 2006 standards and CDC 2000 reference. The overall prevalence of stunting and underweight were 8.3% and 9.3% respectively.

Conclusions: This study presents the first large scale initiative for local reference charts. The growth reference would enable the growth assessment of a Malaysian child compared to the average growth of children in the country. It is suggested that the use of WHO 2006 Child Growth Standards should be complemented with local reference charts for a more wholesome growth assessment.

Introduction

The screening and monitoring of child development and growth are important aspects of a comprehensive child healthcare programme. Problems related to feeding difficulties, chronic illness, social deprivation and poor weight gain can be detected early through screening and growth monitoring. The United Nations Children’s Fund has recommended developing countries to conduct monthly growth monitoring for children up to 18 months old (UNICEF, 1990). Growth reference charts are essential components of the paediatric toolkit for monitoring child growth and development. The two types of growth charts, i.e., growth standards and growth references, can sometimes be confusing. Growth references indicate how the children are growing at the time when the references were constructed. They provide a basis for making comparisons, but deviations from the normal patterns do not necessarily indicate abnormal growth (Zorlu, 2011). On the other hand, growth standards are based on longitudinal data and embrace the notion of a norm and, therefore, provide a more effective guide to improve healthy development and growth of a child.

Height- and weight-based anthropometric measurements are usually used for evaluating the general nutritional status of a population. Comparison of height and weight measurements of an individual with the reference population offers indications of normal or abnormal growth. Their use is not confined to medical practitioners in the field of paediatrics, genetics or epidemiology to assess the growth status of a child, but also as a public tool to summarize and compare the auxological characteristics among children (Cole, 2006). Subjects with unusual measurements might have normal health, but the anthropometric data can help clinicians and public health workers to diagnose or detect preliminary growth-related disorders. Regular assessment of growth patterns among children is a major preventive tool in detecting underweight individuals from low socio-economic groups as well as overweight or obese individuals from higher socio-economic levels (WHO, 1978).

Studies on the height and weight of Malaysian children had been carried out in the early 1950s and 1960s. The first report on height and weight of pre-school children was made in Singapore by Millis (1957, 1958). Thomson (1961) reported on the weight of children in the same age group. Reference charts used in Malaysia are currently based on the 2006 World Health Organizations (WHO) Child Growth Standards and the...
Center for Disease Control and Prevention (CDC) 2000
growth references. A local growth reference is more practical
for growth comparison among children from a similar
environment. International growth charts may be useful for
comparing different countries, but regional or national
references are more relevant in the assessment of local
changes in nutritional status (Eveleth & Tanner, 1990).
Furthermore, the use of WHO 2006 standards for assessing
nutritional status might over-report the prevalence of stunting
and underweight. The results reported here are the first
large scale attempt to develop representative growth
reference charts for Malaysian infants and children from
birth to 6 years old.

Methods

Data acquisition

The study protocol was approved by the Malaysian Institute of
Public Health following a review process. All ethical issues
were considered prior to commencing the study. The research
conforms to the conditions as stated by the Ethics Committee.
No clinical interventions were carried out on the sampled
subjects. Formal permissions were subsequently obtained
from the State Health Division and the Maternal and Child
Health Clinics (MCH) from the five major regions in
Malaysia: Northern, Southern, East Coast, West Coast and
East Malaysia regions. The data were retrieved from health
clinic-based archives and confidentiality of the data was rest
assured.

Subjects were recruited based on a two-stage stratified
cluster sampling technique. In the first stage of the sampling
process, states (primary unit) were randomly selected from
each region. Nine out of 13 states were chosen from these five
regions. In the second stage, MCH clinics were identified and
collected from each state. MCH clinics with the highest child
attendance rate and complete birth records were selected.
Records of all healthy children without any pre-natal disease
were retrieved. These records characterized the general
children population in terms of age, ethnicity and socio-
demographic background. A total of 11 government clinics
from both urban and rural areas were subjected to this study.
All children followed the immunization programme in the
local MCH Clinics. Exclusion criteria were premature child,
children with chronic diseases affecting growth and those
diagnosed by clinicians as unwell or acutely ill. Both
breastfed and formula-fed babies were considered to ensure
an unbiased sample.

The experimental design for this study was multi-centric
and cross-sectional. The child population below 6 years of age
in Malaysia was estimated at 3.2 million, as reported in the
Department of Statistics 2010 (revised) document (Malaysia
DOS, 2012). The sample size, \( n \), was thus calculated from
Yamane’s (1967) formula as follows:

\[
    n = \frac{N}{1 + N(e^2)}
\]

where \( N \) is the population size and \( e \) is the level of precision.
The confidence level for sample size determination indicated
that a size of 15 006 produced a 99.2% confidence interval
with a precision of 0.8%. Thus, the sample size of 15 474 was
deemed sufficient as it represents 0.5% of the children in
Malaysia.

Data were obtained from anthropometric measurement
records kept in the MCH clinics. Manual measurements were
done by qualified and well-trained nurses and healthcare
personnel. Data collection took ~6 months from February–July 2011. Length of an infant or toddler below 2 years old
was measured when lying down, while for children 2 years and
above, the standing height measurement was taken. Supine length was measured using a measuring board and an
infant scale was used to measure birth weight. Two nurses
usually worked together to record body length, with one
holding the head of the child gently and the other moving the
footboard towards the heel. An optimal measurement is
obtained when the child is relaxed with the leg straightened
and the head positioned in the Frankfurt plane. For children
who are able to walk, height was taken in standing position to
the nearest centimetre using a stadiometer. Weight was
measured using the infant scale, with accuracy to the nearest
10 grams, by laying the baby on an infant scale with clothing
removed to increase accuracy. A standing weight scale was
used when the children were 2 years and above.

Statistical analysis

The data were edited before being subjected to statistical
analysis and curve sketching. Subjects with missing data and
those suspected to have growth disorders such as primary
growth abnormalities, secondary growth disorders and endo-
crine disorders (Batubara et al., 2006) were excluded from the
study. Data were analysed with the LMSChartmaker
programme (Pan & Cole, 2011) which fits smooth centile curves
using the LMS method described by Cole & Green (1992).
The LMS method summarizes each standard with three
smooth curves, where the L curve represents the power
needed to normalize the data, the M curve represents the
generalized mean or median and the S curve is the coefficient
of variation of the distribution at each age. These three curves
can be fitted as cubic splines by non-linear regression using
penalized likelihood. The smoothing required can be
expressed in terms of smoothing parameters or equivalent
degrees of freedom (EDFs). Growth charts were then
developed through fitting the least square polynomial regres-
sion model, using age as the independent variable and the
percentiles as dependent variables.

Raw non-parametric centiles of height and weight distribu-
tions show irregular patterns for cross-sectional data
(Cacciari et al., 2002). Height tends to be normally
distributed, but weight does not strictly follow a normal
distribution. This method assumes that the data can be
normalized using a power transformation, stretching one tail
of the distribution and shrinking the other, thus removing the
skewness (Cole, 1990). This method fitted the skewed data
adequately and generated fitted curves that followed closely
the empirical data. The initial smoothing methods were
applied to all seven empirical percentiles (3rd, 10th, 25th,
50th, 75th, 90th and 97th) for each age and gender. The final
set of percentile curves were produced by using the modified
LMS estimation procedure in the LMSChartmaker
programme.
From the $L(t), M(t)$ and $S(t)$ values for each half-year age $(t)$, the 100th centile was derived from the equation

$$C_{100}(t) = M(t)\frac{1}{1 + L(t)S(t)Z_0(t)}.$$  

The SD scores (Z-scores) of height and weight were calculated from the $L$, $M$ and $S$ values for the child’s age and gender. Nutritional status comparison was made with the SD scores for the WHO 2006 Child Growth Standards (WHO, 2006). The cut-off points of the SD scores were ±2 SD, as recommended by the WHO Global Database on Child Growth & Malnutrition (1997), since 95% of the distribution is defined as statistically normal. In particular, nutritional status outcomes of height-for-age SD score and weight-for-age SD score were considered in this study. The nutritional status for height and weight indicators were defined as in Table 1.

**Results**

The total number of children sampled in this study was 15,474, of which 50.94% ($n = 7882$) were boys and 49.06% ($n = 7592$) were girls. Malaysian boys outnumbered girls with the gender ratio of 1:0.96. Mean values (± standard deviations) by gender and age are presented in Table 2. Selected percentiles (3rd, 10th, 25th, 50th, 75th, 90th and 97th) and their LMS values for children’s recumbent length/height and weight are shown in supplementary materials. Smooth centile curves by gender were generated using the LMSChartmaker software (Figure 1).

Body length varied the most among infants and toddlers (aged 1–3 years old), especially at 1 year of age. Mean values for recumbent length/height increased with age for both genders. Boys were significantly longer/taller than girls, especially from 3–12 months old and from 2–3 years old ($p > 0.05$). Both genders showed high growth velocities in stature from birth to 1.5 years old. Birth weights were not significantly different between genders, with mean values of 3.06 kg for boys and 3.09 kg for girls, respectively. However, the weight percentiles diverged as they grew older (Figure 1c and d). The weight curves showed a similar pattern with the height curves, in that the boys were heavier than girls for almost all age groups, except at birth (newborns), 4.5 years old and 5.5 years old. A total of 2.34% of children were estimated as falling below the 3rd percentile, while nearly 2.51% were above the 97th percentile. Tables 3 and 4 were presented to facilitate the differences between centile curves constructed from this study with the CDC growth references and the WHO growth standards. Graphical comparisons are illustrated in Figures 2 and 3 for our datasets and the WHO standards. Comparison was made for the −2 SD, median and +2 SD in order to better deal with the risks of stunting and under-nutrition. Malaysian children were born with longer bodies (50.05 cm for boys and 50.01 cm for girls) in comparison with the WHO standards and the CDC references (Table 3). At birth, the median obtained from this study is the highest compared to the WHO standards and CDC references. However, the median obtained from this study for both boys and girls were the lowest from 0.5–6 years old (Table 3). The WHO standards values for −2 SD were the highest at all ages. The weight values showed similar results in Table 4.

The prevalence of stunting and underweight were determined using our datasets and the WHO 2006 standards (Table 5). Our data-sets revealed a much lower percentage for prevalence of stunting and underweight compared to the WHO 2006 standards (2.2% for both). However, a total of 8.3% of children were stunted and 9.3% were underweight using the WHO 2006 standards as cut-offs. The prevalence of stunting and underweight among boys (9.8% and 11.1%, respectively) were higher than girls (6.7% and 7.4%, respectively). A definite trend was not observed in the age-specific stunting and underweight of both genders.

**Discussion**

To the best of our knowledge, this is the first large scale study to determine the growth characteristics of Malaysian children from birth to 6 years of age. Generally, boys were bigger in size than girls, a result in agreement with that obtained by Guaran et al. (1994) in Australia. Both genders had peak growth velocities in stature from birth to 1.5 years old. The growth velocities in height gradually decreased after this age range. Girls were slightly taller and heavier at the ages of 4.5 and 5.5 years, suggesting a small pre-pubertal (or mid-childhood) growth spurt for girls during infancy.

**Table 2. Descriptive statistics (means ± standard deviations) of height and weight for studied subjects from birth to 6 years old ($n = 15,474$).**

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age (years)</th>
<th>Number of subjects</th>
<th>Height (cm) (Mean ± SD)</th>
<th>Weight (kg) (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys ($n = 7882$)</td>
<td>At birth</td>
<td>38</td>
<td>50.05 ± 4.41</td>
<td>3.06 ± 0.47</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>3729</td>
<td>60.27 ± 6.12</td>
<td>5.75 ± 1.54</td>
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<tr>
<td></td>
<td>1.0</td>
<td>1625</td>
<td>73.53 ± 4.20</td>
<td>8.76 ± 1.25</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>577</td>
<td>78.42 ± 4.87</td>
<td>9.62 ± 1.45</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>499</td>
<td>85.74 ± 5.42</td>
<td>11.13 ± 1.66</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>320</td>
<td>89.30 ± 4.97</td>
<td>11.74 ± 1.87</td>
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<tr>
<td></td>
<td>3.0</td>
<td>317</td>
<td>94.43 ± 5.59</td>
<td>13.24 ± 2.56</td>
</tr>
<tr>
<td></td>
<td>3.5</td>
<td>221</td>
<td>97.26 ± 7.67</td>
<td>13.71 ± 2.71</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
<td>216</td>
<td>101.45 ± 6.59</td>
<td>15.13 ± 3.34</td>
</tr>
<tr>
<td></td>
<td>4.5</td>
<td>130</td>
<td>104.02 ± 5.85</td>
<td>15.37 ± 3.43</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
<td>78</td>
<td>107.90 ± 7.62</td>
<td>17.85 ± 4.86</td>
</tr>
<tr>
<td></td>
<td>5.5</td>
<td>83</td>
<td>109.86 ± 7.94</td>
<td>18.35 ± 4.57</td>
</tr>
<tr>
<td></td>
<td>6.0</td>
<td>49</td>
<td>113.98 ± 7.37</td>
<td>20.33 ± 4.82</td>
</tr>
<tr>
<td>Girls ($n = 7592$)</td>
<td>At birth</td>
<td>52</td>
<td>50.01 ± 6.20</td>
<td>3.09 ± 0.46</td>
</tr>
<tr>
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<td>0.5</td>
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<td>59.14 ± 5.88</td>
<td>5.36 ± 1.39</td>
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<td>72.32 ± 4.03</td>
<td>8.21 ± 1.09</td>
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<td>88.20 ± 4.84</td>
<td>11.33 ± 1.81</td>
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<td>12.87 ± 2.57</td>
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<td>14.94 ± 2.85</td>
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<td>104.11 ± 5.63</td>
<td>15.39 ± 3.16</td>
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<td>79</td>
<td>107.26 ± 6.94</td>
<td>16.65 ± 3.49</td>
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<tr>
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<td>5.5</td>
<td>70</td>
<td>111.73 ± 8.09</td>
<td>18.62 ± 3.70</td>
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<tr>
<td></td>
<td>6.0</td>
<td>70</td>
<td>113.40 ± 7.35</td>
<td>18.67 ± 3.67</td>
</tr>
</tbody>
</table>
Figure 1. Smoothed length-for-age/height-for-age and weight-for-age centiles for Malaysian boys and girls from birth to 6 years of age.
### Table 3. Length/height comparisons between present study with the WHO 2006 and CDC 2000 charts.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age 0.5</th>
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<th>2.5</th>
<th>3.0</th>
<th>3.5</th>
<th>4.0</th>
<th>4.5</th>
<th>5.0</th>
<th>5.5</th>
<th>6.0</th>
<th>Present study</th>
<th>WHO</th>
<th>CDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>1.61</td>
<td>2.40</td>
<td>3.02</td>
<td>4.18</td>
<td>2.40</td>
<td>3.20</td>
<td>4.20</td>
<td>2.35</td>
<td>3.40</td>
<td>4.31</td>
<td></td>
<td></td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Girls</td>
<td>1.61</td>
<td>2.40</td>
<td>3.02</td>
<td>4.18</td>
<td>2.40</td>
<td>3.20</td>
<td>4.20</td>
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<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
</tbody>
</table>

### Table 4. Weight comparisons between present study with the WHO 2006 and CDC 2000 charts.

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<tr>
<th>Gender</th>
<th>Age 0.5</th>
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<th>6.0</th>
<th>Present study</th>
<th>WHO</th>
<th>CDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
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<td>2.40</td>
<td>3.02</td>
<td>4.18</td>
<td>2.40</td>
<td>3.20</td>
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<td></td>
<td></td>
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<td>0.05</td>
</tr>
<tr>
<td>Girls</td>
<td>1.61</td>
<td>2.40</td>
<td>3.02</td>
<td>4.18</td>
<td>2.40</td>
<td>3.20</td>
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<td>4.31</td>
<td></td>
<td></td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Mid-childhood growth spurt, if present, typically occurs between 4–8 years old (Towne et al., 2008). Weight gain was faster from birth to 6 months of age among Malaysian children, probably due to improvements in nutritional and socio-demographic conditions leading to lower prevalence of under-nourishment (Bordom et al., 2008). Boys were heavier than girls, except at 4.5 and 5.5 years of age; however, the weight centiles diverged as they grew older, which was probably due to the diverse feeding regimes. Our data showed that birth weights of children from various ethnic groups were similar, which is in agreement with previous studies done in Singapore and Malaysia (Cheng et al., 1972; Prakash, 1972).
In contrast, a similar study conducted by Hof et al. (2011) found different birth weights between native Dutch and the immigrant children. Comparisons between the growth of Malaysian children and other populations are of practical and theoretical importance. It is now widely accepted that children around the world have fairly similar growth potential up to 7 years of age (de Onis & Blössner, 1997). However, like other Asians, Malaysians are smaller in size with relatively shorter legs and have less body fat as compared with the Western children. Another study conducted in Saudi Arabia (El Mouzan et al., 2008) also reported lower centiles as compared to the CDC references. These growth disparities may be due to the hereditary and environmental factors in addition to economic status.

Our analyses using the WHO 2006 standards revealed that the prevalence of stunting and underweight among Malaysian children below 6 years old was 8.3% and 9.3%, respectively. The nutritional status among Malaysian children has improved since the Third National Health and Morbidity Survey (NHMS) 2006 study, whereby the prevalence of stunting and underweight of children below 5 years old were 17.2% and 12.9%, respectively (Khor et al., 2009). More than 80% of Malaysian children were in the normal range for height-for-age and weight-for-age indicators. This finding supports the NHMS 2006 nutritional status reports (Khor et al., 2009). We also observed that about half of the children population in Malaysia exceeded the 50th percentile cut-offs on the WHO 2006 standards for height, while nearly one third for weight.

The 2006 WHO Child Growth Standards defines how children of the world, regardless of their ethnicity, should grow when optimal conditions in nutrition and health were provided. The 2006 WHO standards were based entirely on selective criteria and sample size of only 17% infants and 31% children of 2 years old and above (Cameron & Hawley, 2009). Furthermore, no children of Mongoloid origin (comprises more than 20% of the world’s population) were included in the study (Binns & Lee, 2012). Prescriptive approach and data truncation were applied during the analysis (Ziegler & Nelson, 2010). Similarly, the CDC 2000 growth references were based primarily on the US sample, thus under-estimating the physical growth of local healthy children (de Onis et al., 2007). In contrast, our data-sets provided a real situation of growth based on local children.

Recently, WHO published the survey of countries which implemented the standards (WHO, 2012). Although the WHO standards provided a good fit for length/height, they were more likely to diagnose a large number of apparently normal children in developing countries as being stunted (Khadiilkar & Khadiilkar, 2010). This was supported by Norris et al. (2009), who reported that the WHO 2006 standards identified...
children as being generally more stunted. By using the WHO 2006 standards, an additional 6.1% of children are defined as having stunted growth, with 7.1% as underweight, as compared to 2.2% for both stunting and underweight using our datasets (Table 5). A growth comparison of Belgian and Norwegian children with the WHO growth standards recommended that locally-developed growth references were more favourable rather than the 2006 WHO growth standards in terms of the growth discrepancies (Juliusson et al., 2011).

The WHO standards were not meant to represent the growth characteristics of the average children in a population. They may provide conflicting and erroneous information if used as growth references rather than standards (Cameron & Hawley, 2009). Growth assessment using the WHO growth standards resulted in more infants falling below the 3rd percentile lines as well as causing more children to be classified as being overweight or obese. Normal children on the WHO standards would appear as shorter and heavier, while children living in social and economically-deprived conditions would demonstrate faltered growth on the WHO standards. Consequently, anxious mothers might introduce formula milk or early cessation of breastfeeding (Binns & Lee, 2007).

Studies have demonstrated that dietary and environmental constraints are the major factors contributing to child growth differences between developed and developing countries (Droomers et al., 1995; Graiter & Gentry, 1981). Malaysian children showed slower weight gain. Although the WHO and most paediatric societies advocated exclusive breastfeeding for infants from birth to 6 months (Binns & Lee, 2007), the proportion of mothers who exclusively breastfeed their babies remains low in many countries (Imdad et al., 2011). Malaysian mothers were reluctant to provide exclusive breastfeeding due to social factors. The prevalence of exclusive breastfeeding up to 4 months and 6 months old were 19.3% and 14.5%, respectively, as reported in the NHMS 2006 (NIH, 2008). Breastfeeding duration is a protective factor for childhood obesity (Serra-Majem et al., 2006). Infants who were not breastfed were more likely to be obese children (Arenz et al., 2004). As such, more efforts are required to promote the importance of breastfeeding among mothers.

Conclusions
This study presents the first large scale initiative for local reference charts. We believe that the WHO 2006 Child Growth Standards should be used for individual longitudinal growth assessment, while the reference charts obtained from this study can be used for comparing the growth of Malaysian children based on their age groups.

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Declaration of interest
The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

References


Supplementary material available online

**Supplementary Tables I and II**