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Comparing body composition measures among Malaysian primary school children

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Abstract: The global rise in the prevalence of childhood overweight and obesity has necessitated the need for global standards, which is very important for cross-cultural or national comparisons, and to assess the effectiveness of various proposed measures of body composition. In this paper, the body composition of 411 children, consisting of 163 boys and 248 girls, aged 10.49 ± 1.12 years, was analysed based on body mass index (BMI) and two body fat references from Korea (BFK) and the UK (BFUK). BMI was the most sensitive estimate of adiposity (overweight = 15.8%; obesity = 6.6%), when compared with BFUK (overweight = 7.8%; obesity = 3.2%) and the BFK (overweight = 10.2%; obesity = 0.5%). Although, there was significant correlation between BFK and BFUK ($r = 0.89$, $p < 0.0001$), BFK and BMI ($r = 0.644$, $p < 0.0001$), and BFUK and BMI ($r = 0.646$, $p < 0.0001$), they fairly agreed (intraclass correlation coefficient = 0.537), as BMI reliably estimated body fat in normal weight, but overestimated body fat in overweight and obese children. Of all the demographic and physical activity variables, only gender was significantly associated with difference in body fat estimation, as BMI estimation of body fat was higher in girls than in boys. Hence, we must be cautious in using BMI as a surrogate for body fat, especially among overweight and obese children.

Subjects: Medicine, Social Sciences, Technology

Keywords: body mass index, body fat, overweight, obesity, school children, physical activity

ABOUT THE AUTHOR



Ademola James Adeyemi was a PhD student in the Materials, Manufacturing and Industrial Engineering Department at the Universiti Teknologi Malaysia (UTM) at the time of carrying out this study. The study is part of the research on the occurrence of back pain among primary schoolchildren using backpack. He is a member of the Ergonomics Research team of UTM and the National Institute of Occupational Safety and Health (NIOSH), Malaysia, where he serves as statistical and electromyography data analyst. The research team has also been investigating the various factors associated with work-related musculoskeletal disorders among workers in the public and private sectors. His research interests include school/children ergonomics and multivariate statistics, on which he has publications in referred journals. He is presently a senior lecturer at the W.U. Federal Polytechnic, Birnin Kebbi, Nigeria.

PUBLIC INTEREST STATEMENT

There is need for urgent action, among all stakeholders, from government agencies to parents, to curb the reported rise in childhood overweight and obesity, across both developed and developing countries. Hence, reliable evaluation of the condition is critical towards effective interventions. This study compares multiple body composition measures in order to determine their level of association and agreement.

1. Introduction

Childhood overweight and obesity, which have been on the increase lately, have been reported to be major health problems, (Jansen et al., 2007; Ng et al., 2014; Prentice-Dunn & Prentice-Dunn, 2012; Wake & Reeves, 2012). This increase calls for attention because obesity has been identified as a major risk factor for cardiovascular disorders such as hypertension, metabolic disorders such as type-2 diabetes and dyslipidemia, gastrointestinal disorders such as gastroesophageal reflux and non-alcoholic fatty liver disease, respiratory and pulmonary disorders such as asthma and obstructive sleep apnoea, and many more (Daniels, 2009; L'Abée et al., 2010; Mohamud et al., 2011; Swinburn et al., 2011; Wang et al., 2011). These diseases, previously associated with the obesity in adults, have now been identified in children and adolescents also (Daniels, 2009; L'Abée et al., 2010; Nightingale et al., 2013). The health implication of the trend, if not well managed, will affect the productivity of the future workforce. This is because children that are obese have the tendency to grow into obese adults (Freedman, Khan, Serdula, Srinivasan, & Berenson, 2005; Guo & Chumlea, 1999). This is worrisome since overweight and obesity have become a pandemic, responsible for significant death rate, life lost years and disability-adjusted life-years (Daniels, 2009; Ng et al., 2014).

The increase in childhood overweight and obesity is an indication of an increase in positive energy balance, which is a function of physical activity and dietary intake (Abbott & Davies, 2004), and is therefore associated with behavioural and environmental factors (Prentice-Dunn & Prentice-Dunn, 2012). Improved mechanisation and advances in food technology, leading to lower food cost, have also contributed to the increase (Swinburn et al., 2011). Apart from preventing children from active participation in physical activity, overweight and obesity can also affect their postural stability while walking and standing (Pau, Kim, & Nussbaum, 2012). This may be due to observed alterations in their lower limb structures (Dowling, Steele, & Baur, 2001; Pau et al., 2012; Wearing, Hennig, Byrne, Steele, & Hills, 2006), and the significant impairment in their proprioception abilities, which is important for postural control (Pau et al., 2012; Wang et al., 2008).

Although prevalence of obesity is higher in developed countries, developing countries have also been reporting high rates lately (de Onis & Blossner, 2000; de Onis, Blossner, & Borghi, 2010; Prentice-Dunn & Prentice-Dunn, 2012; Swinburn et al., 2011). The availability and reliability of comparing measures is important so as to provide global measures. Such comparisons are essential for effective amelioration of public health problems such as obesity (Reilly, 1998). However, since direct measurement of body composition is not possible in humans, various indirect methods of assessment have been developed to serve as estimates (Reilly, 1998). Body mass index (BMI), which is $\text{weight}/(\text{height})^2$ of an individual, has been the most widely used surrogate index to report the body composition (Laurson, Eisenmann, & Welk, 2011; Lee, Lee, Kim, Kim, & Kim, 2007). However, there are reservations about its reliability as a measure of body composition or adiposity (Wang et al., 2011). This is because it cannot differentiate between fat mass and fat-free mass (Laurson et al., 2011), neither can it identify which of fat, tissue or bone is responsible for identified increase in body mass (McCarthy, Cole, Fry, Jebb, & Prentice, 2006), nor does it account for variations in body structures (Ng et al., 2014), such as difference in foot angle and pressure (Dowling et al., 2001), or hip and knee alterations (Pau et al., 2012). Therefore, there are calls to use additional measures apart from BMI to improve health assessment (Laurson et al., 2011; Prentice-Dunn & Prentice-Dunn, 2012). Another widely used measure is the percentage body fat (%BF). Body fat can be determined using bioelectrical impedance analysis (BIA) or skinfold thickness. Although there are other body fat measures (WHO-Expert, 2004), BIA and skinfold thickness, just as BMI, are inexpensive, non-invasive, reasonably accurate and suitable for large samples, when compared with others that require complex instruments (McCarthy et al., 2006; Laurson et al., 2011; Lee et al., 2007). However, BIA is reported to produce a valid measure of body fat in children (Nightingale et al., 2013), unlike skinfold thickness that is less valid in young children (Reilly, 1998).

The call to use BMI with other measures of body composition was meant to reduce the error in assessing the children's true status (Prentice-Dunn & Prentice-Dunn, 2012). However, while BMI has an acceptable international threshold, which has been applied to national and international studies

(Cole, Bellizzi, Flegal, & Dietz, 2000), the same cannot be said of these other percentage body fat measures, which have limited reliability when applied as national or international references (Laurson et al., 2011). The growth variability in age and level of development among children has also raised concern about establishing standards for children. It has been established that a single classification is not suitable for both BMI and %BF (Cole et al., 2000; Lee et al., 2007). However, only BMI has a generally published age-based classification, while percentage body fat standards have been inconsistent because of ethnic or racial effects on adiposity (Deurenberg-Yap, Schmidt, van Staveren, & Deurenberg, 2000; Lee et al., 2007; WHO-Expert, 2004). There is need for up-to-date information on the level of overweight and obesity, so that proper planning towards healthy population can be made (Ng et al., 2014). This study therefore compares both BMI and body fat of Malaysian children with other national and international references, so as to determine whether BMI is a significant representative of the children’s body composition.

2. Methods

2.1. Overview

A total of 411 children aged 9–12 years old participated in the study. There were 163 boys and 248 girls from three primary schools in the Skudai area of the southern state of Johor, Malaysia. Three schools, a National school and two different vernacular schools, were selected to get a good sampling distribution among the three major races in Peninsular Malaysia, which are the Malays, the Chinese and the Indians. The study was approved by the Research Ethics Committee of the Faculty of Mechanical Engineering of Universiti Teknologi Malaysia. After obtaining permission from the ministry of education and the school authorities, only children who secured parental consent and gave their assents participated in the study.

2.2. Instruments and procedures

The height of the children was measured using a SECA 213 stadiometer (made in Germany) with an accuracy of 0.01 cm. The body weight and the percentage body fat (%BF) of the children were measured using a Beurer (made in Germany) BF20 bio impedance diagnostic scale with an accuracy of 0.01 kg. The children stood on the foot-to-foot scale barefooted, with both feet placed on the electrodes, to ensure sufficient conductivity. The left and right feet were not allowed to touch each other during the measurement process.

The children’s BMI were directly calculated from their weight and height ($BMI = \text{weight}/\text{height}^2$). An international Obesity Task Force (IOTF) reference, classified into centiles and based on children’s age and gender (Cole et al., 2000), was used to classify the directly measured BMI of the children into normal weight, overweight and obese (see Table 1 for the cut-off values used for the classification). The children’s ages were recorded to the nearest year, as was done by Lee et al. (2007). The directly measured percentage body fat (%BF) of the children was also classified into normal weight, overweight and obese, based on the centile values from two different references, based on the IOTF

Table 1. Cut-off values for the BMI and percentage body fat using 85th percentile for overweight and 95th percentile for obesity

| Age (years) | Boys | | | | | | Girls | | | | | |
|----------------|------------|------|------|-------|------|------|------------|------|------|-------|------|------|
| | Overweight | | | Obese | | | Overweight | | | Obese | | |
| | BMI | BFK | BFUK | BMI | BFK | BFUK | BMI | BFK | BFUK | BMI | BFK | BFUK |
| 9 | 19.46 | 22.6 | 22.2 | 23.39 | 30.0 | 26.8 | 19.45 | 26.2 | 27.2 | 23.46 | 36.5 | 31.2 |
| 10 | 20.2 | 21.8 | 22.8 | 24.57 | 29.6 | 27.9 | 20.29 | 27.7 | 28.2 | 24.77 | 39.8 | 32.2 |
| 11 | 20.89 | 21.6 | 23.0 | 25.58 | 29.9 | 28.3 | 21.2 | 29.5 | 28.8 | 26.05 | 43.3 | 32.8 |
| 12 | 21.56 | 21.3 | 22.7 | 26.43 | 29.7 | 27.9 | 22.14 | 31.5 | 29.1 | 27.24 | 46.6 | 33.1 |

Notes: BMI: Body Mass Index; BFK: % body fat based on the Korean estimate; BFUK: % body fat based on the UK estimate.

recommendation, since no standardised classification exists for percentage body fat (Flegal et al., 2009). The two %BF references were based on data from Korean children (BFK), which is an Asian population similar to Malaysia (Lee et al., 2007), and the other (BFUK) from the Caucasian population in UK (McCarthy et al., 2006). These two references also used the bio impedance analyser used in this study. Table 1 shows the age and gender cut-off for both BMI and the two %BF classification used in this study. Using a validated backpack–back pain questionnaire (Cronbach $\alpha = 0.6 - 0.8$; intraclass correlation coefficient (ICC) = 0.6 – 0.8) from a previous study among children from the same location (Adeyemi, Rohani, & AbdulRani, 2014), the children also gave information about their involvement in physical activity and computer games. They were also asked to estimate for how long they were involved in these activities daily.

2.3. Statistical analysis

All data were analysed using Predictive Analytics Software Statistics 18. The descriptive summary of the variables were inspected for normality using Shapiro–Wilk test. However, the large sample size used in this study ensures that the study significantly accommodated the normality requirement (Hair, Black, Babin, & Anderson, 2010; Tabachnick & Fidell, 2007). The mean, standard deviation (SD) and the percentile of the %BF and BMI (continuous) variables were provided, while the categorical and demographic variables were expressed as frequencies. A 3 × 3 contingency table was used to compare the BMI and %BF categorisation of the children into normal, overweight and obese. Pearson’s (for continuous variables) and Spearman’s (for categorical variables) correlation coefficients were used to describe the significant association among the variables and Bland–Altman’s method and ICC was used to access the level of agreement between BMI and %BF. One-way analysis of variance (ANOVA) was used to identify any significant difference in categorised BMI and %BF based on the children’s demography. Wherever there was a significant difference, Bonferroni *post hoc* test was carried out to identify the significant groups. The partial η^2 was also computed to determine the effect size. Levene’s test of homogeneity was also carried out to ascertain if the assumption of homogeneity of variance was violated, and when significant, Welch ANOVA was carried out. Multiple regression analysis was also carried out to determine which of the categorical variables was significantly associated with the directly measured BMI and the %BF. All analyses were conducted at a significant level of 0.05.

3. Results

Table 2 shows the percentile distribution of the children’s directly measured BMI and %BF, based on weighted average. Table 3 presents the children’s distribution based on the three references estimates of BMI, BFK and BFUK. There was a significant gender difference in the BFUK ($r = 0.107$, $p = 0.029$) and BMI ($r = 0.106$, $p = 0.032$, but not in the BFK ($r = 0.085$, $p = 0.085$). All the three estimates, BFK ($r = 0.115$, $p = 0.02$), BFUK ($r = 0.108$, $p = 0.029$) and BMI ($r = 0.143$, $p = 0.004$), showed difference in the duration of physical activity. However, none of the three standards revealed any

Table 2. Mean, standard deviation (SD) and percentiles for the children’s BMI and percentage body fat (%BF)

| | Age (years) | N | Mean ± SD | Percentiles | | | | | | |
|--------------------------------------|-------------|-----|--------------|-------------|-------|-------|-------|-------|-------|-------|
| | | | | 5 | 10 | 25 | 50 | 75 | 90 | 95 |
| Percentage body fat | 9 | 105 | 15.25 ± 7.38 | 4.79 | 6.04 | 10.35 | 14.80 | 18.30 | 27.28 | 29.94 |
| | 10 | 101 | 13.68 ± 8.01 | 3.50 | 4.32 | 6.60 | 12.40 | 19.60 | 25.80 | 28.84 |
| | 11 | 102 | 15.33 ± 8.44 | 4.23 | 4.99 | 8.98 | 13.85 | 20.45 | 28.44 | 31.43 |
| | 12 | 103 | 17.24 ± 8.08 | 5.70 | 6.52 | 10.40 | 15.90 | 23.20 | 28.20 | 31.46 |
| Body mass index (kg/m ²) | 9 | 105 | 16.92 ± 3.86 | 13.04 | 13.50 | 14.61 | 15.85 | 17.97 | 21.65 | 24.41 |
| | 10 | 101 | 17.46 ± 3.89 | 12.57 | 13.03 | 14.47 | 16.69 | 19.85 | 23.41 | 24.67 |
| | 11 | 102 | 18.02 ± 4.36 | 13.55 | 14.08 | 14.83 | 16.99 | 19.50 | 24.74 | 27.46 |
| | 12 | 103 | 19.23 ± 4.20 | 13.88 | 14.74 | 16.12 | 18.06 | 21.88 | 25.21 | 28.43 |

Table 3. Differences in BFK, BFUK and BMI estimates of adiposity with the children's demography and involvement in activities

| Parameter | | BFK | | | | BFUK | | | | BMI | | | |
|----------------------------------|---------|--------|-------------|-------|-------|--------|-------------|-------|-------|--------|-------------|-------|-------|
| | | Normal | Over weight | Obese | p | Normal | Over weight | Obese | P | Normal | Over weight | Obese | p |
| Gender | Boys | 151 | 10 | 2 | 0.085 | 152 | 7 | 4 | 0.029 | 118 | 30 | 15 | 0.032 |
| | Girls | 216 | 32 | 0 | | 214 | 25 | 9 | | 201 | 35 | 12 | |
| Age | 9 | 94 | 10 | 1 | 0.47 | 94 | 7 | 4 | 0.37 | 86 | 12 | 7 | 0.19 |
| | 10 | 93 | 8 | 0 | | 93 | 5 | 3 | | 78 | 17 | 6 | |
| | 11 | 90 | 11 | 1 | | 90 | 9 | 3 | | 80 | 14 | 8 | |
| | 12 | 90 | 13 | 0 | | 89 | 11 | 3 | | 75 | 22 | 6 | |
| Ethnicity | Malay | 124 | 17 | 1 | 0.77 | 123 | 12 | 7 | 0.48 | 112 | 14 | 16 | 0.85 |
| | Chinese | 122 | 10 | 1 | | 121 | 9 | 2 | | 100 | 26 | 6 | |
| | Indian | 121 | 15 | 1 | | 122 | 11 | 4 | | 107 | 25 | 5 | |
| Physical activities | None | 58 | 3 | 1 | 0.50 | 57 | 3 | 2 | 0.65 | 52 | 8 | 2 | 0.35 |
| | Field | 74 | 11 | 1 | | 76 | 7 | 3 | | 66 | 12 | 8 | |
| | Court | 167 | 17 | 0 | | 163 | 16 | 5 | | 141 | 33 | 10 | |
| | Board | 67 | 11 | 0 | | 70 | 6 | 3 | | 59 | 12 | 7 | |
| Physical activities duration (h) | No | 39 | 2 | 1 | 0.02 | 38 | 2 | 2 | 0.029 | 35 | 5 | 2 | 0.004 |
| | <1 | 166 | 11 | 0 | | 167 | 5 | 5 | | 149 | 18 | 10 | |
| | 1-2 | 118 | 24 | 1 | | 117 | 20 | 6 | | 100 | 32 | 11 | |
| | 2-4 | 32 | 4 | 0 | | 32 | 4 | 0 | | 26 | 6 | 4 | |
| | >4 | 12 | 1 | 0 | | 12 | 1 | 0 | | 9 | 4 | 0 | |
| Computer games | Yes | 303 | 36 | 0 | 0.85 | 302 | 29 | 8 | 0.87 | 263 | 56 | 20 | 0.90 |
| | No | 64 | 6 | 2 | | 64 | 3 | 5 | | 56 | 9 | 7 | |
| Computer game duration (h) | No | 44 | 4 | 2 | 0.92 | 44 | 3 | 3 | 0.71 | 38 | 7 | 5 | 0.89 |
| | <1 | 132 | 16 | 0 | | 130 | 16 | 2 | | 116 | 25 | 7 | |
| | 1-2 | 127 | 13 | 0 | | 128 | 7 | 5 | | 109 | 24 | 7 | |
| | 2-4 | 47 | 6 | 0 | | 46 | 6 | 1 | | 41 | 7 | 5 | |
| | >4 | 17 | 3 | 0 | | 18 | 0 | 2 | | 15 | 2 | 3 | |
| Total prevalence | Count | 367 | 42 | 2 | | 366 | 32 | 13 | | 319 | 65 | 27 | |
| | % | 89.3 | 10.2 | 0.5 | | 89.1 | 7.8 | 3.2 | | 77.6 | 15.8 | 6.6 | |

Notes: BMI: Body Mass Index; BFK: % body fat based on the Korean estimate; BFUK: % body fat based on the UK estimate.

difference in age, type of physical activity, involvement in computer games and duration of time playing computer games. Neither body fat nor BMI was significantly associated with the children's involvement in physical activity or involvement in computer games. BMI was, however, significantly correlated with children's duration in physical activity ($r = 0.148$, $p < 0.003$). Multiple regression analysis did not reveal that any of the physical activity or computer games variables has significant odds to predict the children's BMI or %BF.

Table 3 also shows that BMI is more sensitive to overweight and obesity (overweight = 15.8%; obesity = 6.6%), when compared with the two body fat estimates, BFK (overweight = 10.2%; obesity = 0.5%) and BFUK (overweight = 7.8%; obesity = 3.2%). BMI overestimated overweight and obesity in both %BF estimates, while both the Korean and the UK cut-offs produce similar estimation for normal-weight children. However, BFK underestimated obesity, while it overestimated overweight in the BFUK. The Spearman's correlation coefficient, however, reveals a strong association among the three children's body composition, based on the three references, i.e. BFK and BFUK ($r = 0.89$, $p < 0.0001$), BFK and BMI ($r = 0.644$, $p < 0.0001$), and BFUK and BMI ($r = 0.646$, $p < 0.0001$). Despite these correlation coefficients, Table 4 reveals low level of agreement in overweight and obesity

Table 4. Comparison of BMI and %BF classifications of the children into normal, overweight and obese in a 3 × 3 contingency table

| BMI | BFK | | | | BFUK | | | |
|------------|--------|------------|-------|------------|--------|------------|-------|------------|
| | Normal | Overweight | Obese | <i>r</i> * | Normal | Overweight | Obese | <i>r</i> * |
| Normal | 317 | 2 | 0 | 0.644 | 317 | 2 | 0 | 0.646 |
| Overweight | 45 | 20 | 0 | | 42 | 23 | 0 | |
| Obese | 5 | 20 | 2 | | 7 | 7 | 13 | |

Notes: BMI: Body Mass Index; %BF: percentage body fat; BFK: % body fat based on the Korean estimate; BFUK: % body fat based on the UK estimate.

**p* < 0.0001.

classifications of the three references. For example, 45 (69.2%) and 42 (64.6%) of the children classified as overweight in BMI were classified as normal in the BFK and BFUK, respectively. Also, only 2 (7.4%) and less than half of those classified as obese, using BMI, falls within the same classification for BFK and BFUK, respectively. The ICC, using an absolute agreement definition and assuming that the estimator is the same, was 0.537. Furthermore, scatterplot, based on the Pearson’s correlation coefficient, and Bland–Altman analysis were carried out to investigate correlation and agreement between BMI and %BF, using their directly measured (continuous) values.

Figure 1, which is a scatterplot of the BMI against %BF ($r = 0.709, p < 0.0001$), based on gender, however, reveals that BMI predicted a lower value of %BF in boys than in girls. BMI and %BF for girls are also more correlated than that for boys, and girls have a higher body fat than boys at the same BMI. Figure 2, which is the Bland–Altman plot, confirms the effect of gender depicted in Figure 1 and also shows the level of agreement between %BF and BMI. Although the values lie within the upper and lower limits of agreement, the range of the difference (9.02 to -14.06) is too high for practical acceptability. However, level of agreement will increase when the estimation is gender-based as it

Figure 1. Scatterplot of BMI against percentage body fat for boys and girls.

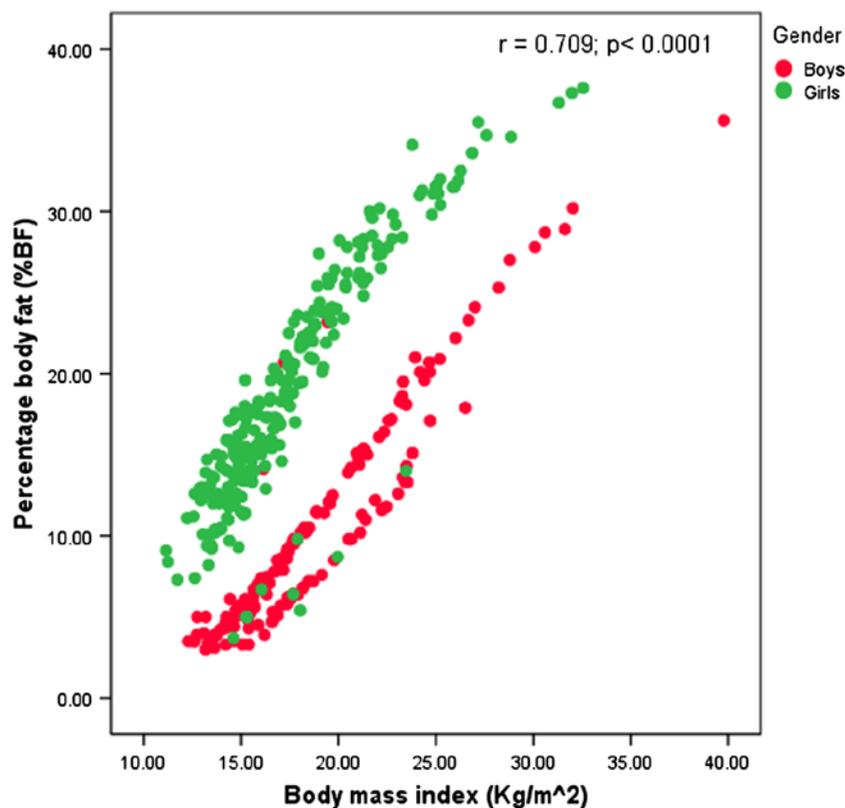
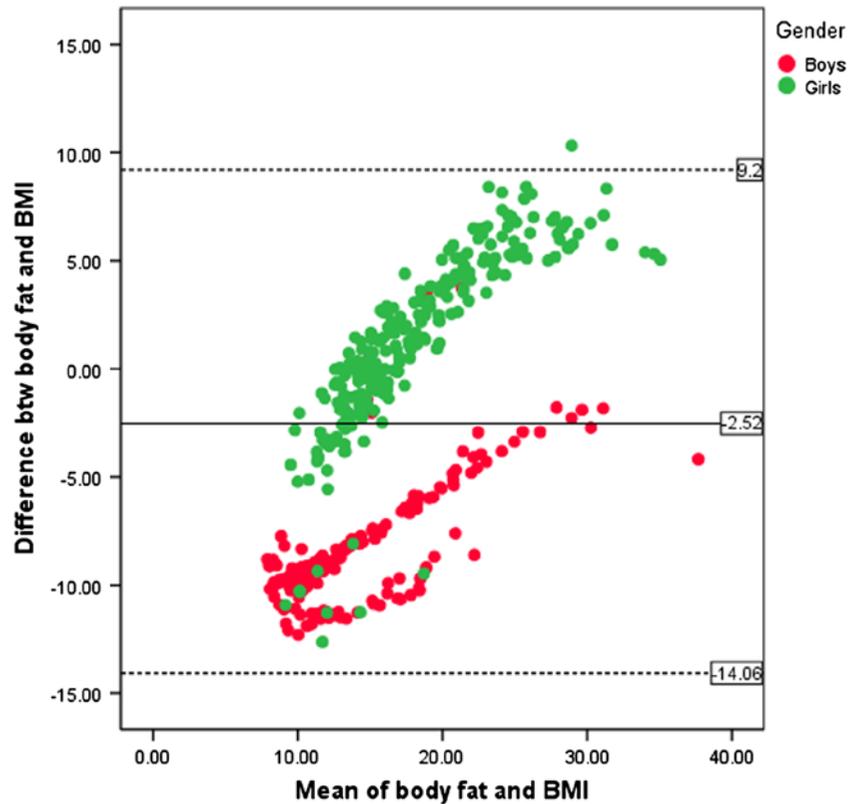


Figure 2. Bland–Altman comparison of body fat (%BF) and BMI values for agreement.



will be almost half the limits of agreement as shown in Figure 2. Figure 3 shows a reverse trend in the age distribution of the children’s BMI and %BF. While girls have a significant %BF when compared with boys of the same age, boys were shown to have a higher average of BMI, although it is less significant than in %BF. This reverse trend was also highlighted by the division along the slope line in the Bland–Altman plot, where girls are at the upper side of the gradient and boys are at the lower side of the gradient. However, both body composition indices increase with age.

As seen in Figure 3, Table 5 shows that both BMI ($F(3,407) = 6.087, p < 0.0001$) and %BF ($F(3,407) = 3.405, p < 0.0001$) vary significantly among children of different ages. The Bonferroni posthoc analysis shows that the 12-year-old children’s body composition was significantly different

Figure 3. Relationship between the children’s age and the body composition variables.

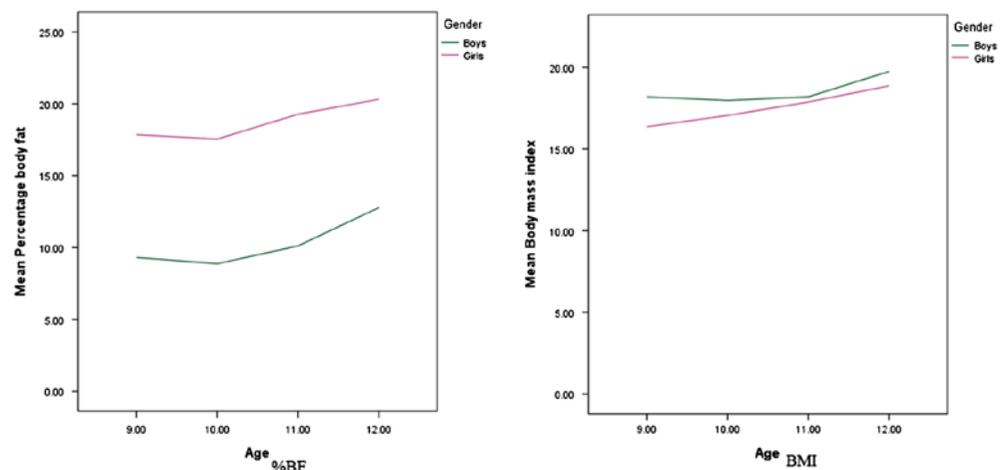


Table 5. Differences between the children’s body fat estimates and their demographic variables

| | Mean ± SD | Age | | | Gender | | | Race | | |
|--------|--------------|-------|--------|------------------------|--------|--------|------------------------|-------|-------|------------------------|
| | | F | Sig | Effect size η_p^2 | F | Sig | Effect size η_p^2 | F | Sig | Effect size η_p^2 |
| %BF | 15.39 ± 8.05 | 3.405 | 0.018 | 0.024 | 145.47 | 0.0001 | 0.262 | 4.147 | 0.016 | 0.02 |
| BMI | 17.90 ± 4.16 | 6.087 | 0.0001 | 0.043 | 6.312 | 0.012 | 0.015 | 2.307 | 0.102 | 0.01 |
| BFK | 1.11 ± 0.33 | 0.468 | 0.704 | 0.003 | 1.706 | 0.192 | 0.004 | 1.447 | 0.237 | 0.006 |
| BFUK | 1.14 ± 0.43 | 0.301 | 0.825 | 0.002 | 3.910 | 0.049 | 0.009 | 1.372 | 0.255 | 0.006 |
| BMI(C) | 1.29 ± 0.58 | 0.35 | 0.789 | 0.003 | 4.584 | 0.033 | 0.012 | 0.465 | 0.628 | 0.002 |

Notes: %BF: directly measured percentage body fat; BMI: directly measured body mass index; BFK: % body fat based on the Korean estimate; BFUK: % body fat based on the UK estimate; BMI(C): body mass index categorised into normal, overweight and obese.

from that of 9- and 10-year-old children. Table 5 also shows that there is no age difference in their categorisation into normal, overweight and obese, based on the three references of BMI, BFK and BFUK. However, gender differences were observed in all the classification based on the references except in BFK. The Levene’s test for homogeneity was significant for the gender analysis except in the %BF and BMI. Hence, the Welsh Robust test of equality of means was displayed in Table 5 for these values. Racial differences did not have significant effect in this study as shown in Table 5. The only significant racial difference, a weak association based on the effect size measure (partial $\eta^2 = 0.02$), occurs in directly measured %BF. Bonferroni posthoc analysis reveals that the difference only occurs between Malay and Chinese children ($p = 0.025$). Unlike what was observed for gender, the Bland–Altman analysis did not reveal any racial effect in the level of agreement between BMI and %BF.

4. Discussion

The importance of determining the body composition of the children cannot be overemphasised, especially now that Malaysia has been reported to have the highest prevalence of overweight and obesity among Southeast Asian countries (Ng et al., 2014). This can be linked to the improved GDP reported over the decades, because obesity is linked to national wealth (Moy, Gan, & Zaleha, 2004; Swinburn et al., 2011). The study finds a strong correlation between BMI and percentage body fat. This strong correlation has previously been reported in the literature (Duncan, Duncan, & Schofield, 2009; WHO-Expert, 2004; Widhalm, Schönegger, Huemer, & Auterith, 2001). This significant association is important in multiracial societies such as Malaysia because of difficulty in determining obesity cut-offs among Asian populations (Samaha, 2007). However, it is not sufficient to conclude that there is an agreement between BMI and %BF (Bland & Altman, 2010; Reilly, 1998). The difference between the high correlation ($r = 0.709$) and the level of agreement was highlighted by lower ICC value of 0.537, which indicated fair agreement (Adeyemi et al., 2014), and the wide range in the limits of agreement (9.02 to -14.06) of the Bland–Altman plot in Figure 2, which is an indication of poor agreement between BMI and %BF estimates. Based on Table 4, BMI was seen to reliably estimate %BF in children with normal weight, while it is less reliable among overweight and obese children. The poor agreement is less obvious because normal-weight children constituted about 80% of the sampling population, thus hiding the significant disagreement of the two estimates in categorising the children into overweight and obese. Also, BMI estimation of %BF was also observed to be higher in girls than in boys. It therefore attests to the assertion that BMI poorly represents body composition in multiracial societies (Duncan et al., 2009). While BMI has been used as a global estimate for overweight and obesity in children, the finding did not justify its use as a surrogate for percentage body fat, especially among overweight and obese children. This limitation of BMI, as a surrogate estimate for body fat in children, has also been highlighted in other studies (L’Abée et al., 2010).

Although it is difficult to determine which reference is more accurate (Laurson et al., 2011), because there is not yet a generally acceptable body fat cut-off (Ho-Pham, Campbell, & Nguyen, 2011), BMI can be observed to overestimate overweight and obesity compared to the %BF references. However, BFUK is more consistent with the BMI than the BFK. Table 3 shows that the Korean estimate reveals the lowest rate of obesity and is less sensitive to overweight and obesity than the UK estimates and the BMI. BMI based on the children's anthropometry shows most sensitivity. The lower estimation of the %BF references might arise from a limitation of bio impedance analysis, which has been reported to be less accurate in estimating body composition in populations different from where it was derived (Reilly, 1998). Also, the socio-economic status and ethnic/ racial differences between Malaysia and the two %BF references, i.e. the UK and Korea, could also be responsible for the different estimations. These factors may also account for the difference observed in the BMI and %BF relationship in this study, which was contrary to what was observed among South Asians in another study, where it was reported to underestimate body fat (Nightingale et al., 2013). However, racial differences did not play any significant role among the Malaysian children involved in this study. This non-significant effect of the children's race in body composition measures had previously been reported in other Malaysian studies (Kasmini et al., 1997; Moy et al., 2004).

Although obesity can be less captured by sight, the BMI groupings will be most relevant to recent concern of rise in obesity among children in Malaysia and globally. An obesity prevalence of 9% for boys and 5% for girls in this study is similar to the reported prevalence rate for Asia (Ng et al., 2014) but lower than the prevalence rate reported among Malaysian adolescents (Lekhraj Rampal et al., 2007) and adults (Mohamud et al., 2011; Ng et al., 2014). This lower rate cannot be interpreted as safe level for the children, because overweight and obesity vary with age, which explains why age and gender specifications are required until 18 years (Duncan et al., 2009; McCarthy et al., 2006).

The study has revealed the level of overweight and obesity among the children. While body composition varies with age, there is no significant difference in percentage overweight or obesity among the various age groups. However, general difference was observed between boys and girls. The study has also provided additional information on the level of overweight and obesity among the Malaysian children. The study also show that the level of overweight and obesity is lower among the Malaysian children when compared with Koreans (Lee et al., 2007), Caucasian or Americans (Laurson et al., 2011). Although other studies have also highlighted the influence of age and gender in the relationship between %BF and BMI (Lee et al., 2007), the distinction observed in Figure 1 was more significant than what was observed among Korean children, where there is more interaction between boys and girls. This is an indication of a higher %BF in girls compared with boys of the same age and BMI in Malaysia. This higher %BF for girls is not limited to Malaysia, but has been found in other countries or ethnicities (Liu et al., 2011). This serves as justification for gender specification for classification for body composition in children, since such approach will reduce systematic errors in children's body composition measurement (Reilly, 1998). However, age effect is limited in this study when compared with other studies that involved wider age groups, which cut across prepubertal and other pubertal groups.

Unlike what was commonly reported (Mohamud et al., 2011), physical activity and computer games were not significantly associated with body composition in this study. The increase in time used in playing computer and little involvement in physical activity increase the sedentary level of children. This has been identified as a major risk factor for overweight and obesity (Abbott & Davies, 2004; Müller, Khoo, & Lambert, 2013). Hence, the present school-based assessment, which is part of the new National Education Blueprint by the Malaysia education ministry, is a step in the right direction, because it increases schools' emphasis on physical activity, a timely intervention that can curb the increasing trend in obesity and overweight among the schoolchildren. Since, obesity and overweight have been associated with socio-economic status and national wealth, all hands must be on deck to prevent it going out of control since Malaysia is already aspiring to be a developed nation by 2020, an aspiration that will increase the disposable income, a risk factor for obesity and overweight. There is need to carry out effective strategies to manage the obesity pandemic. One

major area is the feeding habit of the children. This is because advancement of food technology, sale of junk food, and better and modern lifestyles are all contributing factors (McPherson, 2014; Swinburn et al., 2011). This, coupled with increasing sedentary lifestyle and increasing urbanisation, has been seen as a contributing factor (Mohamud et al., 2011). Hence, new and effective public health policy needs to be pursued.

A major limitation of this study is that it is cross-sectional and subnational, since the sample is based on data from a city. Hence, care need to be taken in using it for national interpretation. However, it is more reliable than some of the reported prevalence in overweight and obesity, which are based on self-reported BMI (Ng et al., 2014). Moreover, because of the complexity associated with obesity and body composition measurement, there is still need for a larger longitudinal study, which employs more measures of adiposity and has samples drawn from all parts of the country.

5. Conclusion

In this study, BMI overestimated %BF in the participating children. The age and gender-based IOTF BMI reference reveals higher rate of overweight and obesity than two other %BF references used in this study. The BMI rate, however, correlates with other prevalence rate reported about obesity in Malaysia and the Asian region. While BMI was found to be highly correlated with percentage body fat, the level of agreement between both estimates is poor and practically unacceptable, because of the wide differences that constitute the limits of agreement. This poor agreement was highlighted in their classification of the children into overweight and obese. Also, BMI estimated higher values for body fat in girls than boys. Hence, there is the need to be cautious in using BMI as a surrogate for body fat in children.

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