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# Validation of the Luscombe weight formula for estimating children's weight

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## Abstract

**Objective:** Several paediatric weight estimation methods have been described for use when direct weight measurement is not possible. A new age-based weight estimation method has recently been proposed. The Luscombe formula, applicable to children aged 1–10 years, is calculated as (3 × age in years) + 7. Our objective was to externally validate this formula using an existing database.

**Method:** Secondary analysis of a prospective observational cohort study. Data collected included height, age, ethnicity and measured weight. The outcome of interest was agreement between estimated weight using the Luscombe formula and measured weight. Secondary outcome was comparison with performance of Argall, APLS and Best Guess formulae. Accuracy of weight estimation methods was compared using mean difference (bias), 95% limits of agreement, root mean square error and proportion with agreement within 10%.

**Results:** Four hundred and ten children were studied. Median age was 4 years; 54.4% were boys. Mean body mass index was 17 kg/m$^2$ and mean measured weight was 21.2 kg. The Luscombe formula had a mean difference of 0.66 kg (95% limits of agreement –9.9 to +11.3 kg; root mean square error of 5.44 kg). 45.4% of estimates were within 10% of measured weight. The Best Guess and Luscombe formulae performed better than Argall or APLS formulae.

**Conclusion:** The Luscombe formula is among the more accurate age-based weight estimation formulae. When more accurate methods (e.g. parental estimation or the Broselow tape) are not available, it is an acceptable option for estimating children's weight.

**Key words:** *Luscombe formula, paediatric, weight.*

## Introduction

In EDs, it is often necessary to know a child's weight for assessment of clinical status, for accurate drug and i.v. fluid dose calculation, for selection of correctly sized equipment and to determine the strength of electrical cardiac counter shock for paediatric resuscitation. Measuring a child's weight on a set of calibrated scales is the gold standard, but is not always be possible due to the severity of illness and urgency of treatment. There is

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also significant advantage in being able to estimate a child's weight sight unseen in the event of pre-notification of cases by emergency services.

Several methods have been devised, which aim to accurately estimate a child's weight. Some of these are age-based mathematical formulae (e.g. APLS,[1] Argall,[2] Best Guess[3]), some are based on length–weight relationships (e.g. Broselow tape[4]), some on other physical features such as foot or mid-arm size[5] and some on clinician or parent estimate.[6] A new age-based weight estimation method has been proposed.[7] The Luscombe formula, applicable to children aged 1–10 years, is calculated as (3 × age in years) + 7. Our objective was to externally validate this formula using an existing database.

## Methods

This was a secondary analysis of a prospective, observational study that has been previously reported.[8] We studied a convenience sample of paediatric patients who presented to the ED of a metropolitan community teaching hospital with a paediatric ED census of 23 000 annually. We collected data on stable children, aged between 1 and 11 years, with a wide variety of clinical conditions. Children were excluded if their condition was such that urgent care or resuscitation was required. Patients were recruited across shifts and days with the vast majority being collected on day and evening shifts by the principal investigator (KN), supplemented with some data collected by nurses. Staff were not blinded to the study hypothesis.

Data collected included demographic data, child's height (in centimetres), child's weight (to the nearest kilogram) and ethnicity. All children were weighed on a single set of standing scales (Seca electronic) or a chair-like scale (Healthometer electronic), without shoes or heavy layers of clothing. Scales were calibrated by the biomedical engineering department prior to the commencement of the study, on a monthly basis after the study commencement and at study conclusion. Children's weights were obtained by indirect weighing for uncooperative children. The parent's weight was subtracted from the combined parent and child weight to determine the child's weight. Height was measured without shoes using a stadiometer. Children who could not stand and were less than 1 metre tall were measured in the supine position using a Seca 207 infant measurement rod.

The primary outcome of interest was agreement between weight estimated by the Luscombe weight estimation formulae and measured weight. Secondary outcome was comparison of estimation performance with the Argall, APLS and Best Guess formulae. Data were analysed using Stata[9] and Analyse-It[10] data analysis programs. We report descriptive statistics (numbers, mean, standard deviation, range, proportions) for age, sex, body mass index and weight. Agreement between the Luscombe formula and measured weight was assessed by calculation of mean bias, 95% limits of agreement and root mean square error (RMSE). RMSE combines an assessment of both bias and spread of data. We also report the proportion of cases that were accurate in weight estimation to within 10% of measured weight. Performance of weight estimation methods was compared using mean difference (bias), RMSE and proportion with agreement within 10%.

Melbourne Health Research Directorate Ethics Committee waived the requirement for formal ethics approval as the study was considered a quality assurance/clinical audit/clinical best practice development activity under the National Health and Medical Research Council guidelines (Australia). Consent was not required for study participation.

## Results

Four hundred and ten children were studied. The median age was 4 years, there were more boys (54.4%) and the majority of cases were of Caucasian ethnicity (74.9%). The mean body mass index of the sample was 17 kg/m$^2$ (range 12–35 kg/m$^2$) and mean actual weight was 21.2 kg (range 7.5–71 kg).

The Luscombe formula had a mean difference of 0.66 kg, with 95% limits of agreement −9.9 to +11.3 kg and RMSE 5.44 kg (Fig. 1). Accuracy deteriorated at higher measured weight. 45.4% of estimates were within 10% of measured weight. The performance of the Luscombe formula was similar to the Best Guess formulae and better than the Argall formula and the APLS formula (Table 1).

## Discussion

Several methods have been developed for estimating children's weight.[11] We found the Luscombe formula to be among the better age-based weight estimation formulae. It had similar performance to the Best Guess formulae and better performance than APLS and Argall

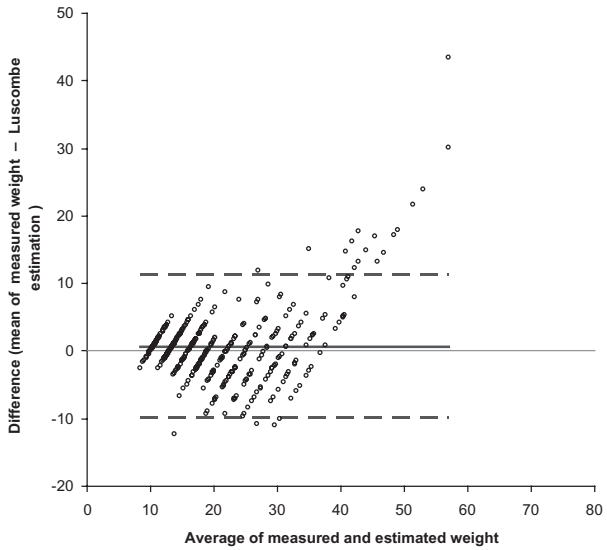


**Figure 1.** Bland-Altman plot of the difference between Luscombe estimate and actual weight. Solid line indicates bias and dashed lines indicate 95% limits of agreement.

**Table 1.** Performance of weight estimation methods

| Method | Bias (kg) | % agreement within 10% | RMSE (kg) |
|---|---|---|---|
| Luscombe | 0.66 | 45.4 | 5.4 |
| Best Guess† | 0.7 | 42 | 5.4 |
| Argall | –1.7 | 37 | 5.7 |
| APLS | –4.2 | 34 | 7.5 |

*†Pooled data with appropriate formulae used for age subgroups. RMSE, root mean square error.*

formulae. To our knowledge, this is the first study reporting an external validation of the Luscombe formula.

When compared with the other common age-based weight estimation formulae, the Luscombe formula performed similarly to the Best Guess formulae and better than the APLS or Argall formula. The reasons for this are not clear but might include changes in age–weight relationships over time or geographical variation in age–weight relationship as most of the formulae were derived from single centres or a single region dataset.

The Luscombe formula has a significant advantage over the Best Guess formula in that it is a single formula over the age range rather than two (one for children aged 1–5 and another for children aged 5–10) as is the case with the Best Guess formulae. This might make it easier to remember and less prone to calculation error.

Whereas age-based formulae are, in the main, easy to calculate, the evidence suggests that ethnicity and body habitus pose serious challenges to their accuracy.[9] In comparative studies, age-based formulae were found to be less accurate than the Broselow tape and parental estimate, with parental estimate being the most accurate weight estimation method.[6,12] In light of this evidence, age-based formulae should only be used when these more accurate methods are not available.

The present study has some limitations that must be considered when interpreting the results. This was a convenience sample that excluded seriously ill children and, therefore might not truly represent the group of most interest. The sample is derived from a single, multi-ethnic Australian study site and might not be generalizable to other settings. It is possible that the formulae studied perform differently for different age groups. Comparative analysis on age subgroups was not performed as the sample sizes in the subgroups would have been small.

## Conclusion

The Luscombe formula is among the more accurate age-based weight estimation formulae. When more accurate methods (e.g. parental estimation or the Broselow tape) are not available, it is an acceptable option for estimating children's weight.

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### Author contributions

AMK, DK and KN were involved in concept and design of study. KN performed most of the data collection. AMK performed most of the analysis. AMK, DK and KN interpreted the results. AMK drafted the manuscript and DK and KN contributed to its revision.

### Competing interests

None to declare.

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