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Estimating height using ulna and tibia measurements in paediatric patients

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Tables 1 to 3 are available in the supplementary files section

Abstract

Background/Objectives:
Accurate height measurement is essential in paediatric assessment but may be unreliable or impossible in non-ambulatory children or those with skeletal deformities. This study aimed to develop height-prediction equations based on ulna and tibia lengths measured with a non-stretchable tape and to validate their performance in two clinical paediatric populations.

Subjects/Methods:
Prediction equations were derived from healthy UK children: 700 with ulna measurements (4–14 years) and 133 with tibia measurements (10–17 years). Standing height, weight, and segmental lengths were measured in duplicate using standardised techniques. Multiple linear regression models were created and refined by testing age, sex, and weight as additional predictors. Validation was conducted in two clinical cohorts at Great Ormond Street Hospital: the BodyBasics (BB) cohort of children with complex conditions (n=17) and a cystic fibrosis (CF) cohort (n=58). Agreement between measured and predicted height was assessed using Bland–Altman analysis. A "wisdom of crowds" approach combining predictions from multiple equations was also explored.

Results:
In healthy children, ulna- and tibia-based equations showed strong predictive accuracy (adjusted $R^2 \approx 0.87$) when age and weight were included; sex was not a significant predictor. In the BB cohort, both equations consistently overestimated height (mean bias +4 to +6 cm) with wide limits of agreement but no proportional bias. In the CF cohort, the tibia-based model showed minimal but proportional bias (+0.8 cm). Aggregated predictions reduced mean bias in some cases but did not improve limits of agreement.

Conclusion:
Tape-based ulna and tibia measurements provide practical and accurate height-prediction tools for healthy children and perform reasonably well in ambulatory clinical populations. Systematic overestimation in children with complex conditions highlights the need for further validation in larger and more heterogeneous cohorts.

Estimating height using ulna and tibia measurements in paediatric patients

Introduction

Height (HT) is a fundamental anthropometric parameter in pediatric clinical practice, central to growth monitoring and nutritional assessment (1–3). Accurate HT measurement is required for calculating body mass index (BMI), fat mass index (FMI), and lean mass index (LMI), as well as body surface area (BSA), which is widely used for drug dosing, including chemotherapy (4,5). Clinical guidelines recommend obtaining a measured HT, or recumbent length in children under two years, at hospital admission to ensure accurate evaluation (6,7). However, discrepancies between measured and self- or parent-reported HT are well documented, underscoring the need for objective assessment (8,9).

Accurate measurement is not always feasible. Children with neuromuscular disorders, spinal deformities, or critical illness may be unable to stand for standard stadiometric assessment, and factors such as equipment availability, calibration, and staffing can further limit the reliability of routine measurements (10).

To address these limitations, segmental bone lengths, particularly ulna or tibia, have been proposed as alternative anthropometric measures. These methods have been used to generate reference growth data (11,12) or to derive predictive equations for HT estimation (13,14). Although practical, prediction accuracy varies depending on the segment used (e.g., knee, HT, arm span) (15) and often reflects population-specific differences in growth patterns, body proportions, ethnicity, sex, clinical conditions, and environmental factors (16,17).

Ulna and tibia length measurements are especially advantageous: they are quick to obtain with a simple measuring tape, require minimal patient cooperation, and do not rely on specialized equipment or posture, making them suitable for non-ambulatory patients and routine clinical practice.

This study aimed to evaluate the validity and practicality of using ulna and tibia length as predictors of HT in a diverse paediatric population admitted to a UK tertiary care hospital. The primary objective was to develop UK-specific prediction equations for HT based on tibia and ulna length measurements obtained from healthy children. The secondary objective was to assess the performance of these equations in estimating HT among

paediatric patients with various clinical conditions. Specifically, the study sought to (i) evaluate the agreement between measured and predicted HT, (ii) compare the newly derived estimates with those obtained from previously published paediatric equations, and (iii) explore whether prediction accuracy could be improved by combining multiple equations through a “wisdom of crowds” approach.

Materials and methods

The study consisted of two phases: the derivation of HT prediction equations based on ulna and tibia length measurements in a sample of healthy children, and the subsequent application and validation of these equations in two paediatric clinical populations (18,19).

Derivation phase

The prediction equations based on ulna and tibia measurements were developed using anonymized data from healthy children aged approximately 4 to 17 years who had previously participated in departmental research studies (19). Participants had no chronic conditions or growth disorders, and trained staff collected HT, weight, body mass index, and ulna and tibia lengths. HT was measured twice to the nearest 0.1 cm using a wall-mounted stadiometer, while ulna and tibia lengths were measured in duplicate on the left side using a non-stretchable tape measure. Ulna length was measured from the tip of the olecranon to the midpoint of the wrist styloid, with the arm folded across the chest and the fingers pointing toward the opposite shoulder (20-23). Tibia length was measured from the medial knee joint line to the distal edge of the medial malleolus, keeping alignment with the long axis of the leg (24–25). Tibia measurements included only children aged 10 to 17 years, as this parameter was introduced in later study phases when peripheral quantitative computed tomography (pQCT) replaced the earlier single-photon absorptiometry system (SPA). The use of a tape measure was chosen to provide a simple, quick, and low-cost method suitable for routine clinical practice.

Validation phase

The second phase involved data collected from two clinical cohorts of children under the care of Great Ormond Street Hospital (GOSH), London, UK. These children were participants in previous, ethically approved research studies. Written informed consent was provided by the parent/guardian or by the patient if over 16

years of age. The first cohort, referred to as the BodyBasics (BB) group, included hospitalised children aged five years and older (mean age 13 ± 3 years), consistent with the lower age limit of the newly developed body composition reference dataset. Eligible participants that were expected to remain in hospital for at least 3 days were measured within 48 hrs of their admission. Baseline assessments were conducted prior to any major medical interventions, such as surgery or the administration of large volumes of intravenous fluids. Inclusion criteria were intentionally broad to encompass a diverse range of clinical conditions, and recruitment occurred across all inpatient wards, including children with complex and/or chronic diseases admitted for diagnostic, medical, or surgical management. Only participants with valid standing HT and at least one segmental bone measurement (ulna or tibia) were included in the current analyses (18,19). Ulna and tibia lengths were measured using a flexible non-stretch tape measure, and as the tibia-based equation was developed in healthy children aged 10–17 years and the ulna-based equation in those aged 5–17 years, only BB participants within the respective age ranges were included in the analyses. A second clinical subgroup consisted of children with cystic fibrosis (CF), included to test the performance of the predictive equations in a nutritionally vulnerable but largely ambulatory population (26). This group comprised children aged 7–19 years (mean age 13 ± 2 years) under the care of GOSH, with a confirmed diagnosis of CF and clinically stable for at least 14 days prior to recruitment. In this cohort, only tibia length was measured; therefore, only the tibia-based predictive equation applicable to the 10–17-year age range was applied.

Data analysis and statistics

Linear regression analysis was used to derive prediction equations for measured HT from ulna and tibia length in healthy children. Both absolute HTs and HT standard deviation scores (SDS), calculated using the British 1990 reference data (27) were analysed. Separate models were generated for each bone segment, and additional predictors (age, sex, and weight) were evaluated for their contribution to model performance. The goodness of fit was assessed using the adjusted R^2 and the statistical significance of model coefficients. Agreement between measured and predicted HT for the patient groups was evaluated using the Bland–Altman method, which estimates the mean bias (MB) and the 95% limits of agreement (LLOA = MB − 1.96 × SD; ULOA = MB + 1.96 × SD). Correlation coefficients (r) were calculated to assess the strength of the linear

relationship between measured and predicted values, and the potential presence of proportional bias was tested by examining the relationship between measurement differences and the magnitude of the measurements. In addition, a “wisdom of crowds” approach (28.) was applied by averaging HT estimates derived from different prediction equations, both those developed in this study and those previously published by Gauld et al. (14), to explore whether aggregated predictions improved agreement with measured HT. All statistical analyses were performed using a two-tailed significance threshold of $p < 0.05$.

Results

HT prediction equations from ulna and tibia lengths in healthy UK children

Data from 700 healthy children (362 boys and 338 girls) aged 4–14 years were analysed to develop HT prediction equations based on ulna length. The main anthropometric characteristics of the cohort are shown in Table 1S. Weight, HT and BMI standard deviation scores (SDS) were calculated using UK reference data (26,27), and mean SDS values for both sexes fell within the normal range (±2 SDS), although girls had slightly lower means than boys. A few children had low SDS values (−3 to −4), but their inclusion did not materially affect model performance.

Ulna length showed a strong linear association with standing HT, with a coefficient of determination of $R^2 = 0.789$, indicating that about 79% of HT variance was explained by ulna length alone. In multiple regression models (Table 1), ulna length was a highly significant independent predictor in all models ($p < 0.001$). Adding age and weight progressively improved model fit, raising the adjusted R^2 from 0.79 (ulna only) to 0.871 in the final model. Sex was initially significant when combined with ulna length but became non-significant ($p = 0.411$) once age and weight were included, indicating that these variables captured most sex-related growth differences. Creating sex-specific equations, as done in previous work including Gauld et al. (2004), did not further improve model performance (adjusted $R^2 = 0.87$).

The final ulna-based equation, developed from 700 children aged 4.3–14.2 years, was: $HT\ (cm) = 53.722 + 2.438 \times U + 1.837 \times A + 0.367 \times WT$, where U is ulna length (cm), A is age (years), and WT is weight (kg).

Tibia-based prediction equations were developed using data from a smaller cohort of 133 healthy children aged 10–17 years, whose main characteristics are shown in Table 2S. Mean SDS values for weight, HT and BMI were within the normal range (±2 SDS) for both sexes, though slightly higher in females, confirming that the sample was representative of a healthy paediatric population.

Tibia length showed a strong positive correlation with HT, with $R^2 = 0.788$, meaning that nearly 79% of HT variance was explained by tibia length alone. Including age and weight increased model accuracy (adjusted $R^2 = 0.866$), while sex remained non-significant ($p = 0.176$) (Table 2).

The final tibia-based equation, derived from children aged 10–17 years, was: HT (cm) = 58.602 + 2.075 × T + 1.219 × A + 0.226 × WT, where T is tibia length (cm).

Both ulna- and tibia-based models reached similar accuracy (adjusted $R^2 \approx 0.87$), indicating that age and weight effectively account for sex-related differences in body proportions.

Performance of the HT Prediction Equations in Clinical Populations

The new ulna- and tibia-based HT prediction equations were tested in two paediatric cohorts at GOSH: the BB cohort ($n = 17$), comprising hospitalised children with complex medical needs, and the CF cohort ($n = 58$), including clinically stable but nutritionally vulnerable patients.

In the BB cohort (Table 3S), both equations consistently overestimated measured HT. Bland–Altman analysis (Figure 1 and Table 4S) showed a mean bias of +4.0 cm (95% LoA, −9.6 to +17.6) for the ulna model and +6.1 cm (95% LoA, −3.5 to +15.7) for the tibia model. In SDS units, the corresponding biases were +0.59 and +0.84 SDS (both $p < 0.05$). Correlation coefficients ($r = 0.71$–0.73, $p > 0.2$) did not indicate proportional bias, suggesting that the degree of overestimation was broadly consistent across the HT range.

In the CF cohort (Table 5S), the tibia-based model showed minimal overall systematic error. Bland–Altman analysis (Figure 1 and Table 4S) showed a mean bias of +0.8 cm (95% LoA, −7.8 to +9.3) and −0.21 SDS (95% LoA, −1.50 to +1.07). However, a significant correlation (*r = 0.92, p = 0.00010*) indicated proportional bias, showing that prediction error varied across the HT range. Specifically, the tibia-based equation tended to overestimate HT in shorter children and underestimate it in taller children: in the shortest quartile (128.0–

144.7 cm), mean overestimation was approximately 3.5 cm, whereas in the tallest quartile (162.4–182.7 cm), mean underestimation was approximately 3.0 cm.

To assess whether predictive accuracy could be improved, estimates from the newly developed equations were combined with those from Gauld et al. (2004) using a “wisdom of crowds” approach (Table 6S).

In the BB cohort, HT estimates from the Salatto, Gauld, and aggregated models (Table 3) all showed systematic overestimation. Bland–Altman analysis (Figure 2) showed mean biases of +4 cm (Salatto) and +8.5 cm (Gauld) for the ulna-based equations (Figure 2A), while the aggregated estimate produced an intermediate bias of +6.8 cm with slightly narrower limits of agreement. Tibia-based results were similar (Figure 2C), with mean biases of +6 cm (Salatto), +3.8 cm (Gauld), and +6.2 cm (aggregated). HT SDS values confirmed the same pattern (Figure 2B,D), with positive biases across all models (+0.59 to +1.45 SDS for ulna; +0.84 to +0.99 SDS for tibia).

In the CF cohort, tibia-based predictions from the three models (Table 3) showed different patterns: the Salatto equation slightly overestimated HT, whereas the Gauld and aggregated equations underestimated it (Figure 2E). Bland–Altman analysis (Figure 2) gave mean biases of +0.7 cm, −3.1 cm, and −1.5 cm, respectively, with limits of agreement of approximately −9.9 to +9.3 cm. When converted to SDS, all models showed negative mean biases (−0.21 to −0.88 SDS) (Figure 2F), indicating an overall tendency towards underestimation. Significant correlation coefficients for most models suggested that prediction error varied according to HT. This pattern was most evident in taller children: for the Salatto model, mean error shifted from an overestimation of approximately 3.5 cm in the shortest quartile to an underestimation of approximately 3.0 cm in the tallest quartile; for the Gauld model, underestimation increased from approximately 1.6 cm to 6.5 cm; and for the aggregated model, mean error shifted from a slight overestimation of approximately 1.0 cm to an underestimation of approximately 4.8 cm.

Discussion

Despite the recognised importance of HT assessment in paediatrics, several clinical conditions can hinder accurate stadiometric measurement, resulting in underreporting in medical records (28,29). Surrogate

methods for non-ambulatory children exist, but evidence remains limited and often restricted to specific subgroups, reducing generalisability. Additionally, inconsistencies in measurement protocols, anatomical landmarks, and equipment further complicate clinical use.

In this study, ulna and tibia length were selected as surrogate measures because they are frequently reported in the literature and easily obtained without requiring the patient to stand. Although some authors (14) recommend rigid anthropometers for greater precision, our aim was to identify methods feasible in routine practice; we therefore adopted a standard non-stretchable tape measure, widely available in hospital settings.

Among published predictive models based on skeletal segments, Gauld et al. remains the primary reference, having used a rigid anthropometer in a large Australian cohort aged 5–20 years. Abrahamyan et al., by contrast, estimated bone lengths from DXA scans, a method not applicable in routine care. The present work is thus one of the first to develop equations specifically tailored to tape-based measurements in a large healthy paediatric population.

The resulting ulna- and tibia-based equations showed strong predictive performance (R^2 = 0.87). Incorporating age and weight improved the model, whereas sex did not contribute once weight was included, allowing the development of a single equation per bone segment. A limitation is that tibia data were available only for children aged 10–17 years, restricting applicability in younger ages.

Clinical validation in two paediatric cohorts admitted to GOSH revealed distinct patterns. In the BB cohort, both equations systematically overestimated measured HT, as shown by positive Bland–Altman biases and wide limits of agreement. Nonetheless, correlations remained moderate–high, suggesting systematic rather than random error. Overestimation likely reflects difficulties in obtaining reliable standing HT in children with postural abnormalities, where measured HT may underestimate true skeletal length.

In the CF cohort, bias was small overall, but its direction depended on the metric and model used: the Salatto equation slightly overestimated HT height in centimetres (mean bias +0.7 cm, 95% CI −0.3 to +1.9), whereas SDS values and the alternative models, Gauld and aggregated models underestimated it (mean bias −3.1 cm, 95% CI −4.4 to −1.8, and −1.1 cm, 95% CI −2.3 to −0.01, respectively). Although agreement was better than

in the BB cohort, proportional bias was present; HT was overestimated in shorter children and underestimated in taller ones. SDS values remained within approximately ±1 SDS, supporting their usefulness for group-level assessments, though caution remains warranted in individual interpretation.

Model aggregation did not significantly improve accuracy; although mean biases were intermediate, limits of agreement remained wide, suggesting that combining similar models does not eliminate systematic error. This strategy may become more effective as future validated equations incorporate more diverse predictive approaches.

Overall, bias direction differed between cohorts: BB children showed systematic overestimation, likely due to measurement challenges, while CF patients exhibited a smaller underestimation, consistent with more stable skeletal proportions and more reliable HT measurements.

Strengths and Limitations

This study presents both strengths and some limitations that should be considered when interpreting the results. It provides updated and clinically applicable prediction equations for estimating HT from ulna and tibia length in children, derived from a large, healthy reference sample and validated in two independent clinical cohorts. The use of simple, low-cost, tape-based anthropometric measurements enhances the practicality of the method in both hospital and field settings. In addition, the new equations were systematically compared with previously published models and evaluated using Bland–Altman analysis, providing a rigorous and transparent assessment of accuracy and agreement.

Nonetheless, several limitations should be acknowledged. The clinical validation cohorts were relatively small, particularly the BB group, which may limit the generalisability of the findings. In both cohorts, the mean bias and limits of agreement were relatively wide, indicating potential imprecision when applying the equations at the individual level. Moreover, a proportional bias was observed for the tibia-based model in the CF cohort, suggesting that prediction accuracy may vary across the HT spectrum, particularly in taller or shorter children. A further limitation is that validation could only be performed in children whose HT remained measurable, since direct comparison between predicted and observed HT was required. Yet these equations are primarily

intended for children in whom standing HT cannot be obtained reliably. In such patients, altered body proportions or disease-related growth disturbances may affect the relationship between ulna or tibia length and true HT, meaning that performance in the intended target population remains uncertain. Although the equations performed well at the group level and were tested in clinical populations, their use for individual assessment should therefore be interpreted with caution. Further validation in larger and more heterogeneous paediatric populations, especially in children without reliable direct HT measurements, is warranted.

Conclusions

The new equations developed in this study, based on ulna and tibia lengths measured with a non-stretchable tape, showed good predictive performance in a large healthy paediatric population and acceptable performance in selected clinical cohorts. Compared with previously published models, they generally provided estimates closer to measured HT, particularly in the CF cohort, where preserved skeletal proportions and the absence of major postural abnormalities may have favoured better agreement between predicted and observed values.

The aggregated approach, which combined multiple predictive models, did not consistently improve performance over the new equations alone. Although averaging slightly reduced mean bias in some instances, limits of agreement remained relatively wide, indicating that this strategy does not by itself resolve individual-level imprecision. Nevertheless, model aggregation remains conceptually promising and may prove more useful as a broader range of validated equations becomes available.

These findings support the potential clinical utility of tape-based ulna and tibia measurements as practical surrogate methods when direct HT measurement is difficult. However, the equations should be applied cautiously at the individual level, particularly in children with altered body proportions or conditions affecting skeletal growth. Further studies in larger and more heterogeneous paediatric populations, especially in children for whom standing HT cannot be measured reliably, are needed to confirm validity and refine predictive accuracy across different clinical settings.

Data Availability Statement

The datasets generated and/or analysed during the current study are not publicly available due to privacy restrictions involving paediatric clinical data, but are available from the corresponding author on reasonable request.

References

1. Aurangzeb B, Whitten KE, Harrison B, Mitchell M, Kepreotes H, Sidler M, Lemberg DA, Day AS. Prevalence of malnutrition and risk of under-nutrition in hospitalized children. *Clin Nutr*. 2012;31:35–40.
2. Meisel-Roca A, Granger A. The height of children and adolescents in Colombia: a review of more than sixty years of anthropometric studies, 1957–2020. *Int J Environ Res Public Health*. 2021;18:8868.
3. Leite HP, Isatugo MK, Sawaki L, Fisberg M. Anthropometric nutritional assessment of critically ill hospitalized children. *Rev Paul Med*. 1993;111:309–13.
4. Atherton RR, Williams JE, Wells JC, Fewtrell MS. Use of fat mass and fat-free mass standard deviation scores obtained using simple measurement methods in healthy children and patients: comparison with the reference 4-component model. *PLoS One*. 2013;8:e62139.
5. Wells JC. A critique of the expression of paediatric body composition data. *Arch Dis Child*. 2001;85:67–72.
6. Velandia S, Hodgson MI, Le Roy C. Evaluación nutricional en niños hospitalizados en un servicio de pediatría. *Rev Chil Pediatr*. 2016;87:359–65.
7. Pichler J, Hill SM, Shaw V, Lucas A. Prevalence of undernutrition during hospitalisation in a children's hospital: what happens during admission? *Eur J Clin Nutr*. 2014;68:730–5.
8. Riley M, Godwin M, Deonandan R. Comparison of self-reported height and measured height in primary school children and their parents. *BMC Public Health*. 2020;20:1234.

9. Yu X, Cao X, Duan H. Accuracy of parental reporting of child height and its clinical implications. *Pediatr Res*. 2021;89:1540–5.
10. Milani S, Wright C, Purcell O, Macleod I, Gerasimidis K. Acquisition and utilisation of anthropometric measurements on admission in a paediatric hospital before and after the introduction of a malnutrition screening tool. *J Hum Nutr Diet*. 2013;26:294–7.
11. Dangour AD, Schilg S, Hulse JA, Cole TJ. Sitting height and subischial leg length centile curves for boys and girls from Southeast England. *Ann Hum Biol*. 2002;29:290–305.
12. Fredriks AM, van Buuren S, van Heel WJ, Dijkman-Neerincx RH, Verloove-Vanhorick SP, Wit JM. Nationwide age references for sitting height, leg length, and sitting height/height ratio and their diagnostic value for disproportionate growth disorders. *Arch Dis Child*. 2005;90:807–12.
13. Abrahamyan L, Pai H, Willems D, Mazzone L, Fehlings D. A comparison of alternative methods for measuring height in children with cerebral palsy. *Dev Med Child Neurol*. 2008;50:820–5.
14. Gauld LM, Kappers J, Carlin JB, Robertson CF. Height prediction from ulna length. *Dev Med Child Neurol*. 2004;46:475–80.
15. Froehlich-Grobe K, Nary DE, Van Sciver A, Lee J, Little TD. Measuring height without a stadiometer: empirical investigation of four height estimates among wheelchair users. *Am J Phys Med Rehabil*. 2011;90:658–66.
16. Neyestani TR, Dad-Khah M, Haidari H, Zowghi T, Maddah M, Nematy M, Aliabadi M. Determination of the actual height predictors in Iranian healthy children. *Acta Med Iran*. 2011;49:173–8.
17. Prentice AM, Ward KA, Cole TJ. Stunting, linear growth, and bone length: towards a unified theory. *Lancet Child Adolesc Health*. 2021;5:625–32.
18. Lara-Pompa NE, Hill S, Williams J, Macdonald S, Fawbert K, Valente J, et al. Use of standardized body composition measurements and malnutrition screening tools to detect malnutrition risk and predict clinical outcomes in children with chronic conditions. *Am J Clin Nutr*. 2020;112:1456–67.
19. Wells JC, Williams JE, Chomtho S, Darch T, Grijalva-Eternod C, Kennedy K, et al. Body-composition reference data for simple and reference techniques and a 4-component model: a new UK reference child. *Am J Clin Nutr*. 2012;96:1316–26.

20. Fewtrell MS, Prentice A, Jones SC, Bishop NJ, Stirling D, Buffenstein R, et al. Bone mineralization and turnover in preterm infants at 8–12 years of age: the effect of early diet. *J Bone Miner Res*. 1999;14:810–20.
21. BAPEN. Malnutrition Universal Screening Tool (MUST). 2023.
22. Madden AM, Tsikoura T, Stott DJ. The estimation of body height from ulna length in healthy adults from different ethnic groups. *J Hum Nutr Diet*. 2012;25:121–8.
23. Gauld LM, Kappers J, Carlin JB, Robertson CF. Prediction of childhood pulmonary function using ulna length. *Am J Respir Crit Care Med*. 2003;168:804–9.
24. Yousafzai AK, Filteau SM, Wirz SL, Cole TJ. Comparison of armspan, arm length and tibia length as predictors of actual height of disabled and nondisabled children in Dharavi, Mumbai, India. *Eur J Clin Nutr*. 2003;57:1230–4.
25. Oeffinger D, Conaway M, Stevenson R, Hall J, Shapiro R, Tylkowski C. Tibial length growth curves for ambulatory children and adolescents with cerebral palsy. *Dev Med Child Neurol*. 2010;52:e195–201.
26. Williams JE, Wells JC, Benden C, Jaffe A, Suri R, Wilson CM, Fewtrell MS. Body composition assessed by the 4-component model and association with lung function in 6–12-year-old children with cystic fibrosis. *Am J Clin Nutr*. 2010;92:1332–43.
27. Cole TJ, Freeman JV, Preece MA. Body mass index reference curves for the UK, 1990. *Arch Dis Child*. 1995;73:25–9.
28. Wells JC, Williams JE, Haroun D, Fewtrell MS, Colantuoni A, Siervo M. Aggregate predictions improve accuracy when calculating metabolic variables used to guide treatment. *Am J Clin Nutr*. 2009;89:491–9.
29. Surowiecki J. *The wisdom of crowds*. New York: Doubleday; 2004.

Supplementary material

Table 1S. Subject characteristics of ulna measurement cohort of healthy children.

Table 2S. Subject characteristics of tibia measurement cohort of healthy children.

Table 3S. Height, ulna and tibia length descriptives in BB group (a) SDS <-2 or >2, Freq=number of patients; (b) measured standing height

Table 4S. Mean bias, limits of agreement and correlation coefficients between measured and estimated heights using ulna and tibia lengths in the BB group and CF group (a) *Mean bias (cm or SDS); (b) One-sample t-test of mean bias (H_0: MB=0), (*) significant ($p<0.05$); (c) Pearson's correlation coefficient; (d) significance of r (H_0: r=0) testing the effect of magnitude of the measurement on the difference observed between measurements of height, all non-significant.*

Table 5S. Height, ulna and tibia length descriptives in CF group (a) SDS <-2 or >2, Freq=number of patients; (b) measured standing height

Table 6S. The new (Salatto et al.) and published prediction equations for height estimation using ulna and tibia lengths in healthy children

Tables

Table 1. Height prediction models using ulna length measurements (*n=700; (a) Coefficients for the predictors in the model; (b) 95% CI of the coefficients; (c) p-value for significance of the coefficients ($p<0.05$). (*) Chosen as best model)*

Table 2. Height prediction equations using tibia length measurements (*n=133; (a) Coefficients for the predictors in the model; (b) 95% CI of the coefficients; (c) p-value for significance of the coefficients ($p<0.05$). (*) Chosen best as model)*

Table 3. Calculated heights, height SDS of individual and aggregate prediction equations using ulna and tibia length. *"Salatto et al." refers to predictive equations generated in this study, "aggregate" is the average of all estimates of height by the different equations*

Figures

Figure 1. Line-based Bland–Altman summary plots showing mean bias (MB) and 95% limits of agreement (LOA) between measured height and height estimated from ulna or tibia length in the BB group and CF group. Panel A reports MB and LOA for height (cm); Panel B reports MB and LOA for height SDS.

Figure 2. Line-based Bland–Altman summary plots showing mean bias (MB) and 95% limits of agreement (LOA) between measured height and height predicted from segmental bone length using our equation (Salatto et al.), a published equation (Gauld et al., 2004), and their average ("Aggregate"). Panels A–B refer to ulna-estimated height in the BB group *(n=17)*: A reports MB and LOA for height (cm) and B for height SDS. Panels C–D refer to tibia-estimated height in the BB group *(n=17)*: C reports MB and LOA for height (cm) and D for height SDS. Panels E–F refer to tibia-estimated height in the CF group *(n=58)*: E reports MB and LOA for

height (cm) and F for height SDS. “Aggregate” indicates the mean of the height estimates obtained with the different equations.

Figures

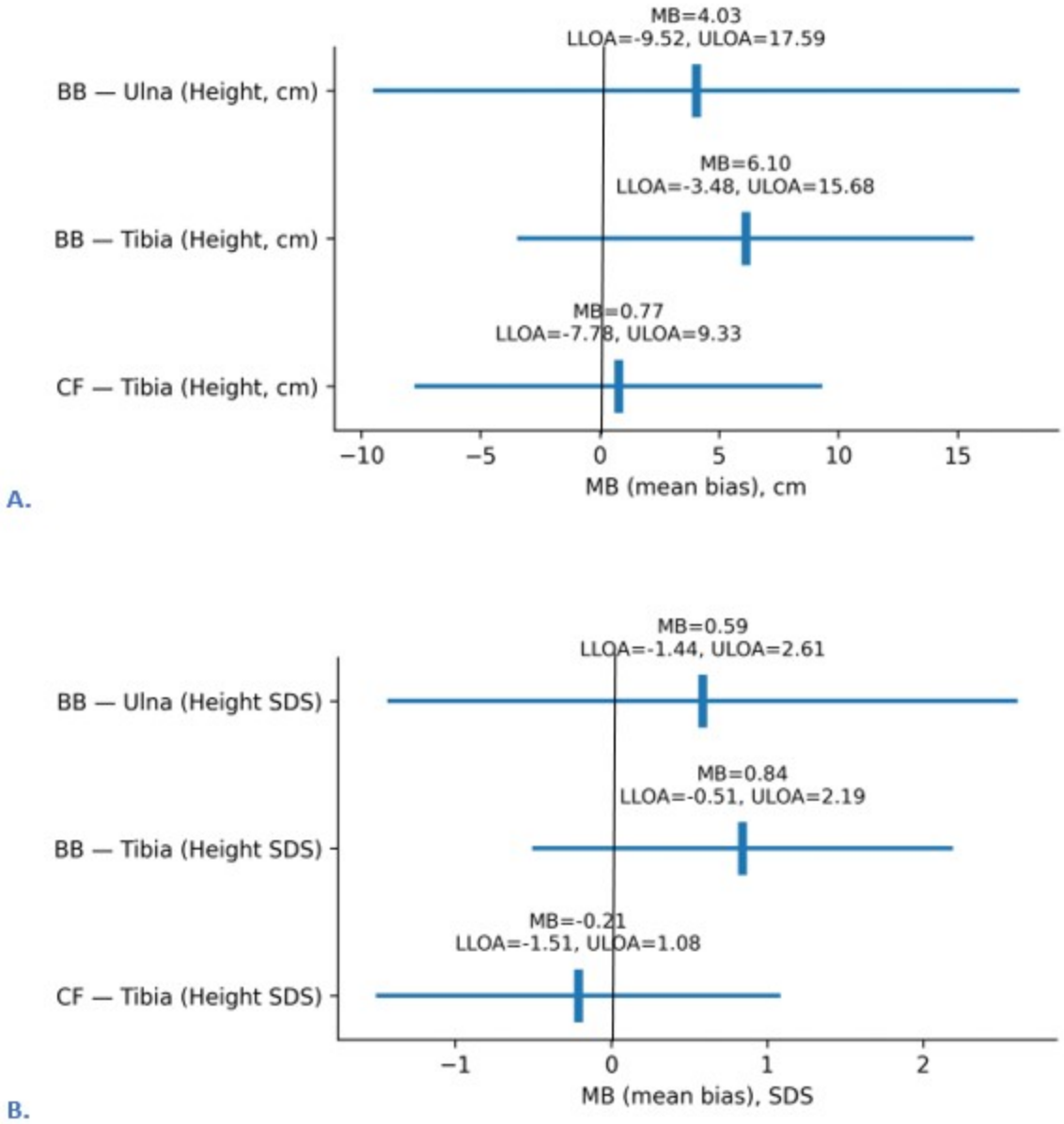


Figure 1

Line-based Bland–Altman summary plots showing mean bias (MB) and 95% limits of agreement (LOA) between measured height and height estimated from ulna or tibia length in the BB group and CF group. Panel A reports MB and LOA for height (cm); Panel B reports MB and LOA for height SDS.

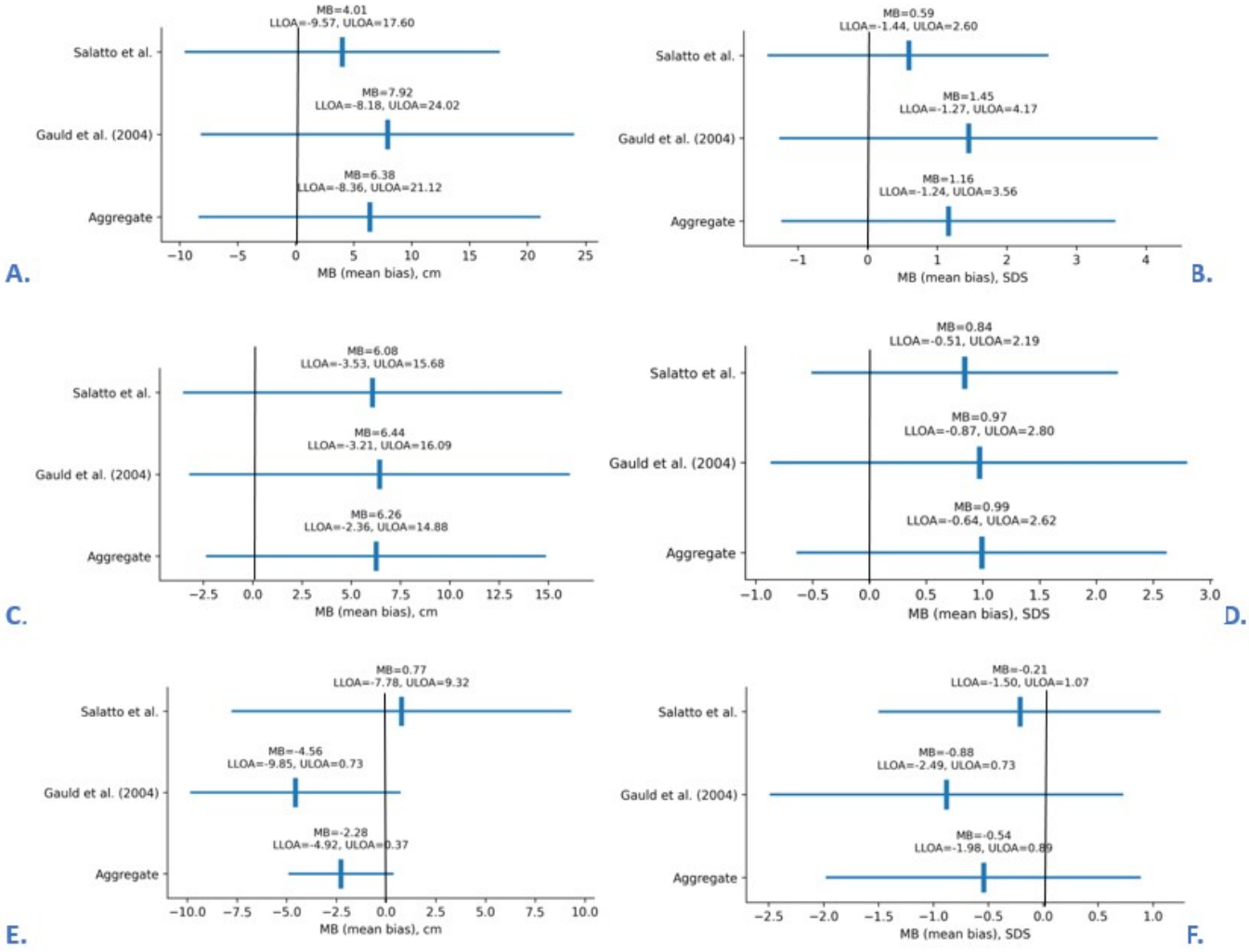


Figure 2

Line-based Bland–Altman summary plots showing mean bias (MB) and 95% limits of agreement (LOA) between measured height and height predicted from segmental bone length using our equation (Salatto et al.), a published equation (Gauld et al., 2004), and their average (“Aggregate”). Panels A–B refer to ulna-estimated height in the BB group *(n=17)*: A reports MB and LOA for height (cm) and B for height SDS. Panels C–D refer to tibia-estimated height in the BB group *(n=17)*: C reports MB and LOA for height (cm) and D for height SDS. Panels E–F refer to tibia-estimated height in the CF group *(n=58)*: E reports MB and LOA for height (cm) and F for height SDS. “Aggregate” indicates the mean of the height estimates obtained with the different equations.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1.docx
- Table2.docx

- Table3.docx
- Supplementarymaterial19.04.docx