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ORIGINAL ARTICLE

Agreement between Fenton and intergrowth curves in assessing birth weight of preterm infants: bland-altman analysis by degree of prematurity and birth weight for gestational age¹

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KEYWORDS

Preterm infant;
Birth weight;
Gestational age;
Small for gestational age;
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Growth charts

Abstract

Objective: To assess the agreement between the Fenton and INTERGROWTH charts in classifying birth weight for gestational age in preterm infants, considering prematurity degree and small/adequate/large-for-gestational-age (SGA/AGA/LGA) status individually and simultaneously.

Methods: Retrospective cohort study including 2529 preterm infants admitted between 2018 and 2021. Gestational age was estimated from obstetric data or by the Capurro/Ballard methods. Birth weight-for-gestational-age Z-scores were calculated according to both charts. Agreement was analyzed overall and by subgroups defined by prematurity degree and SGA/AGA/LGA status using the Bland-Altman method, complemented by boxplots.

Results: Overall agreement was reasonable (mean bias: -0.08 ; limits of agreement: -0.67 to 0.50), with slight overestimation of Z-scores by INTERGROWTH. Relevant variability was observed across subgroups. Disagreement extended across all prematurity strata with distinct patterns: greater dispersion in extremely and very preterm infants and more consistent but systematically biased differences in moderate-to-late preterm infants (bias: -0.12). The largest discrepancies occurred among SGA, especially in extremely preterm infants, among whom 50% had Z-scores beyond the limits of agreement. In this subgroup, Fenton tended to assign higher Z-scores, especially between 26 and 32 weeks of gestation, attenuating birth weight deficit severity. Agreement was considerable among AGA and LGA infants, especially in more mature preterm groups.

Conclusion: Although overall agreement between the charts was acceptable, clinically relevant differences were observed across all prematurity strata, particularly among more immature SGA infants. The charts are not interchangeable at the individual level, and their use may influence

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nutritional diagnosis and clinical management, reinforcing the importance of consistent and context-appropriate selection of growth reference.

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Q3 Introduction

2 The assessment of intrauterine growth is essential in neonatal care, guiding the diagnosis of intrauterine growth restriction (IUGR), nutritional planning, and risk stratification [1].
3 Birth weight for gestational age (GA) is the indicator that
4 allows classification of newborns as small-for-gestational-age- (SGA), appropriate (AGA), or large-for-gestational-age
5 (LGA), thereby guiding early interventions [2].

6 Several growth charts have been developed for nutritional assessment of preterm infants both at birth and thereafter, taking into account population, methodological, and epidemiological specificities. However, there is still no consensus regarding the choice of the most appropriate reference, especially for extremely preterm infants [3].

7 Charts such as those of Fenton (2013) and INTERGROWTH (2014) are widely used in clinical practice. The Fenton chart was based on a systematic review of large studies from developed countries using cross-sectional measurements of size at birth, whereas INTERGROWTH was constructed from an international cohort of low-risk pregnancies, with a small number of extremely preterm infants included [4,5]. Methodological differences between these charts affect the estimation of percentiles and Z-scores, potentially leading to practical impacts on the identification of SGA births and on nutritional planning [6,7].

8 Greater divergence between the charts has been reported in vulnerable subgroups, particularly in the presence of maternal risk factors (multiparity, chorioamnionitis, preeclampsia, gestational diabetes, and chronic diseases) [8]. Although numerous studies have compared chart agreement in determining outcomes (e.g. SGA classification) using concordance coefficients, to our knowledge, none have applied formal graphical agreement analysis, such as Bland-Altman or considered stratification by clinically relevant subgroups (degree of prematurity, SGA/AGA/LGA status) [8–14]. Notably, the clinical impact of variance between charts remains poorly characterized.

9 Thus, this study analyzed the agreement between the Fenton and INTERGROWTH charts in the assessment of birth weight for GA in a cohort of preterm infants, applying a formal graphical agreement methodology with analyses stratified by prematurity degree and SGA/AGA/LGA status (individually and simultaneously), to elucidate the implications of growth reference selection for nutritional assessment in this population.

45 Methods

10 This was an observational study of diagnostic agreement based on a retrospective cohort of preterm infants, whose data were extracted from the national QualiNeo database, linked to the Brazilian Ministry of Health. Newborns admitted between January 2018 and December 2021 to three

11 neonatal intensive care units (NICUs) and/or conventional intermediate care units (UCINCOs) of public hospitals in a Brazilian capital city were included.

12 Sex, birth weight, and gestational age at birth were recorded on standardized forms completed by the care team, as part of a larger project to monitor the quality of neonatal care.

13 Gestational age was estimated primarily from the date of the last menstrual period and first-trimester ultrasound; when unavailable, the Capurro or Ballard clinical methods were used. Birth weight was used to calculate the birth weight-for-gestational-age indicator, expressed as percentiles and Z-scores according to the Fenton (2013) and INTERGROWTH (2014) charts, using calculators available at: <https://ucalgary.ca/resource/preterm-growth-chart/calculators-apps> and <http://intergrowth21.ndog.ox.ac.uk/>.

14 Newborns were classified by birth weight adequacy as small for gestational age (SGA; < p10), appropriate for gestational age (AGA; p10–90), or large for gestational age (LGA; > p90) [15]. Prematurity was classified per World Health Organization criteria as extremely preterm (< 28 weeks), very preterm (28 to < 32 weeks), or moderate to late preterm infants (32–37 completed weeks) [16].

15 Term infants, preterm infants admitted exclusively to the Kangaroo Intermediate Care Unit, and those hospitalized for fewer than 14 days were excluded to select a clinically vulnerable population at higher nutritional risk, in whom differences in nutritional classification would be most relevant. Infants with congenital malformations or genetic syndromes were retained for the same reason. Those who died during hospitalization were excluded, as weight measurement at the study time point (required for future longitudinal analyses) would not be available.

16 The definition of the study population is shown in Figure 1.

17 Statistical analyses were performed using R software (version 4.5.0, R Core Team, Vienna, Austria). Sample characteristics were described using descriptive statistics - means and standard deviations (SD) for continuous variables and proportions for categorical variables.

18 Agreement between charts was assessed using Bland-Altman plots [17]. For each individual, the mean of the indicator values was plotted on the X-axis and the difference on the Y-axis (value of the Fenton indicator minus that of INTERGROWTH for each patient, in this order), such that more similar values result in points closer to zero. The mean difference (solid line), or mean bias, represents the systematic difference between methods (i.e., how much one method tends to measure more or less than the other on average; a value of zero indicates no systematic difference, whereas a non-zero value indicates consistent over- or underestimation). The limits of agreement (dotted lines) are defined as the mean difference $\pm 1.96SD$, representing the interval within which 95% of the differences between

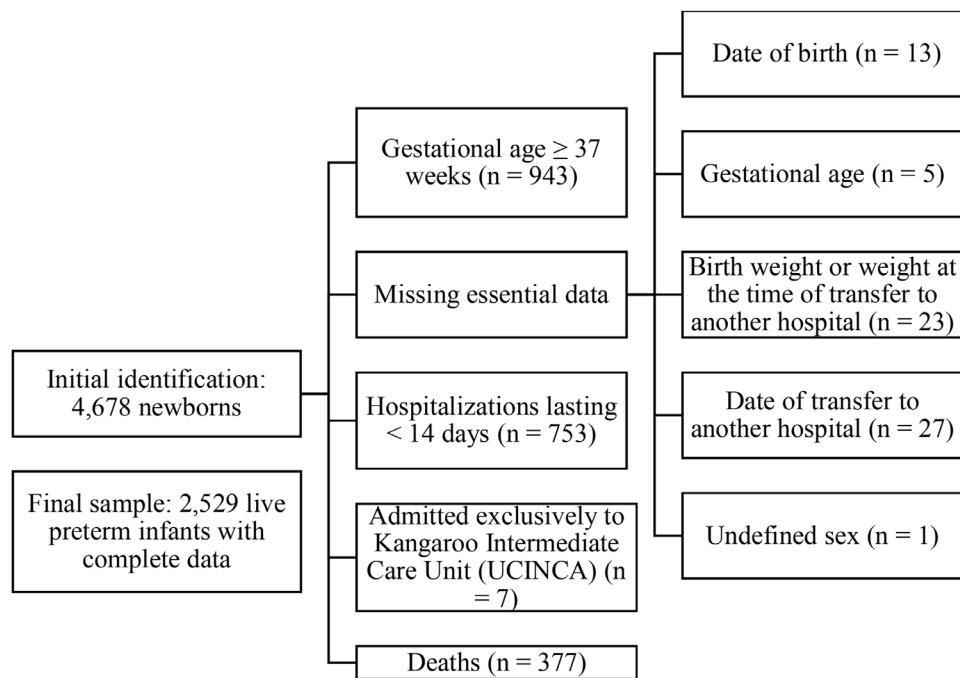


Figure 1 Study population definition.

105 measurements are expected to lie under a normal distribu-
 106 tion. The clinical validity of using both charts interchange-
 107 ably depends, among other factors, on the mean bias, these
 108 limits, and whether they are considered clinically accept-
 109 able. Visual inspection allowed identification of dispersion
 110 patterns - asymmetric or distant from the mean line distri-
 111 butions, suggesting a lower agreement.

112 Analysis was performed for the whole group and stratified
 113 by clinical subgroups: degree of prematurity (extremely pre-
 114 term, very preterm, and moderate-to-late preterm infants)
 115 and SGA/AGA/LGA status at birth, individually and simulta-
 116 neously. The analysis considering only the SGA, AGA, and
 117 LGA subgroups was presented in a single plot; however, the
 118 values of mean bias, SD, and limits of agreement were calcu-
 119 lated separately for each subgroup. Additionally, boxplots
 120 were constructed to assess the distribution of differences
 121 according to different gestational ages (in weeks).

The study was approved by the Research Ethics Committee
 122 of the participating institution (CAAE: 51,489,621.6.0000.5543)
 123 in accordance with current ethical principles for secondary
 124 data use, with consent requirement waived accordingly.
 125

This research received no specific funding from public,
 126 commercial, or not-for-profit agencies.
 127

128 **Results**

The study population’s general characteristics are summa-
 129 rized in Table 1.
 130

Agreement analyses between the methods are described
 131 below. Supplemental Figure 1 presents the overall Z-score
 132 agreement between the Fenton and INTERGROWTH charts,
 133 while Supplemental Table 1 summarizes the corresponding
 134

Table 1 General characteristics of 2529 preterm infants assessed at birth between 2018 and 2021 are presented in mean (standard deviation) or frequency.

Variable	Mean	n	%	n	%
Gestational age at birth (weeks)	32 (2.6)				
Birth weight (grams)	1584.4 (489.5)				
Prematurity degree					
Extremely preterm		195	7.7		
Very preterm		813	32.1		
Moderate to late preterm		1521	60.1		
Sex					
Male		1352	53.5		
Birth weight-for-gestational-age classification					
	SGA	671	26.5	688	27.2
	AGA	1805	71.4	1767	69.9
	LGA	53	2.1	74	2.9

135 mean bias, standard deviation, and limits of agreement for
 136 all analyses. The mean bias was -0.08 , near zero, indicating
 137 good overall agreement. The negative value reflects a slight
 138 overestimation of Z-scores by INTERGROWTH. The SD was
 139 0.29 , with limits of agreement of -0.67 to $+0.50$. Greater
 140 dispersion was observed at the lower end of the X-axis (Z-
 141 score < -2), while the range between -1.5 and $+1.5$ showed
 142 less variation. No cases fell below the lower limit of agree-
 143 ment, although a concentration was noted near and above
 144 the upper limit at the lower extreme of the X-axis.

145 **Figure 2** details agreement according to the degree of pre-
 146 maturity. In extremely preterm infants, the mean bias was
 147 -0.08 (SD 0.30), with limits of agreement from -0.68 to
 148 0.52 ; dispersion was reasonably homogeneous along the cen-
 149 tral range of the X-axis, although more pronounced at the
 150 negative extremes (Z-score < -2). In very preterm infants,
 151 despite a mean bias closer to zero (-0.02), the SD was the
 152 highest among the groups (0.38), yielding wider limits of
 153 agreement (-0.74 to 0.71). Among moderate to late preterm
 154 infants, the greatest bias was observed (-0.12), yet the SD
 155 was the lowest (0.24), with narrower limits of agreement
 156 (-0.60 to 0.35), resulting in points concentrated around the
 157 mean and few, proportionally, above the upper limit.

158 **Supplemental Figure 2** presents the agreement between
 159 charts according to SGA/AGA/LGA status. Since classifica-
 160 tion may differ between references, subgroups were defined
 161 separately for Fenton and INTERGROWTH, resulting in six
 162 stratified plots, with detailed agreement estimates provided
 163 in **Supplemental Table 1**.

164 Within the SGA subgroup, the mean bias was close to zero
 165 (0.08 and 0.12 for Fenton and INTERGROWTH, respectively),
 166 suggesting overall concordance at the group level. However,
 167 this should not be interpreted as indicative of good agree-
 168 ment, given the substantial dispersion observed - reflected

169 by high SD values (0.40 and 0.39), wide limits of agreement,
 170 and a considerable number of data points exceeding the
 171 upper limit, particularly among neonates with the most neg-
 172 ative z-scores. Nevertheless, most SGA infants retained the
 173 same classification across charts. The positive mean bias
 174 denotes a slight overestimation of Z-scores by Fenton. AGA
 175 infants showed the mean bias farthest from zero (-0.14 and
 176 -0.16), but lower SDs (0.22 and 0.20), resulting in less dis-
 177 persion and narrower limits of agreement; only five cases
 178 exceeded the upper limit, represented by gray inverted tri-
 179 angles (AGA by Fenton and SGA by INTERGROWTH). The LGA
 180 group showed the mean bias closest to zero for Fenton
 181 (-0.02), with equally low SD (0.22 for both charts) and limits
 182 of agreement containing all cases, confirming the greatest
 183 agreement among the three subgroups.

184 **Figure 3** explores agreement according to degree of pre-
 185 maturity and SGA/AGA/LGA status simultaneously. The main
 186 discrepancies occurred in the SGA group, especially among
 187 extremely preterm infants - 50% exceeded the upper limit of
 188 agreement (6 cases by Fenton and 7 by INTERGROWTH).
 189 Among very preterm infants, 32.4% of SGA infants by Fenton
 190 (33 cases) and 22.7% by INTERGROWTH (33 cases) also
 191 exceeded this limit. Among moderate or late preterm infants,
 192 the percentages were lower: 7.9% by Fenton (41 cases) and
 193 8.7% by INTERGROWTH (45 cases). AGA and LGA infants
 194 showed few or no cases outside the limits of agreement.

195 The analysis of GA as a continuous variable using boxplots
 196 in **Figure 4** complements the previous results, where this
 197 variable was presented in categories. The greatest discrep-
 198 ancies occurred among SGA infants in the 26–32-week
 199 range, with systematically higher Fenton values. In AGA and
 200 LGA infants, differences were close to zero with lower dis-
 201 persion. Positive outliers were also identified between
 202 27–32 and 34–36 weeks.

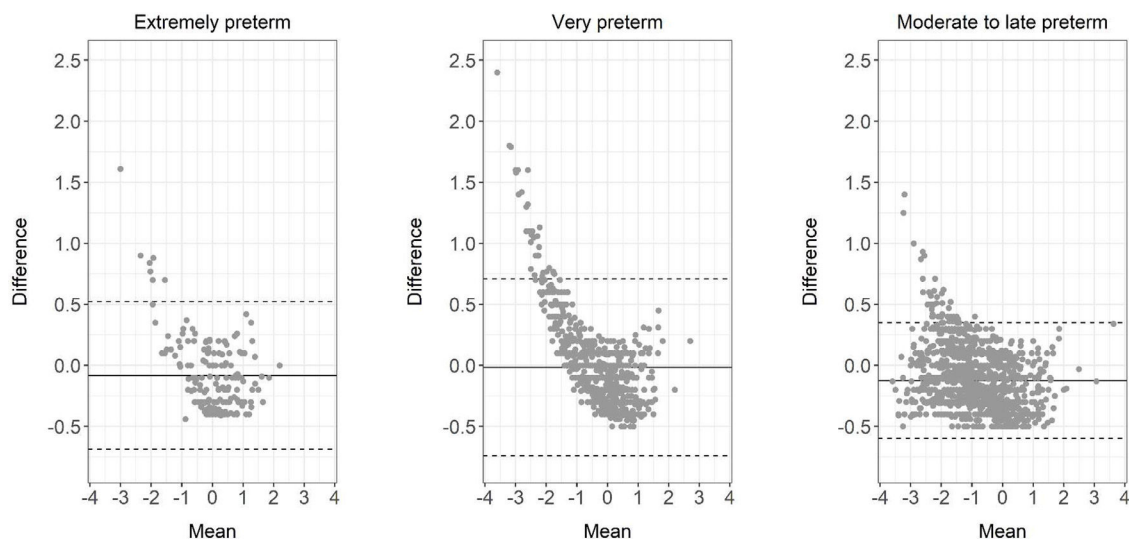


Figure 2 Bland-Altman plots for agreement analysis of birth weight-for-gestational-age Z-scores by prematurity degree between Fenton and INTERGROWTH in preterm infants (2018–2021).

CAPTION: In the Bland-Altman plot, the x-axis represents the mean birth weight-for-gestational-age Z-score obtained from the two charts for each infant (Fenton Z-score + INTERGROWTH Z-score) / 2), and the y-axis represents the difference between charts Fenton Z-score – INTERGROWTH Z-score. The solid horizontal line indicates the mean bias, and the dashed horizontal lines indicate the limits of agreement. Values above zero indicate higher Z-scores according to Fenton, whereas values below zero indicate higher Z-scores according to INTERGROWTH.

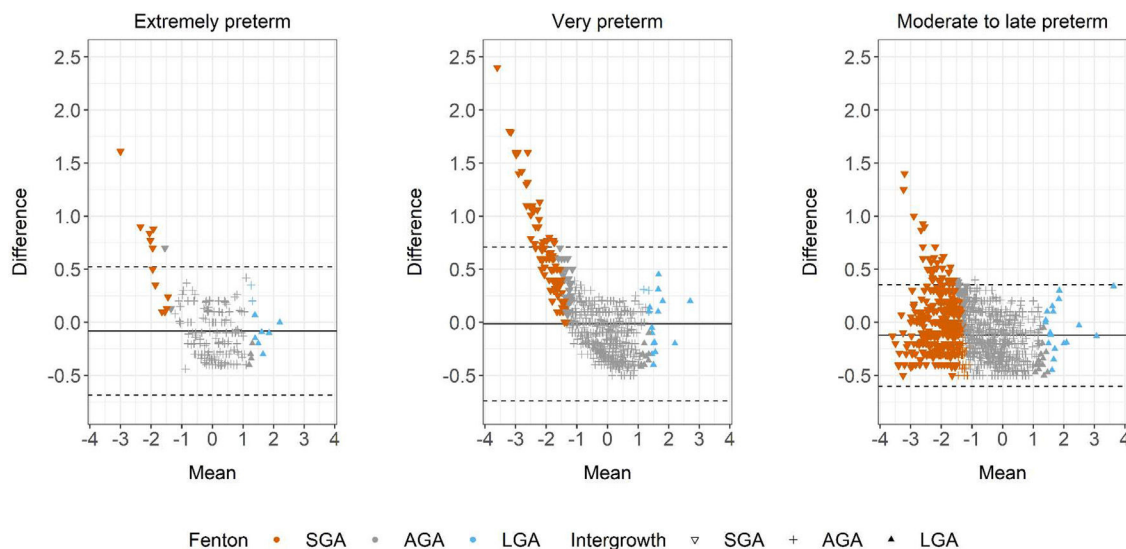


Figure 3 Bland-Altman plots for agreement analysis of birth weight-for-gestational-age Z-scores by prematurity degree and classification as small, appropriate, and large for gestational age between Fenton and INTERGROWTH in preterm infants (2018–2021).

CAPTION: In the Bland-Altman plot, the x-axis represents the mean birth weight-for-gestational-age Z-score obtained from the two charts for each infant (Fenton Z-score + INTERGROWTH Z-score) / 2, and the y-axis represents the difference between charts Fenton Z-score – INTERGROWTH Z-score. The solid horizontal line indicates the mean bias, and the dashed horizontal lines indicate the limits of agreement. Values above zero indicate higher Z-scores according to Fenton, whereas values below zero indicate higher Z-scores according to INTERGROWTH. Colors indicate classification according to the Fenton chart, whereas symbols indicate classification according to the INTERGROWTH chart. SGA, small for gestational age; AGA, appropriate for gestational age; LGA, large for gestational age.

203 **Discussion**

204 The present study provides a comprehensive agreement
 205 evaluation between Fenton and INTERGROWTH charts for
 206 birth weight-for-gestational-age Z-scores in preterm infants,

using Bland-Altman analysis (a continuous, graphical 207
 approach that captures agreement throughout the full dis- 208
 tribution), including clinically relevant subgroups defined by 209
 prematurity degree and SGA/AGA/LGA status. Overall 210
 agreement was reasonable, consistent with previous studies 211

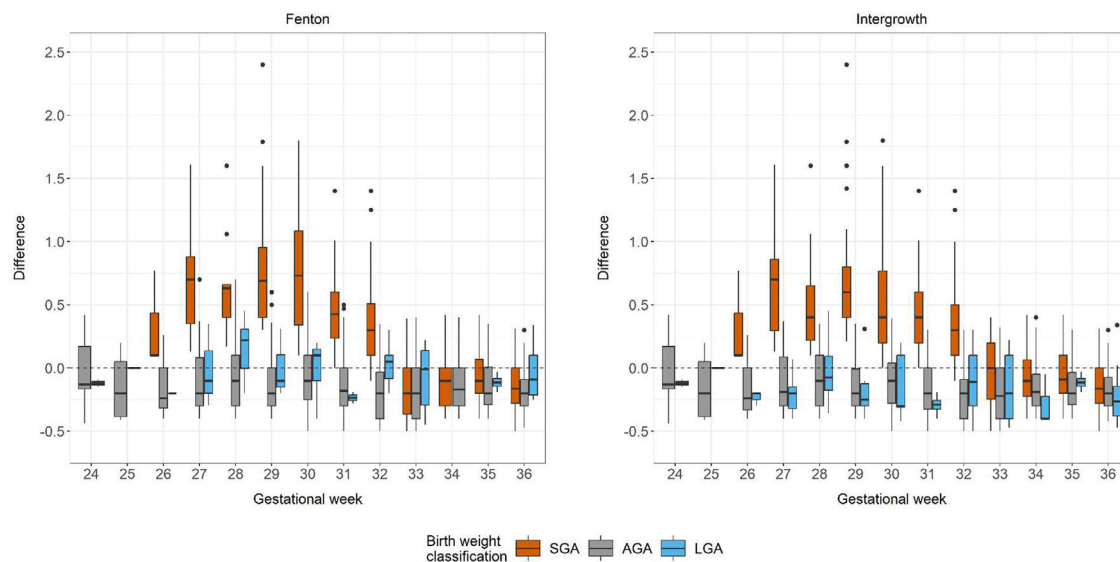


Figure 4 Distribution of differences in birth weight-for-gestational-age Z-scores between Fenton and INTERGROWTH stratified by gestational week and classification as small, appropriate, and large for gestational age in preterm infants (2018–2021).

CAPTION: Boxplots show the distribution of differences between birth weight-for-gestational-age Z-scores calculated according to Fenton and INTERGROWTH (Fenton Z-score – INTERGROWTH Z-score) across gestational weeks. Values above zero indicate higher Z-scores according to Fenton, whereas values below zero indicate higher Z-scores according to INTERGROWTH. Boxes represent the interquartile range, horizontal lines within boxes represent medians, whiskers represent the range of non-outlying values, and isolated points indicate outliers. SGA, small for gestational age; AGA, appropriate for gestational age; LGA, large for gestational age.

212 using concordance coefficients. However, deeper analysis
213 revealed meaningful variation according to indicator values
214 and the subgroups considered. The greatest discrepancies
215 occurred in SGA newborns regardless of prematurity degree,
216 though most pronounced among extremely preterm infants.
217 In this subpopulation, a positive bias indicated that the Fen-
218 ton chart tends to assign systematically higher Z-scores.
219 These findings suggest that global agreement metrics may
220 obscure clinically relevant discrepancies, whereas inter-
221 changeable use of the two charts appears more acceptable
222 among moderate to late preterm infants, particularly those
223 classified as AGA or LGA.

224 Previous studies evaluating agreement between Fenton
225 and INTERGROWTH charts have primarily relied on concor-
226 dance coefficients and categorical classification (SGA/AGA/
227 LGA), both at birth and/or in the postnatal period (extra-
228 uterine growth restriction) [11–13,18]. Such approaches,
229 however, do not perform simultaneous stratification by pre-
230 maturity degree and birth weight adequacy, nor do they fully
231 capture the continuous dimension of weight-for-gestational-
232 age Z-score differences, and therefore do not support robust
233 conclusions regarding clinical interchangeability. By apply-
234 ing continuous agreement analysis using Bland-Altman plots,
235 combined with stratification by prematurity degree and
236 SGA/AGA/LGA status, the present study allows a more
237 nuanced interpretation, encompassing not only classification
238 concordance but also the quantification and distribution of
239 discrepancies across the Z-score range within categories and
240 their potential clinical impact.

241 Stratified analysis by degree of prematurity revealed that
242 disagreement between charts extended beyond extremely
243 preterm infants. In the very preterm group, limits of agree-
244 ment were wide, with the upper limit approaching values
245 that may be clinically unacceptable, suggesting that individ-
246 ual discrepancies in this stratum can be substantial. Among
247 extremely preterm infants, the mean bias was small, but
248 data dispersion was considerable, reflecting low overall
249 agreement despite the apparent proximity of mean values.
250 A different pattern emerged in moderate to late preterm
251 infants: this group showed a greater systematic bias, with
252 INTERGROWTH consistently assigning higher Z-scores than
253 Fenton, but also the lowest SD, indicating more predictable
254 and consistent between-method differences. This distinc-
255 tion matters clinically: systematic bias with low variability is
256 more transparent and manageable than random discrepancy
257 with wide dispersion. These findings suggest that, although
258 interchangeability between charts may be relatively more
259 acceptable in moderate to late preterm infants, caution
260 remains warranted across all prematurity strata, particu-
261 larly when individual clinical decisions depend on precise Z-
262 score values.

263 This concern is further amplified when considering SGA
264 infants, a population in which precise Z-score classification
265 carries direct implications for nutritional diagnosis and
266 intervention. In this subgroup, especially those born
267 extremely preterm, dispersion was markedly higher and lim-
268 its of agreement were wide, indicating that individual Z-
269 score differences frequently reached magnitudes of poten-
270 tial clinical relevance. Differences approaching 0.8SD or
271 more, as observed in this subgroup, correspond to thresholds
272 used in the diagnosis of mild malnutrition according to the
273 consensus published by the Academy of Nutrition and

Dietetics [19]. Critically, even when the mean bias was close
274 to zero, substantial variability persisted at the individual
275 level, underscoring that mean differences alone are insuffi-
276 cient to support interchangeability between charts. This distinc-
277 tion is clinically meaningful: nutritional assessment and
278 monitoring in neonatal practice frequently rely on changes
279 in Z-scores over time (ΔZ), and variations of this magni-
280 tude between charts may lead to misinterpretation of
281 growth trajectories, particularly in more immature SGA
282 infants. Switching between charts during follow-up may arti-
283 ficially amplify or attenuate perceived growth changes,
284 potentially resulting in inappropriate adjustments in nutri-
285 tional management. Therefore, apparently modest differen-
286 ces between charts may carry meaningful implications for
287 longitudinal nutritional assessment and clinical decision-
288 making when charts are used interchangeably. 289

290 Although Fenton and INTERGROWTH are both widely used
291 in clinical practice, their methodological foundations differ
292 substantially: Fenton derives from a meta-analysis of large
293 population-based studies, whereas INTERGROWTH reflects
294 growth under optimal conditions [20]. These differences
295 help explain the discordant classifications observed in this
296 study, particularly at the extremes of gestational age. Nota-
297 bly, Fenton tended to assign higher Z-scores than INTER-
298 GROWTH in the SGA subgroup, especially between 26 and 32
299 weeks. This pattern may reduce SGA birth rate, potentially
300 delaying the recognition of higher-risk infants and impairing
301 earlier nutritional intervention and monitoring. The conse-
302 quences of such divergence are not merely statistical: in
303 clinical settings with a high prevalence of extremely pre-
304 term or SGA infants, such as Brazilian public NICUs, the
305 choice of growth reference may directly impact clinical
306 management [6,7]. Health care providers should be aware
307 that Z-score values are not directly interchangeable across
308 charts and should interpret them within the context of the
309 chosen reference, ideally maintaining a single, consistent
310 chart throughout hospitalization and follow-up. These find-
311 ings highlight that agreement between growth charts should
312 not be interpreted solely based on categorical concordance,
313 but rather on the potential clinical consequences of contin-
314 uous differences, especially in high-risk neonatal popula-
315 tions.

316 This study has several limitations that should be consid-
317 ered when interpreting the findings. As a retrospective anal-
318 ysis based on secondary data, it was not possible to control
319 for all clinical and nutritional variables that may influence
320 growth. Gestational age estimation relied on multiple sources,
321 including clinical methods such as Capurro and Ballard
322 in some cases, which may introduce measurement variabil-
323 ity, particularly among the most immature infants. Further-
324 more, the exclusion of infants hospitalized for fewer than
325 14 days, those admitted exclusively to Kangaroo Intermedi-
326 ate Care Units, and those who died during hospitalization
327 may have introduced selection bias, limiting generalizability
328 to lower-risk or more severe populations. Anthropometric
329 measurements were obtained by different professionals,
330 which may also affect data consistency.

331 Despite these limitations, the study has important
332 strengths. It includes a large sample with representation
333 across all degrees of prematurity and applies a robust ana-
334 lytical framework that goes beyond traditional categorical
335 comparisons. The use of Bland-Altman analysis combined

336 with clinically meaningful stratifications enabled the identi-
 337 fication of agreement patterns that would likely remain
 338 undetected using conventional methods. This approach pro-
 339 vides a more nuanced understanding of how growth charts
 340 perform in real-world clinical populations.

341 Graphical agreement analysis between Fenton and INTER-
 342 GROWTH charts demonstrated that, although reasonable
 343 overall correspondence exists, clinically relevant differen-
 344 ces emerge when stratifying by prematurity degree and
 345 growth classification. Disagreement extends beyond
 346 extremely preterm infants, affecting all prematurity strata
 347 with distinct patterns: greater dispersion and less predict-
 348 able differences among extremely and very preterm infants,
 349 and more consistent but systematically biased differences
 350 among moderate to late preterm infants.

351 The most pronounced inconsistencies were observed in
 352 SGA infants, particularly among the most immature, in
 353 whom differences frequently reached magnitudes of poten-
 354 tial clinical relevance. In this subgroup, the tendency of the
 355 Fenton chart to assign higher Z-scores may attenuate the
 356 apparent severity of birth weight deficit and influence nutri-
 357 tional assessment and management. Notably, even in the
 358 presence of minimal mean bias, wide limits of agreement
 359 indicate that the charts are not interchangeable at the indi-
 360 vidual level.

361 Therefore, growth reference selection should be guided
 362 not only by normative considerations but also by the clinical
 363 context and intended use, with consistent application of a
 364 single chart being essential for longitudinal assessment. This
 365 is particularly relevant in high-complexity neonatal settings
 366 such as Brazilian public NICUs, especially for more immature
 367 SGA infants.

368 The analytical approach adopted allowed identification
 369 of variability patterns not captured by traditional categori-
 370 cal methods, reinforcing the relevance of continuous agree-
 371 ment analysis in neonatal growth evaluation. Further studies
 372 should investigate the longitudinal impact of these discrep-
 373 ancies on growth trajectories to better inform evidence-
 374 based practice.

375 Data availability statement

376 The data that support the findings of this study are available
 377 from the corresponding author.

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380 Conflicts of interest

381 The authors declare no conflicts of interest.

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Supplementary materials 389

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