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Article

International Normative Charts for Twin Weight, Length, and Head Circumference at Birth, By Gestational Age and Sex: The Twin Neonatal Cross-Sectional Study of the INTERGROWTH-21st Project

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Abstract

Assessing the size of twins at birth using charts developed for singletons may over diagnose small for gestational age in this sub-population. The study aimed to produce international, twin-specific, newborn size normative charts by gestational age and sex. This longitudinal observational study in eight geographically diverse settings prospectively collected data between May 2009 and August 2013 from healthy pregnant women and their newborn twins. The participants were enrolled as part of the INTERGROWTH-21st study, and recruited based on World Health Organization recommendations for evaluation of anthropometric measures. All the women met, in addition to the underlying population characteristics of low perinatal risk, strict individual criteria for a population at low risk of impaired fetal growth. Newborn weight, length and head circumference measures were collected independently in duplicate by two trained anthropometrists within 12 hours of birth using identical equipment and protocols at all sites. From 1034 multiple pregnancies, after exclusions of condition such as smoking, high maternal BMI, and congenital malformations, the final sample was 864 twin newborns. Most of the twins were below the 50th centile of the INTERGROWTH-21st standards for singletons. We present international newborn size normative charts for twins using the same methodological approach adopted to construct the singleton standards.

Keywords: Twins; Size at birth; Anthropometric charts; Birth weight

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Assessment of newborn size is a vital component of neonatal care that informs the level of postnatal care required, guides early interventions, and helps to predict future health risks. Birth data at population level is a reliable indicator of the overall health and nutritional status when compared with international standards to inform public health policy.

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In 2014, to standardize individual newborn care and facilitate comparisons across the world, the INTERGROWTH-21st Consortium published international newborn size standards for singletons (Villar et al., 2014), based on World Health Organization (WHO) recommendations for the evaluation of anthropometric measures (de Onis & Habicht, 1996). Using these standards, the estimated prevalence of small vulnerable newborns —born preterm or small for gestational age (SGA)—among 165 million live births in 23 countries from 2000 to 2021 was 11.7%, IQR 9.9−14.2% (Suarez-Idueta et al., 2023).

Whether the same standards should be used to assess the size of newborn twins remains uncertain. Compared to singletons, newborn twins have lower birth weights for gestational age with a distribution shifted to the left (Joseph et al., 2003) and different

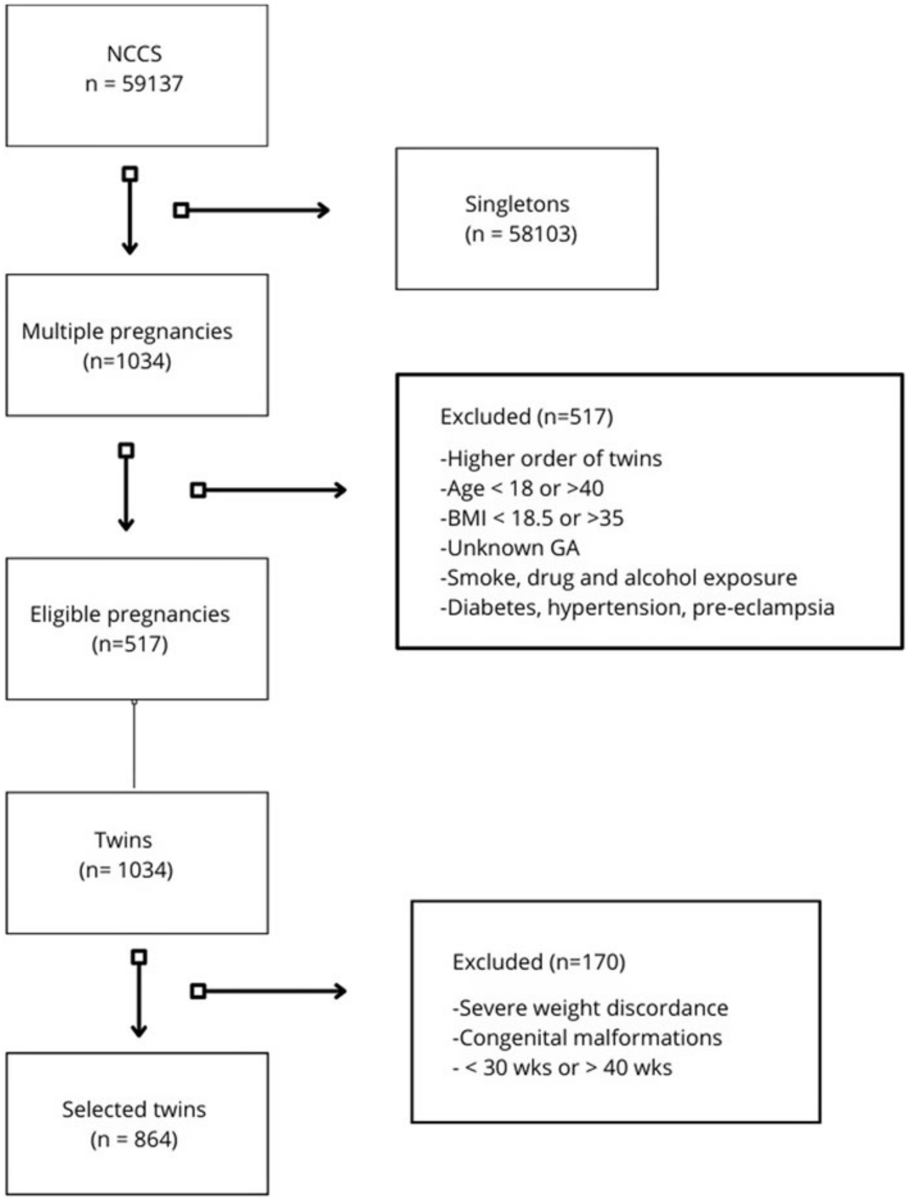

Figure 1. Flow chart.

etiological characteristics of the low birth weight; and the pattern of their intrauterine growth differs from 26–28 weeks' gestation (Ghi et al., 2017; Grantz et al, 2016; Hiersch et al., 2020). Consequently, the SGA rate for newborn twins at birth, based on singleton charts, can be as high as 30–50% (Grantz et al., 2016; Hiersch et al., 2022; Melamed & Hiersch, 2025).

The divergence in fetal growth between twins and singletons has traditionally been explained by the physical constraints imposed by the size of the uterus and the so-called 'placental crowding hypothesis', that is, the concept that the uteroplacental unit fails to meet the fetuses' nutritional requirements late in pregnancy (Bleker et al., 1995).

It has also been suggested that the slower growth of twin fetuses is 'a benign physiological adaptation in a predominantly monotocous species when faced with the challenge of multiple gestations' (Melamed & Hiersch, 2025). The evidence for such a physiological adaptation includes the finding that twins diagnosed as SGA on singleton reference charts are less likely to have abnormal placental histopathology than SGA singletons (Kibel et al., 2017). In addition, it has recently been shown that dichorionic twins have proportionally, in some ultrasonographic markers, less fat accumulation than singletons from as early as 15 weeks' gestation (Gleason et al., 2025). Whether or not this is an early evolutionary adaptive process or a consequence of risk factors associated with multiple pregnancies (i.e., maternal age, assisted conception, infertility history) remains unclear.

Hence, there are arguments for using twin-specific charts to avoid over-diagnosing SGA at birth and potential clinical harms (Townsend & Khalil, 2021). However, the selection of a prescriptive population for the construction of such normative tools is perhaps the most limiting factor, that is, what is a normative twin population considering the multicausality of multiple pregnancies and the associated pathologies?

While the debate about the use of twin-specific charts continues, given that (a) the INTERGROWTH-21st Consortium has collected data to characterize a normative sample matching the singleton standards and (b) there is a clinical demand for such a robust tool, we have decided to offer the size at birth counterpart

Table 1. Population baseline characteristics for twin and singleton NCSS[21] population. All values are mean (*SD*) for continuous variables and absolute numbers (percentage) for categorical variables

	Twins ($n = 864$)	Singletons ($n = 20,486$)
Maternal age, years (Mean, *SD*)	31.12 (5)	28 (4)
Maternal height, cm (Mean, *SD*)	162.53 (6.9)	161.8 (5.6)
Maternal first trimester weight, kg (Mean, *SD*)	63.7 (10.9)	61.3 (8.6)
Years of formal education (Mean, *SD*)	13.7 (3.5)	14.2 (3)
Hb level before 15 weeks gestation, g/dl (Mean, *SD*)	12.1 (1.4)	12.3 (1.2)
Gestational age at birth, weeks (Mean, *SD*)	36.1 (1.8)	38.7 (1.3)
Preterm birth < 37 weeks GA (*N*, %)	424 (47.4)	1136 (5.5)
C-section (*N*, %)	307 (70.9)	7452 (36.4)
Boys (*N*, %)	438 (48.9)	10,482 (51.2)
Exclusive breastfeeding at discharge (*N*, %)	425 (49.2%)	17,992 (87.8)

Note: NCSS[21,] Newborn Cross-Sectional Study of the INTERGROWTH-21st Project.

for twin newborns. Thus, here we present international newborn size normative charts for twins using the same methodological approach adopted to construct the singleton standards.

Materials and Methods

Study Design and Participants

A detailed description of the study design, methodology, and strategy for selecting the study populations is available elsewhere (Villar et al., 2013). In brief, the Newborn Cross-Sectional Study (NCSS) of the INTERGROWTH-21st Project was a population-based study, conducted between 2009 and 2014, in eight delimited urban centers in three high-income, three middle-income and two low-income countries worldwide: Pelotas, Brazil; Turin, Italy; Muscat, Oman; Oxford, UK; Seattle, USA; Shunyi County, a suburban district of the Beijing municipality, China; Central Nagpur, Maharashtra, India; and the Parklands suburb of Nairobi, Kenya.

The populations were selected in settings in which mothers' health and nutritional needs were met, adequate antenatal care was offered and there were no major environmental constraints on fetal growth. Participating hospitals covered >80% of all deliveries in their corresponding geographically demarcated areas during the study period. Data were collected from all newborns over 12 consecutive months at each study site, or until the target of >7000 deliveries per site was attained.

Detailed information on maternal social, demographic, environmental and clinical characteristics, as well as pregnancy and delivery outcomes were abstracted from medical records, complemented by information from care providers (if records were incomplete) and by interviewing the mothers using a structured questionnaire. During the study period, all newborns—including those admitted to the neonatal intensive care unit (NICU), to special care or to another referral-care level—were assessed daily until hospital discharge to document mortality and morbidity.

All body size measures were collected independently in duplicate by two trained anthropometrists. Measures were taken within 12 hours of birth using identical equipment at all sites: an electronic scale (Seca, Hangzhou, China) for birth weight, a specially designed Harpeden infantometer (Chasmors, London, UK) for length, and a metallic nonextendable tape (Chasmors) for head circumference. The equipment, which was calibrated twice a week, was selected for accuracy, precision, and robustness. Measurement procedures were standardized across sites. If any differences between measurements exceeded the set maximum allowable values (birth weight = 50 g, birth length = 7 mm and head circumference = 5 mm), both observers independently obtained a second measurement. The intra- and inter-observer error of measurement values, obtained during the standardization and retraining sessions of the anthropometry staff, were 0.3 to 0.5 cm for recumbent length (Cheikh Ismail et al., 2013).

Methods for training, standardization and quality control were uniformly employed across all sites and have been described elsewhere (Cheikh Ismail et al., 2013). Neonatal clinical practices, including NICU care and feeding, were also standardized across sites based on a package of minimum evidence-based practices, following an agreed protocol adopted by the INTERGROWTH-21st Neonatal Study Group (Bhutta et al., 2013).

To construct the INTERGROWTH-21st newborn size standards for singletons, we selected an 'NCSS prescriptive subpopulation' that consisted of all pregnancies meeting, in addition to the underlying population characteristics, strict individual eligibility criteria for a pregnant population at low risk of impaired fetal growth (Villar et al., 2014). Women also had a reliable ultrasound estimate of gestational age using crown-rump length <14 weeks' gestation or biparietal diameter, the latter if antenatal care started ≥14 weeks and ≤24 weeks' gestation.

In the present analysis, we have produced international newborn size normative charts for twins using the same conceptual framework and methodology as for singletons, except that we slightly modified the inclusion criteria used for the original study on singleton pregnancies because we also included women: (a) aged >35 and <40; (b) who conceived using assisted reproductive technology (ART); and (c) with a history of previous miscarriages because these are causally associated with twin pregnancies. We performed a sensitivity analysis to ascertain any effect of these variables on twin size at birth.

Data Collection

The data processing and management systems are described in detail elsewhere (Ohuma et al., 2013). In brief, all supporting documentation and data collection forms used in the INTERGROWTH-21st Project were translated into the main local language, tested locally and introduced into the specially developed, electronic data management system. All forms were integrated and linked to reduce duplication in the data collection process and facilitate data quality control mechanisms. During data cleaning, all implausible measures were excluded from the analysis. All data collection forms and manuals of operation are freely available online (www.intergrowth21.org.uk).

Statistical Analysis

Our analytical approach has been described in detail previously (Villar et al., 2014). In brief, fractional polynomials (Royston & Altman, 1994), LMS (Cole, 1988, 1989; Cole & Green, 1992), LMST

Table 2. Maternal baseline characteristics, by country

	Brazil (*n* = 26)	China (*n* = 38)	India (*n* = 71)	Italy (*n* = 74)	Kenya (*n* = 55)	Oman (*n* = 25)	UK (*n* = 88)	USA (*n* = 56)	Total (*n* = 433)
Maternal age (years) mean (*SD*)	28.62 (5.58)	27.37 (4.03)	28.52 (4.61)	33.96 (3.49)	30.84 (4.91)	29.16 (4.61)	33.15 (4.61)	32.38 (4.40)	31.12 (5.00)
Maternal height (cm) Mean (*SD*)	162.15 (5.23)	160.21 (5.15)	156.61 (3.98)	164.93 (6.19)	162.20 (6.34)	157.88 (5.58)	164.90 (6.29)	167.29 (8.07)	162.53 (6.96)
Maternal weight (kg) Mean (*SD*)	62.19 (9.30)	61.18 (10.77)	57.20 (9.00)	61.84 (8.83)	66.33 (10.36)	64.88 (10.96)	67.34 (10.54)	67.84 (12.91)	63.68 (10.91)
Maternal BMI (kg/m2) Mean (*SD*)	23.61(3.12)	23.76 (3.73)	23.28 (3.46)	22.78 (3.28)	25.20 (3.64)	25.97 (3.86)	24.78 (3.68)	24.23 (4.10)	24.08 (3.71)
Gestational age at first visit (wks) Mean (*SD*)	13.78 (7.44)	16.95 (6.15)	16.13 (8.04)	12.95 (3.82)	15.96 (8.50)	14.72 (5.81)	13.09 (3.28)	11.95 (4.27)	14.28 (6.14)
Years of formal education Mean (*SD*)	11.42 (4.04)	12.21 (3.08)	14.56 (3.18)	14.08 (3.91)	14.51 (3.05)	13.36 (2.78)	15.5 (3.01)	15.67 (3.20)	13.77 (3.53)
Hb concentration before 15 wks GA (g/L) Mean (*SD*)	12.21 (0.97)	13.92 (1.24)	10.85 (1.27)	12.20 (1.03)	12.80 (2.28)	11.50 (0.98)	12.34 (1.08)	12.73 (0.85)	12.08 (1.35)
Married or cohabiting *N* (%)	24 (92.31)	36 (94.74)	69 (97.18)	70 (94.59)	53 (96.36)	23 (92.00)	84 (95.45)	48 (85.71)	407 (94.00)
Nulliparous *N* (%)	12 (46.15)	17 (44.74)	35 (49.3)	44 (59.46)	17 (30.91)	4 (16.00)	34 (38.64)	21 (37.5)	184 (42.49)
Pyelonephritis *N* (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (4)	0 (0)	0 (0)	1 (0.23)
Maternal sexually transmitted infection *N* (%)	1 (3.85)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	8 (14.29)	9 (2.08)
Spontaneous initiation of labor *N* (%)	14 (53.85)	11 (28.95)	24 (33.8)	36 (48.65)	20 (36.36)	10 (40.00)	32 (36.36)	28 (50.0)	175 (40.42)
PROM *N* (%)	9 (34.62)	7 (18.42)	8 (11.27)	19 (25.68)	8 (14.55)	5 (20.00)	14 (15.91)	12 (21.43)	82 (18.94)
Cesarean section N (%)	23 (88.46)	35 (92.11)	64 (90.14)	53 (71.62)	43 (78.18)	20 (80.00)	43 (48.86)	26 (46.43)	307 (70.9)
Mother admitted to intensive care unit *N* (%)	0 (0)	0 (0)	1 (1.41)	1 (1.35)	1 (1.82)	0 (0)	0 (0)	1 (1.79)	4 (0.92)

Note: PROM, prelabor rupture of membranes.

Table 3. Neonatal baseline characteristics and perinatal events, by country

	Brazil (*n* = 52)	China (*n* = 76)	India (*n* = 140)	Italy (*n* = 149)	Kenya (*n* = 110)	Oman (*n* = 50)	UK (*n* = 175)	USA (*n* = 112)	Total (*n* = 864)
NICU admission > 1 day *N* (%)	24 (46.2)	15 (19.7)	32 (22.9)	30 (20.1)	26 (23.6)	8 (16.0)	49 (28.0)	50 (44.6)	234 (27.1)
Preterm birth (< 37 weeks) *N* (%)	28 (53.85)	24 (31.58)	64 (45.71)	111 (74.5)	43 (39.09)	20 (40.0)	58 (33.14)	76 (67.86)	424 (49.07)
Term low birth weight (< 2500 g. %)	5 (9.62)	8 (10.53)	0 (0)	4 (2.68)	26 (23.64)	9 (18)	6 (3.43)	11 (9.82)	69 (7.99)
Neonatal mortality *N* (%)	0 (0)	0 (0)	2 (1.43)	0 (0)	0 (0)	0 (0)	1 (0.57)	0 (0)	3 (0.35)
Boys *N* (%)	29 (55.8)	34 (44.7)	61 (43.6)	78 (52.4)	62 (52.4)	28 (56.0)	85 (48.6)	61 (54.5)	438 (50.7)
Exclusive breastfeeding at hospital discharge *N* (%)	26 (50.0)	46 (60.5)	124 (88.6)	7 (4.7)	83 (75.5)	40 (80.0)	72 (41.1)	27 (24.1)	425 (49.2)
Number of term twins	*N* = 24	*N* = 52	*N* = 76	*N* = 38	*N* = 69	*N* = 30	*N*= 117	*N* = 36	*N* = 442
Term birth weight (kg) Mean (*SD*)	2.38 (0.44)	2.74 (0.33)	2.34 (0.33)	2.58 (0.37)	2.64 (0.33)	2.51 (0.32)	2.68 (0.36)	2.69 (0.39)	2.59 (0.37)
Term birth length (cm) Mean (*SD*)	45.77 (2.35)	46.94 (1.81)	46.31 (1.94)	46.59 (1.87)	46.93 (1.68)	46.98 (1.73)	47.22 (1.76)	47.45 (2.0)	46.87 (1.85)
Term head circumference (cm) Mean (*SD*)	31.94 (1.55)	32.67 (1.24)	31.54 (1.27)	32.42 (0.94)	32.88 (1.24)	32.31 (1.15)	33.05 (1.33)	33.06 (1.18)	32.57 (1.35)

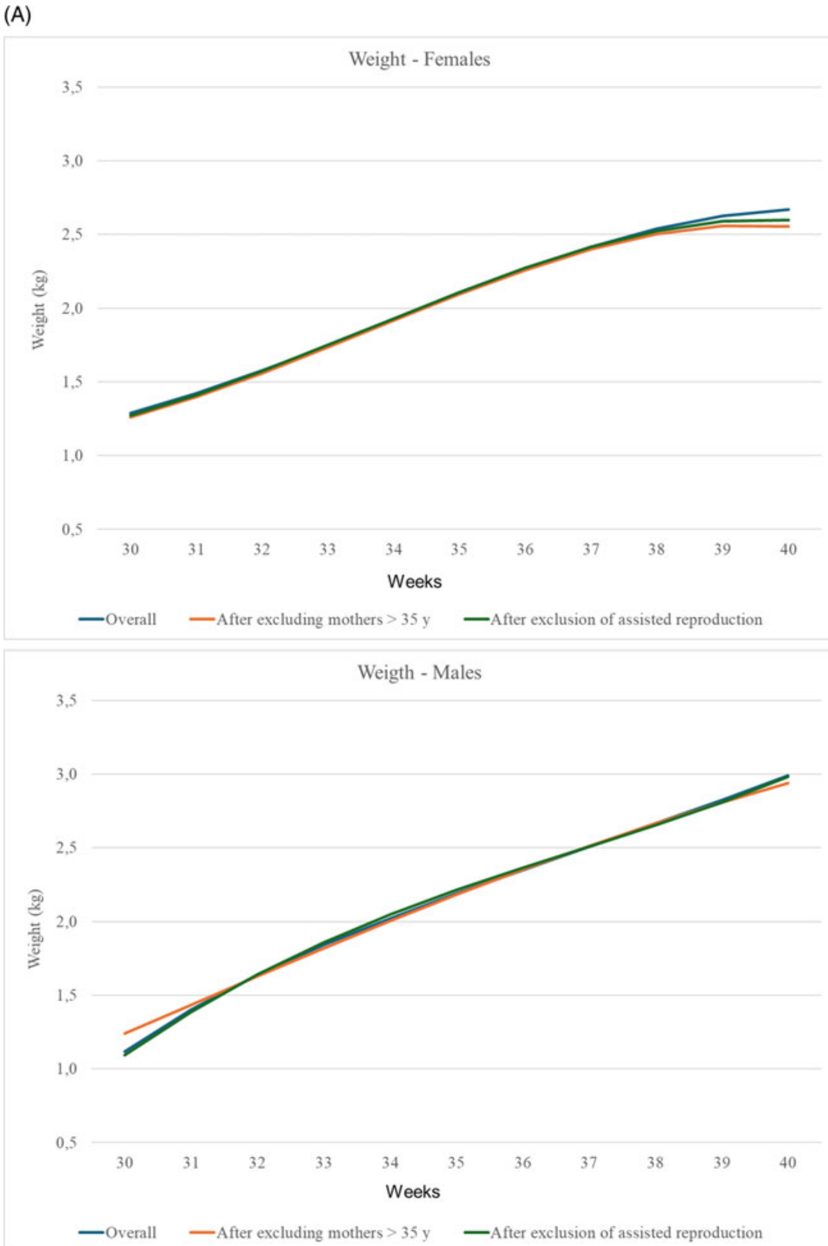

Figure 2. Sensitivity analyses for maternal age > 35 years and assisted reproduction techniques for birth weight (A), birth length (B) and head circumference (C) for females and male.

(Rigby & Stasinopoulos, 2006) and LMSP (Rigby & Stasinopoulos, 2004) methods assuming a skewed *t* distribution were used to estimate the fitted centiles. Although fractional polynomials provided satisfactory estimates compared to the other three methods, here we applied all approaches given that our twins sample is smaller and could have different characteristics to the singletons.

As before, we employed the Generalized Additive Models for Location, Scale and Shape (GAMLSS) framework (Rigby & Stasinopoulos, 2005, 2007), which provides the option of fitting various distributions other than the normal (skewed and kurtotic distributions) and modeling other parameters of a distribution that determine scale and shape using fractional polynomials. Furthermore, we evaluated three smoothing techniques: fractional polynomials (Royston & Altman, 1994), cubic splines (Green and Silverman, 1994) and penalized splines (Eilers & Marx, 1996).

Goodness-of-fit was assessed by four methods: visual inspection of the overall fit of the model using residual quantile-quantile graphs; Worm plot (van Buuren & Fredriks, 2001); Q statistic (Royston & Wright, 2000) for a particular gestational age range; plots of residual versus fitted values and the distribution of fitted *z* scores across gestational ages.

Data Availability

Anonymized data will be made available upon reasonable request for academic use and within the limitations of the informed consent. Requests must be made to the corresponding author. Every request will be reviewed by the INTERGROWTH-21st

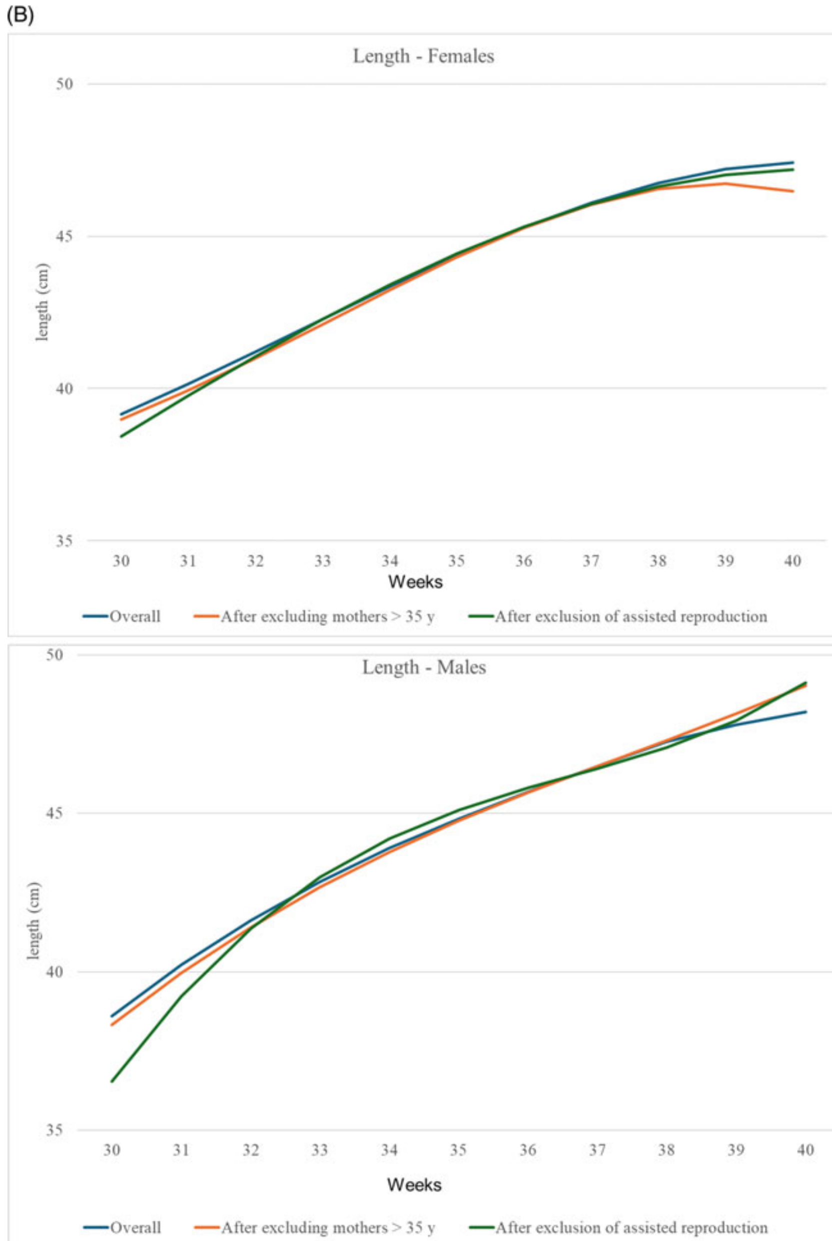

Figure 2. (Continued).

Consortium Executive Committee. After approval the researcher will need to sign a data access agreement with the INTERBIO-21st Consortium.

Results

Of the 59,137 deliveries included in NCSS between May 2009 and August 2013, 1034 (1.7%) were multiple pregnancies (Figure 1). Among those deliveries, we excluded higher order multiple pregnancies ($n = 32$, 3.1%) and pregnancies with an unreliable estimate of gestational age ($n = 122$, 11.8%), as well as mothers aged < 18 or > 40 years ($n = 61$, 5.9%), with a body mass index (kg/m2) > 35 or < 18.5 (124; 12,5%), who smoked or used alcohol or drugs ($n = 36$; 3.5%), and had pregnancy complications ($n = 142$, 13.7%) i.e. diabetes, hypertension, preeclampsia. We also excluded infants with a congenital malformation ($n = 26$, 2.5%, excluding only the newborn with a malformation and not the twin if healthy), those born <30 or > 40 weeks' gestation ($n = 30$, 2.9%) and those with a birth-weight discrepancy > 25% that was found in literature to be associated with higher risk ($n = 114$, 11.0%), leaving a final sample of 864 twin newborns.

Table 1 shows the baseline maternal and neonatal characteristics of the twin sample and, for comparison, those for the pregnancies in NCSS, which contributed to the newborn size standards for singletons (Villar et al., 2014). The marked differences between the twin and singleton datasets were the rates

(C)

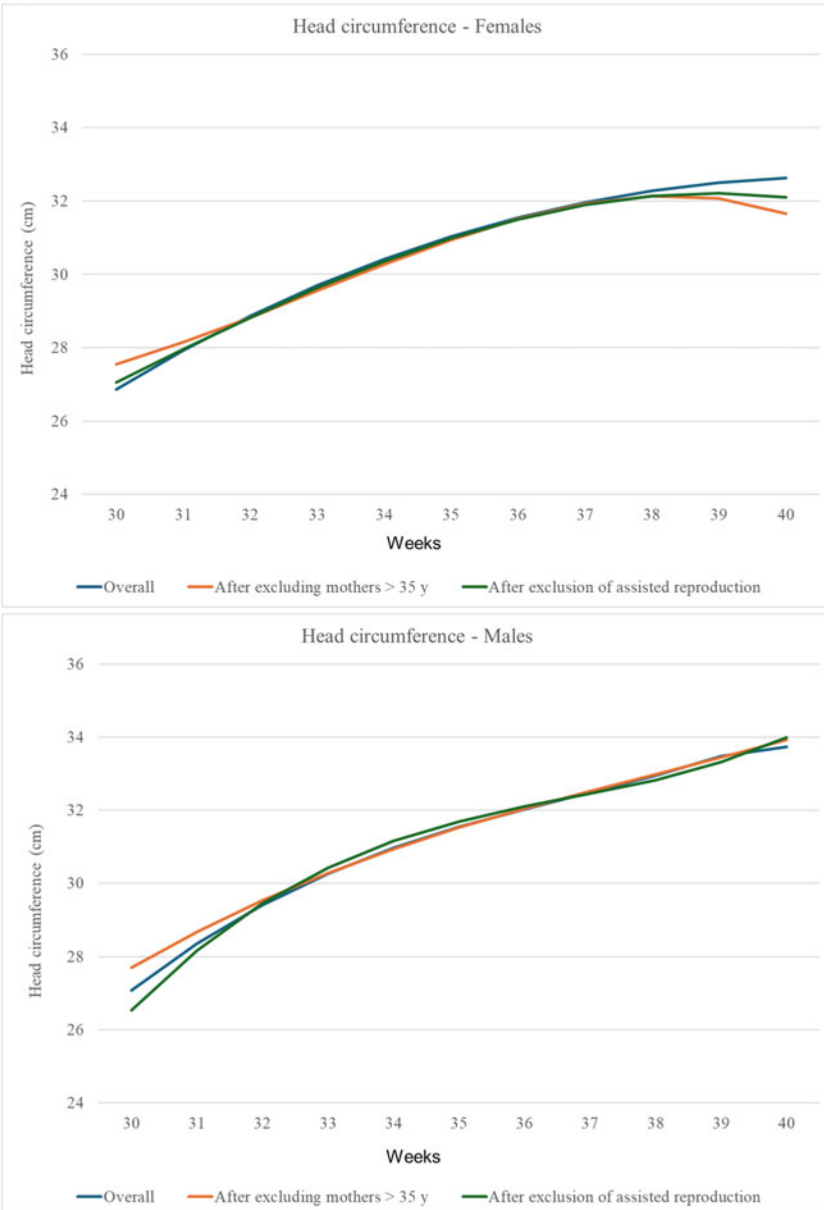

Figure 2. (Continued).

of cesarean section (70.9% vs. 36.4%), preterm birth (47.4% vs. 5.5%) and exclusive breastfeeding at hospital discharge (49.2% vs. 87.8%).

Tables 2 and 3 show maternal and neonatal baseline characteristics and perinatal events by study site. The rates of cesarean section were highest in Beijing (92.1%) and Nagpur 90.1%) and lowest in Oxford (48.9%) and Seattle (46.4%). The preterm birth rates were highest in Turin (74.5%) and Seattle (67.9%) and lowest in Beijing (31.6%) and Oxford (33.1%). Although NICU admission rates for >1 day varied from 16% (Muscat) to 46.2% (Pelotas), overall neonatal mortality was very low (0.4%).

Figure 2 shows the sensitivity analyses for birth weight (A), length (B) and head circumference (C) for boys and girls separately after excluding maternal age > 35 years, previous miscarriages and conception due to ART in our sample; neither maternal age, previous miscarriages nor ART had any major effect on the pooled centiles.

Figure 3 shows the scatter plots of the birth weight (A), length (B), and head circumference (C) of each individual female twin, and compares the 50th centiles of the singleton and twin charts. Interestingly, most of the twin population falls below the 50th centile of the singletons. There is also an increasing divergence between the 50th centiles as gestational age increases towards term

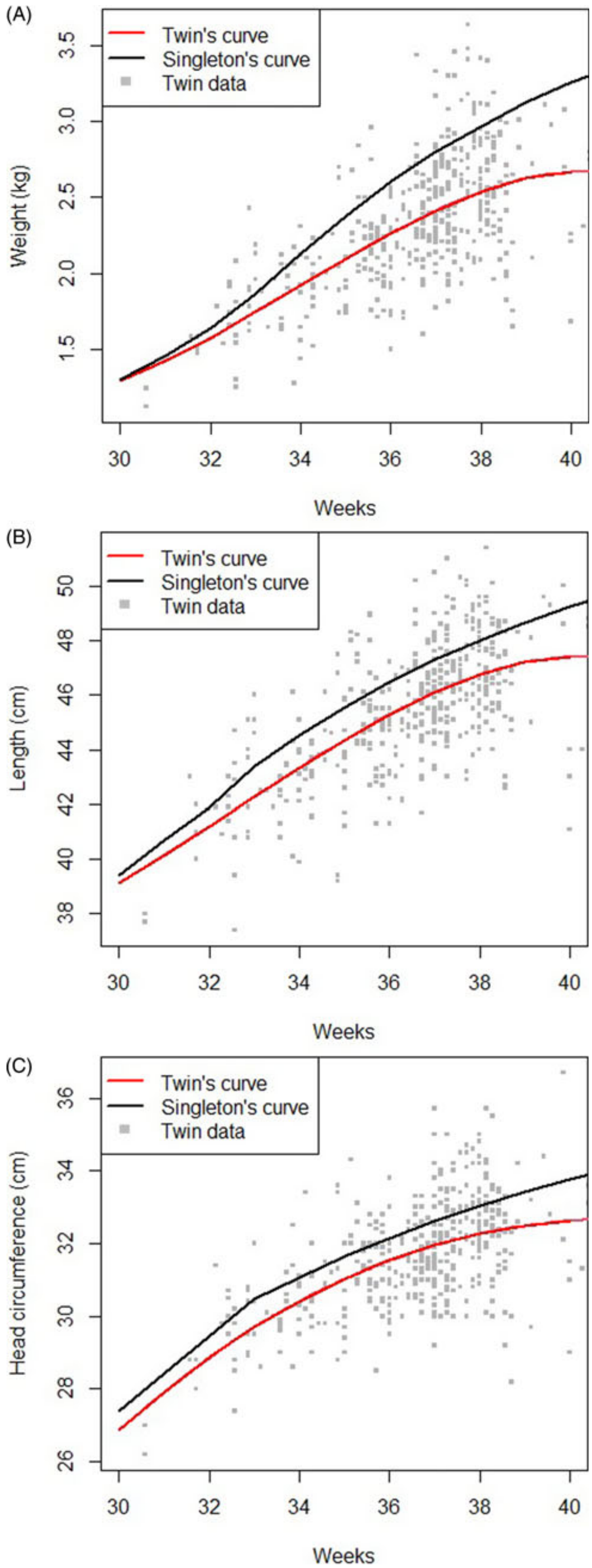

Figure 3. Comparison between the 50th centile of singleton (black) and twin (red) standards of females, for weight (A), length (B) and head circumference (C), for females, with twin measurements scatter plot superimposed.

for all three measures, but mainly for weight. The same pattern can be observed in boys (data not shown).

Figure 4A-4F shows the 3rd, 10th, 50th, 90th and 97th smoothed centile curves from 30 to 40 weeks' gestation for weight (A), length (B) and head circumference (C) according to gestational age and sex, which represent the international normative charts for newborn twins.

Tables 4–6 show the smoothed 3rd, 10th, 50th, 90th and 97th centiles for twin boys and girls for birth weight (kg), length (cm) and head circumference (cm) according to gestational age. Overall, boys were heavier and longer, and had larger head circumferences than girls.

Discussion

To our knowledge these are the first international, multi-ethnic, sex-specific, anthropometric normative charts for assessing the size of newborn twins, mirroring the methodological approach used to produce the INTERGROWTH-21st newborn size standards for singletons (Villar et al., 2014).

These twin-specific normative charts meet the WHO recommendations as compared to our systematic review of the methodological quality of studies designed to create twin-specific newborn charts (Giuliani et al., 2015), which did not identify any studies that did so. Among the included studies, most had methodological flaws, such as unreliable gestational age assessment, lack of head circumference and length measures, single center recruitment, and lack of a preplanned design or unclear statistical methodology, thus making comparisons difficult across different populations.

Beyond the variables shared with singleton pregnancies, there are specific factors affecting twin fetal growth that can challenge the prescriptive concept: (a) pathological (i.e., selective FGR in monochorionic twins with unequal placental sharing or twin-to-twin transfusion) or (b) an adaptation secondary to a demand–driven constraint, whose mechanisms are still not completely understood. This explains why various groups, such as the UK Southwest Thames Obstetric Research Collaborative (STORK), have produced twin-specific fetal growth charts that enable the causes for the disproportionately high SGA rate found when using singleton charts to be explored (Kalafat et al., 2019; Kalafat & Khalil, 2022).

Predictably, birth-weight thresholds related to neonatal morbidity and mortality differ between singletons and twins, being lower for the latter (Hiersch et al., 2022). In addition, many studies have shown that even if the proportion of twins identified as SGA on singleton charts is much higher than that for singletons, the association between SGA and adverse neonatal outcomes is only apparent when SGA is diagnosed using twin-specific charts (Briffa et al., 2022; Mendez-Figueroa et al., 2018; Nowacka et al., 2021; Shea et al., 2021).

Furthermore, Joseph et al. (2009), instead of using a fixed centile cut-off across gestational ages as a measure of impaired fetal growth, estimated the risk for adverse neonatal outcomes in relation to absolute birth weight as a continuous variable at each gestational week that was associated with the lowest risk. They found that the threshold was lower in twins than in singletons across all gestational ages, supporting the hypothesis that an important component of size difference between twins and singletons is benign, that is, the smaller size of twins compared to singletons is not necessarily predictive of pathology.

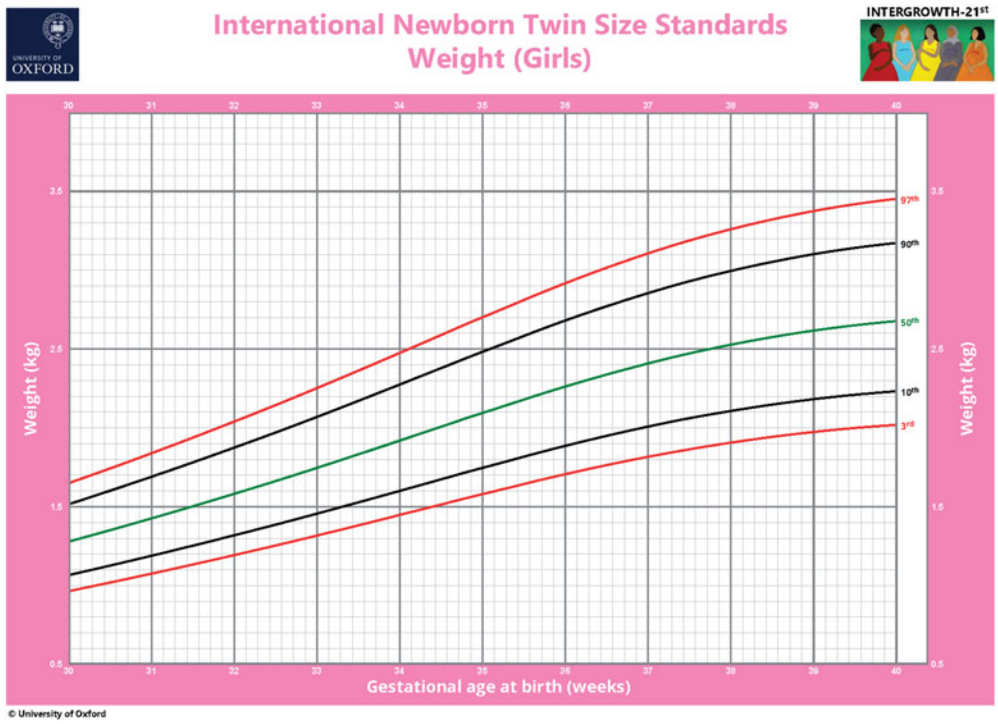

Figure 4 **A.** International newborn twin size standards for weight for girls.

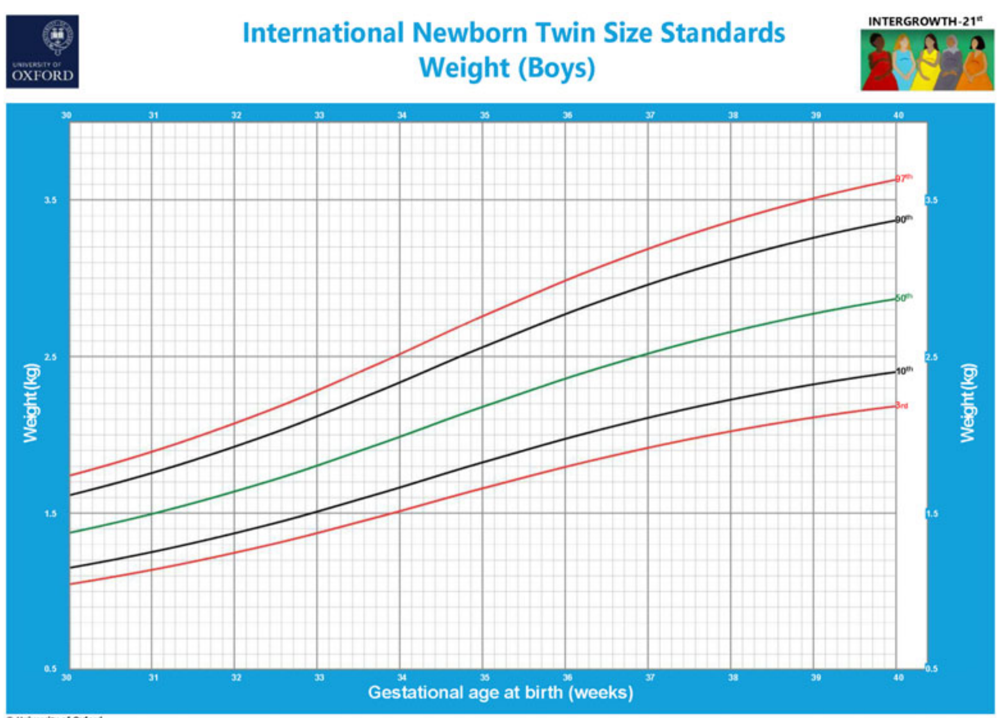

Figure 4 **B.** International newborn twin size standards for weight for boys.

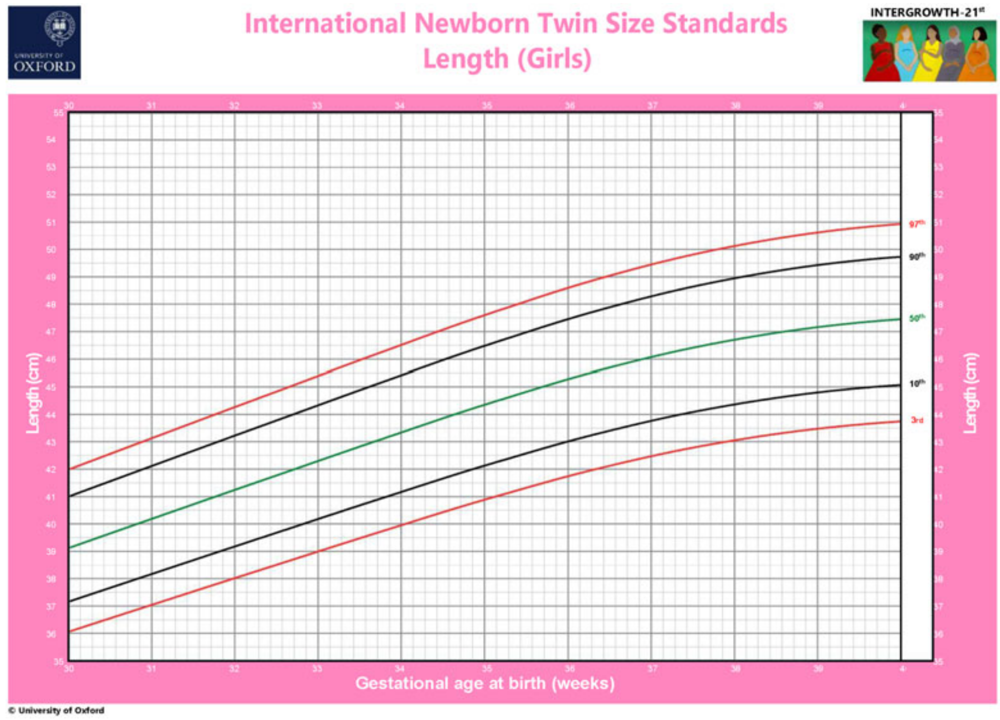

Figure 4 C. International newborn twin size standards for length for girls.

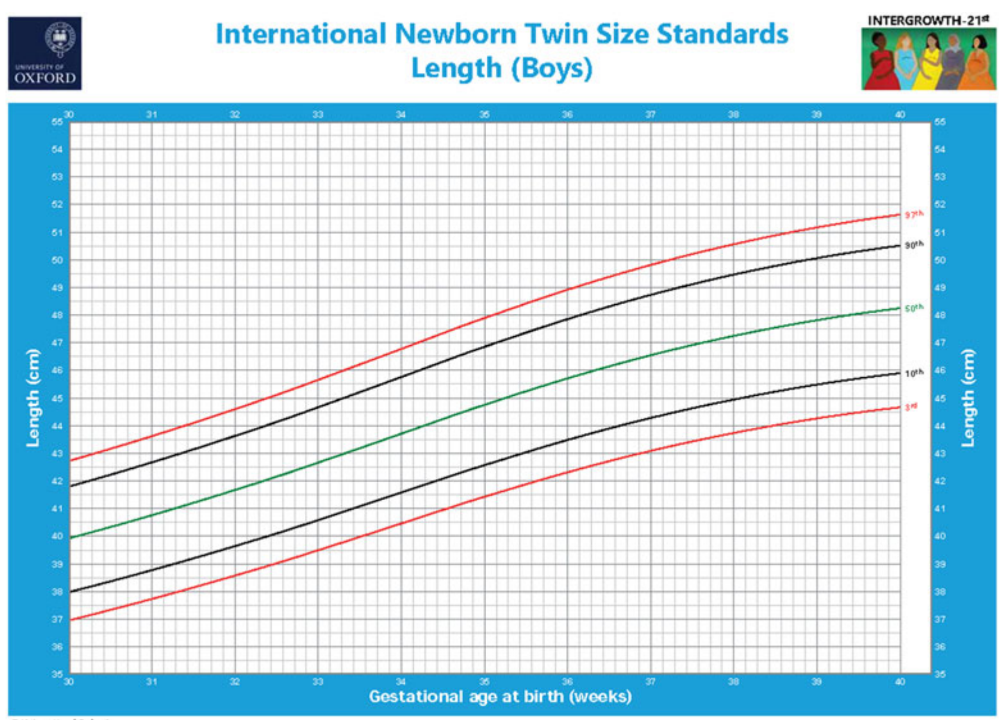

Figure 4 D. International newborn twin size standards for length for boys.

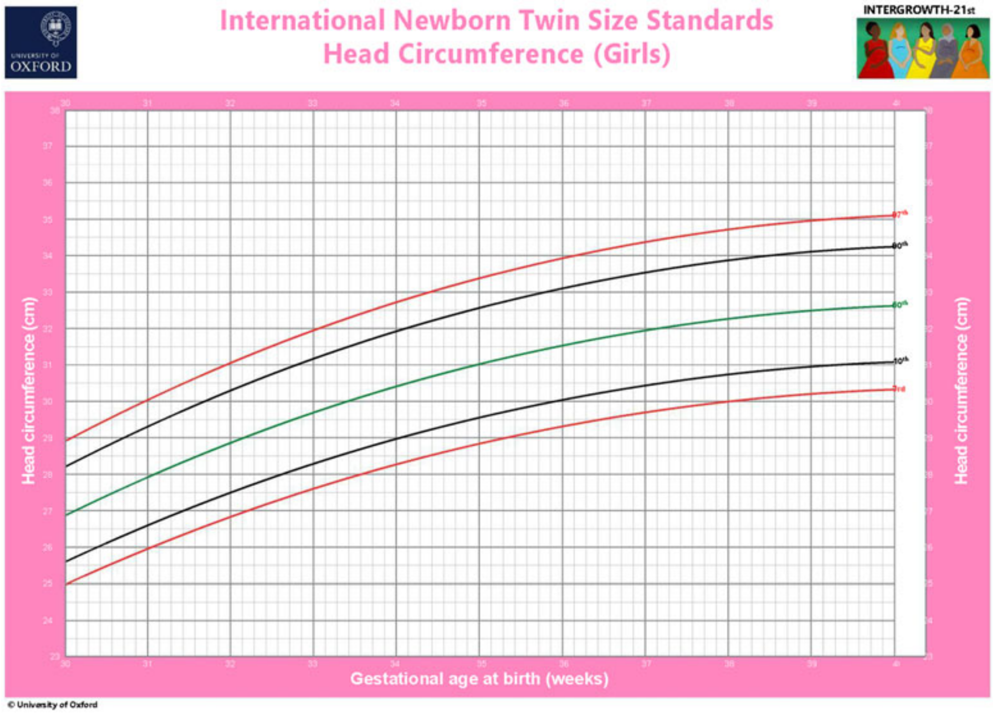

Figure 4 E. International newborn twin size standards for head circumference for girls.

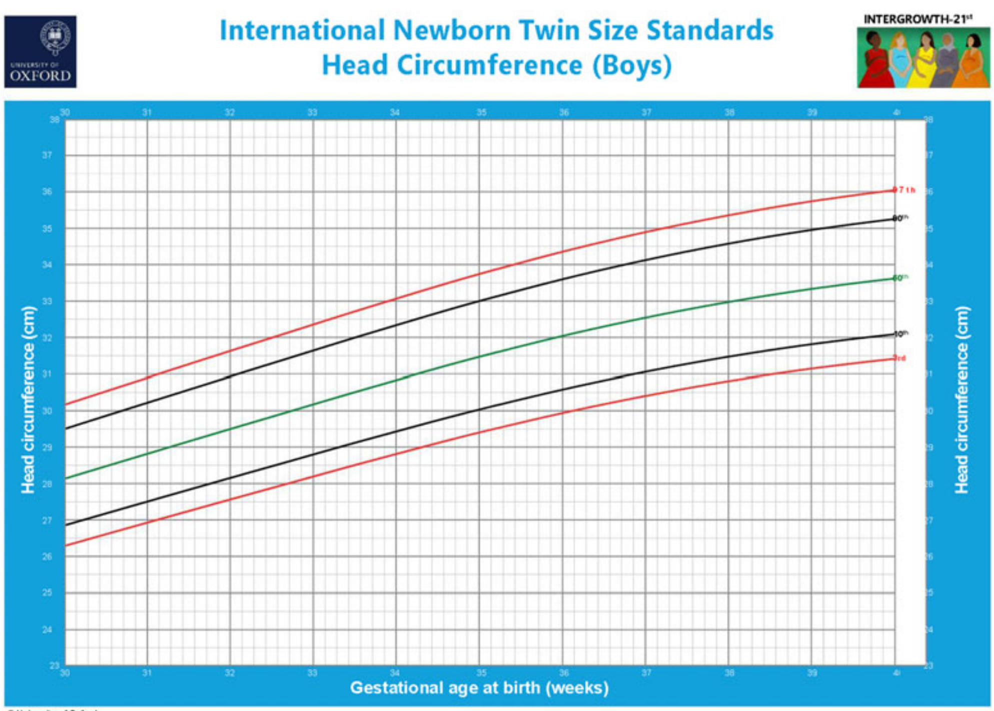

Figure 4 F. International newborn twin size standards for head circumference for boys.

Table 4. Smoothed centiles for birthweight, of girls and boys, according to gestational age

	Girls					
		Centiles for birth weight (kg)				
GA	Number of observations	3rd	10th	50th	90th	97th
30	3	0.97	1.07	1.29	1.53	1.66
31	7	1.07	1.18	1.42	1.68	1.83
32	13	1.19	1.31	1.58	1.87	2.03
33	16	1.32	1.45	1.74	2.07	2.25
34	31	1.45	1.60	1.92	2.28	2.48
35	68	1.58	1.75	2.10	2.48	2.70
36	84	1.71	1.89	2.26	2.68	2.92
37	129	1.82	2.01	2.41	2.86	3.11
38	69	1.91	2.12	2.54	3.01	3.27
39	14	1.98	2.19	2.63	3.11	3.39
40	4	2.01	2.22	2.67	3.16	3.44
	Boys					
		Centiles for birth weight (kg)				
GA	Number of observations	3rd	10th	50th	90th	97th
30	3	1.06	1.17	1.40	1.64	1.77
31	5	1.13	1.24	1.48	1.74	1.87
32	18	1.23	1.36	1.62	1.91	2.05
33	18	1.37	1.51	1.80	2.11	2.28
34	27	1.51	1.67	1.99	2.34	2.52
35	55	1.66	1.83	2.18	2.56	2.76
36	76	1.80	1.98	2.36	2.77	2.99
37	126	1.92	2.11	2.52	2.96	3.19
38	86	2.03	2.23	2.66	3.13	3.37
39	6	2.11	2.33	2.78	3.26	3.51
40	6	2.18	2.40	2.87	3.37	3.63

Note: GA, gestational age.

Table 5. Smoothed centiles for birth length, of girls and boys, according to gestational age

	Girls					
		Centiles for length (cm)				
GA	Number of observations	3rd	10th	50th	90th	97th
30	3	36.09	37.19	39.15	41.03	42.02
31	7	37.02	38.15	40.16	42.09	43.11
32	13	37.99	39.15	41.22	43.20	44.24
33	16	38.98	40.17	42.29	44.32	45.39
34	31	39.96	41.17	43.34	45.43	46.52
35	68	40.89	42.13	44.35	46.49	47.60
36	84	41.74	43.02	45.28	47.46	48.60
37	129	42.49	43.79	46.10	48.31	49.47
38	69	43.10	44.41	46.75	49.00	50.18
39	14	43.51	44.84	47.20	49.47	50.66
40	4	43.71	45.04	47.41	49.69	50.89

GA	Boys					
		Centiles for length (cm)				
GA	Number of observations	3rd	10th	50th	90th	97th
30	3	37.06	38.08	40.03	41.91	42.84
31	5	37.66	38.70	40.69	42.59	43.54
32	18	38.51	39.57	41.60	43.55	44.52
33	18	39.48	40.57	42.64	44.65	45.64
34	27	40.47	41.59	43.72	45.77	46.79
35	55	41.44	42.58	44.76	46.86	47.90
36	76	42.32	43.49	45.72	47.87	48.93
37	126	43.11	44.30	46.57	48.75	49.83
38	86	43.76	44.97	47.27	49.49	50.59
39	6	44.28	45.50	47.83	50.08	51.19
40	6	44.66	45.89	48.24	50.50	51.62

Note: GA, gestational age.

Table 6. Smoothed centiles fors head circumference, of girls and boys, according to gestational age

	Girls					
		Centiles for head circumference (cm)				
GA	Number of observations	3rd	10th	50th	90th	97th
30	3	24.97	25.59	26.86	28.19	28.9
31	7	25.96	26.61	27.93	29.32	30.05
32	13	26.84	27.51	28.87	30.31	31.07
33	16	27.61	28.29	29.7	31.18	31.96
34	31	28.27	28.98	30.42	31.93	32.73
35	68	28.84	29.56	31.03	32.57	33.38
36	84	29.32	30.04	31.54	33.11	33.93
37	129	29.7	30.44	31.95	33.54	34.38
38	69	30	30.74	32.27	33.87	34.72
39	14	30.21	30.96	32.49	34.11	34.96
40	4	30.33	31.09	32.63	34.25	35.11
	Boys					
		Centiles for head circumference (cm)				
GA	Number of observations	3rd	10th	50th	90th	97th
30	3	26.32	26.88	28.17	29.54	30.2
31	5	26.9	27.48	28.79	30.19	30.87
32	18	27.54	28.13	29.47	30.91	31.6
33	18	28.19	28.79	30.17	31.64	32.35
34	27	28.82	29.44	30.84	32.34	33.07
35	55	29.41	30.04	31.47	33	33.75
36	76	29.94	30.58	32.04	33.6	34.36
37	126	30.41	31.07	32.55	34.13	34.9
38	86	30.82	31.48	32.98	34.58	35.36
39	6	31.15	31.82	33.34	34.96	35.75
40	6	31.41	32.09	33.62	35.25	36.05

Note: GA, gestational age.

The observed centile differences between the NCSS twins and singletons in our dataset are also supportive of the hypothesis.

Our study is uniquely positioned to provide such normative data because: (1) by selecting an 'NCSS prescriptive subpopulation' of twins, we have adhered as strongly as possible to the WHO recommendations for constructing international anthropometric standards (de Onis & Habicht, 1996). Hence, the included pregnancies were selected on the basis of their social, economic, health and nutritional status, creating a low-risk environment for fetal growth impairment. Indeed, the baseline characteristics of the twin population were similar to the sample used to produce the INTERGROWTH-21st newborn size standards for singletons (Villar et al., 2014), except for maternal age (although the difference was not statistically significant), and the cesarean section and preterm birth rates which were, as expected, significantly higher in twins; (2) We did not exclude twins conceived through ART as they represent such a high proportion of the total twin population, especially in high-income countries, although they are most likely different in terms of 'prescriptiveness' (Marleen et al., 2024). Reassuringly, the sensitivity analysis showed that excluding them did not change the pooled extreme centiles, which supports the clinical applicability of the standards.

However, we had relatively few twins (15.6%) born < 34 weeks' gestation, although ample numbers were available at more advanced gestational ages that are arguably more relevant clinically. On the other hand, aiming to create normative standards for the more critical infants, that is, those with gestational age below 30 weeks age, would be questionable. We also lacked information regarding chorionicity; however, small differences are reported between the growth of mono- and dichorionic twin fetuses that are probably not relevant clinically, making reasonable the use of the same chart for both types of pregnancy (Hiersch et al., 2022). Moreover, in a recent systematic review and individual participant data meta-analysis, the risks of adverse perinatal outcomes for both monochorionic and dichorionic twins appeared similar when one or both twins were SGA (Koch et al., 2022).

In summary, we have produced international, sex-specific, smoothed normative centiles for weight, length, and head circumference for gestational age at birth for twin newborns, starting from 30 weeks' gestation, thereby extending the INTERGROWTH-21st clinical tools to the twin population. It is now incumbent upon research teams and specialized societies to continue this work by conducting validation studies, selecting the most appropriate clinically relevant cut-off points (as opposed to statistically selected centiles; e.g., 3rd or 10th) to determine which twin newborns are most at risk of adverse postnatal outcomes.

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Ethics. The INTERGROWTH-21st Project was approved by the Oxfordshire Research Ethics Committee 'C' (reference 08/H0606/139), the research ethics committees of the individual participating institutions, and the corresponding regional or national health authorities where the project was done. We obtained institutional consent to use routinely collected data and women gave oral consent for the use of those data.

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