# Predicted Birthweight for Singletons and Twins

Yingxin C. Liu and Eve M. Blair

*Center for Child Health Research, University of Western Australia*

This population-based study determined the impact of co-twin gender on twin intrauterine growth in addition to their infant gender, maternal height, maternal age and parity on intrauterine growth rate of singletons and twins. All singletons and twins born in Western Australia during the period of 1980 to 1995 were considered for the study. The multiple linear regression models showed that 76% of the variance in the mean birthweight was explained by the selected variables for twins and 51% for singletons. Twins grew more slowly than singletons from 26 weeks gestation. Among twins, opposite-sex twin pairs grew consistently faster than like-sex twins. Primiparous twin pairs grew more slowly than subsequently born twins. These regression equations can be used to assess the appropriateness of intrauterine growth in twin pairs of various gender combinations.

Birthweight is an important indicator of perinatal mortality and morbidity. Birthweight is dependent on length of gestation and intrauterine growth rate, both of which can be affected by biological, demographic, psychosocial, obstetric, nutritional, and maternal factors (Dowding 1981; Järvelin et al., 1997). The appropriateness of intrauterine growth rate is often inferred from birthweight and gestational age, and can thus be classified as small, appropriate, or large for gestational age. Being small for gestational age has been associated with poor pregnancy outcomes and affects health from the perinatal period to adult life (Skjærven et al., 2000). Intrauterine growth rates are affected by several non-pathological factors such as infant gender, maternal height, maternal age, and parity (Ananth et al., 1998; Roberts & Lancaster, 1999a; Sebire et al., 1998; Seidman et al., 1988; Skjærven, et al., 2000).

Intrauterine growth rates also differ between singletons and twins with the divergences increasing with increasing gestational age during the last trimester (Alexander et al., 1998; Ananth et al., 1998; Glinianaia et al., 2000; Min et al. 2000; Roberts & Lancaster 1999b; Taylor et al., 1998). While the reduced growth rate in twins may be considered as a suboptimal result of excessive demands on maternal supply, given that they are a twin their optimal intrauterine growth rate appears to be lower than that of singletons (Alexander et al., 1998; Ananth et al., 1998; Min et al., 2000). These differences in optimal growth pattern demonstrate that different standards are needed to identify suboptimal growth in twins and in singletons (Alexander et al., 1998; Ananth et al., 1998). It is, therefore, appropriate that intrauterine growth in twins should be compared with standards specific for twins. Moreover, growth patterns of fetuses may differ in different study populations (Alexander et al., 1996; Glinianaia et al., 2000). Australian standards currently available in the literature are not specific for different sex combinations or for parity. This paper examines the effects of gestational age, parity, maternal height, maternal age, gender and co-twin's gender on birthweight, and provides more specific criteria for identifying intrauterine growth restriction in singletons and in twins in the Western Australian population.

## Materials and Methods

Data pertaining to 377,000 singletons and 4610 twin pairs born in Western Australia during the same period of 1980 to 1995 were available from the Maternal and Child Health Research Database (Stanley et al., 1994). We wished to select a population-based sample of twins and singletons with optimal intrauterine growth patterns. We therefore selected 374,188 liveborn singletons and 4445 twin pairs where both twins were liveborn. Optimal intrauterine growth rate is associated with gestational duration, therefore it is of importance to estimate gestational age accurately. Gestational age (GA) was calculated based on five data fields recorded in the Maternal and Child Health Research Database. These were date of last normal menstrual period (LMP); whether the date of LMP was certain; baby's date of birth; estimated due date; and neonatally estimated gestational age. The estimated due date was the date the baby was expected to be born, based on mother's LMP, ultrasound or clinical acumen according to a hierarchy of available evidence. Neonatally estimated gestational age (EGA) was estimated by the midwife at the time of birth, based on an appraisal of the baby according to specified criteria. If the LMP was certain, gestational age was calculated based on this. If the date of the LMP was not certain, the difference between the baby's date of birth and the estimated due date (in days) was subtracted from 280 and the remainder was then divided by 7. The gestational age for 14 twin pairs and 1865 singletons was missing, but among them 5 pairs and 875 singletons had information on neonatally estimated gestational age, in which case neonatally estimated gestational age was used. Although having gestational duration records, three singletons were excluded due to missing birthweight. The gestational ages for 2 twin

*Address for correspondence: Yingxin Liu, Center for Child Health Research, University of Western Australia, TVW Telethon Institute for Child Health Research, 100 Roberts Road, Subiaco, WA 6008, Australia. Email: liu@ichr.uwa.edu.au.*



https://doi.org/10.1375/twin.5.6.529 Published online by Cambridge University Press

pairs and 97 singletons were replaced by neonatally estimated gestational age since they were coded as having gestational duration over 50 weeks. Six twin pairs were excluded because reported gestational age differed between co-twins by more than one week. Five twin pairs were excluded because recorded maternal race of co-twins differed, and 1 pair excluded due to missing sex of one co-twin. These exclusions reduced the sample size to 372,226 singletons and 4417 twin pairs who were liveborn.

Some unlikely birthweight-gestational duration combinations remained. Birthweights for gestation exceeding those shown in Table 1 were excluded. The cut off birthweights were chosen to exclude infants with misclassified gestation who were actually four gestational weeks older than reported, since breakthrough bleeding at 4-week intervals in early pregnancy is a common source of gestational error in women claiming to know the date of their last menstrual period (Blair & Stanley, 1985). By assuming that birthweight is distributed normally within each gestation week for non-pathological pregnancies we can estimate that less than 0.5% of normally grown singletons delivered in the third trimester would be excluded by these criteria, and about 0.01% of normally grown singletons in the second trimester. The co-twins of any excluded twins were also excluded thereby excluding cases of twin–twin transfusion or grossly unequal placental sharing. While these data may have been accurate, exclusion would nonetheless be desirable, as such cases do not represent optimal intrauterine growth patterns. Finally subjects were restricted to the 92% of mothers who were Caucasians, in order to exclude ethnic differences in birthweights, and to deliveries between 23 and 42 completed gestational weeks. These exclusions and restrictions left sample sizes of 3982 twin pairs and 324,412 singletons for the analysis, see Table 2 for summary of exclusions.

Multiple linear regression using SAS (Version 6.12) (SAS Institute Inc.) was applied separately for singletons and twins. The logarithm of birthweight was modeled as a function of GA (weeks), $(GA)^2$, maternal height (cm), maternal age (years), infant sex, maternal parity (first or subsequent birth) and, for twins, co-twin sex. In order to facilitate interpretation of regression coefficients, three variables were "centered", by subtracting 40 from GA, 25 from maternal age and 162 from maternal height. The fit of the models was tested by plotting residuals against GA and predicted birthweight. Because log (birthweight) was used as the response variable, the regression coefficients were estimated as ratios, representing the proportional increase in birthweight for each unit increase of the respective covariate. Predicted birthweight was plotted against GA for the four possible combinations of sex and parity standardized for maternal height (162 cm) and age (25 years).

## Results

Of 3982 twin pairs included in the study, 1,214 pairs (30.5%) were opposite sex, 1410 pairs (35.4%) were both male and 1,358 pairs (34.1%) both female. One thousand five hundred and thirty-six pairs (38.5%) were delivered by primiparous women compared with 61% of the 324,412 singleton live births (Table 3). Mean gestational age at delivery for singletons did not differ by gender and parity, but was greater than that of twins. Mean birthweight for male singletons was 130g more than female singletons. Primiparous singletons and twins weighed 120g and 242g less than subsequently born singletons and twins, respectively. The male twins in opposite-sex pairs on average weighed 73g more than male twins in like-sex pairs. Similarly female twins in opposite-sex pairs weighed 68g more than female twins in like-sex pairs.

The results of multiple linear regression showed that 76% of variance was explained by the selected independent

**Table 1**

Cutoff Points of Birthweight for Gestational Age and Numbers (%) of Maternities Excluded by These Criteria

| Gestational age (weeks) | Cutoff points of birth weight (g) | Number (%) of maternities reported at each gestational age excluded by these birth weight criteria | |
|---|---|---|---|
| | | Twin pairs (%) | Singletons (%) |
| 23 | 900 | 0 | 10 (3.6%) |
| 24 | 1000 | 2 (4.1%) | 9 (3.5%) |
| 25 | 1120 | 1 (2.4%) | 18 (5.9%) |
| 26 | 1250 | 3 (6.5%) | 38 (10.6%) |
| 27 | 1450 | 5 (10.3%) | 36 (9.3%) |
| 28 | 1600 | 1 (1.8%) | 46 (9.6%) |
| 29 | 1750 | 2 (3.0%) | 58 (10.5%) |
| 30 | 1950 | 5 (5.5%) | 76 (11%) |
| 31 | 2200 | 7 (6.3%) | 113 (13.2%) |
| 32 | 2550 | 0 | 152 (12.3%) |
| 33 | 2900 | 1 (0.4%) | 190 (10%) |
| 34 | 3300 | 2 (0.5%) | 255 (8.2%) |
| 35 | 3700 | 0 | 233 (4.2%) |
| 36 | 4000 | 0 | 206 (2.0%) |

**Table 2**

Summary of Exclusions

| | Twin pairs | Singletons |
|---|---|---|
| Total births | 4610 | 377000 |
| Still births | 165 | 2812 |
| Non-Caucasian livebirths | 347 | 42804 |
| Missing data* | 22 | 1868 |
| Unlikely/pathological BWT/GA combinations | 29 | 1440 |
| GA < 23 or GA > 42 | 65 | 3664 |
| Sample for analysis | 3982 | 324412 |

Note: * Missing data included missing gestational age, birthweight, sex and difference of gestational age between co-twins over one week.

variables for twins and 51% for singletons. For both singletons and twins, birthweights increased with increasing gestational age, maternal age, maternal height, and parity. Compared with females, singleton males grew 4.4% faster and twin males 4.6% faster. Co-twins of opposite-sex grew 2.1% faster than those of same sex (Table 4). Maternal height (0.4% increase per cm) and age (0.2% increase per year) had a similar effect on both singletons and twins. As anticipated, singletons grew faster (3.2% increase per week) than twins (2.1% increase per week). Primiparous singletons grew 3.3% slower and twins 3.9% slower than subsequent ones. Interactions between gestational age and maternal age, sex, and parity were investigated but not found to significantly affect birthweight.

Predicted birthweights to mothers at age of 25 years and height of 162 centimeters are shown by gestational age and stratified by parity in Figures 1–4. Plots of singletons, twins with the same sex of like-sex pairs and twins with the same sex from opposite-sex pairs as singletons were superimposed. From the charts, birthweights are shown to increase at a similar rate for singletons and twins up to the 26th gestational week regardless of sex and parity. Thereafter, however, the gap in birthweight between singletons and twins increased dramatically with singletons

**Table 3**

Comparison of Birthweight and its Determinants Between Singletons and Twins

| | Number | Mean birthweight ± *SD*, g | Mean gestational age ± *SD*, weeks | Mean maternal age ± SD, years | Mean maternal height ± *SD*, cm |
|---|---|---|---|---|---|
| All | | | | | |
| Singletons | 324412 | 3398.4 ± 532.9 | 39.2 ± 1.8 | 27.4 ± 5.0 | 163.4 ± 6.5 |
| Twins | 7964 | 2449.9 ± 600.6 | 35.9 ± 3.0 | 28.6 ± 4.9 | 164.2 ± 6.5 |
| Primiparous | | | | | |
| Singletons | 127870 | 3325.8 ± 532.8 | 39.2 ± 1.9 | 25.3 ± 4.8 | 163.7 ± 6.5 |
| Twins | 3072 | 2301.7 ± 618.0 | 35.4 ± 3.2 | 26.9 ± 4.9 | 164.7 ± 6.5 |
| Multiparous | | | | | |
| Singletons | 196542 | 3445.6 ± 527.6 | 39.2 ± 1.8 | 28.7 ± 4.7 | 163.2 ± 6.5 |
| Twins | 4892 | 2543.3 ± 570.0 | 36.3 ± 2.7 | 29.6 ± 4.7 | 163.8 ± 6.5 |
| Male | | | | | |
| Singletons | 166809 | 3461.8 ± 544.3 | 39.2 ± 1.9 | 27.3 ± 5.0 | 163.4 ± 6.5 |
| Like-sex twins | 2820 | 2481.9 ± 610.2 | 35.9 ± 3.0 | 28.4 ± 4.9 | 164.3 ± 6.5 |
| Opposite-sex twins | 1214 | 2555.1 ± 598.3 | 36.0 ± 2.9 | 29.2 ± 4.8 | 164.2 ± 6.4 |
| Female | | | | | |
| Singletons | 157603 | 3331.3 ± 512.1 | 39.2 ± 1.8 | 27.4 ± 5.0 | 163.4 ± 6.5 |
| Like-sex twins | 2716 | 2373.4 ± 595.6 | 35.9 ± 3.0 | 28.1 ± 5.0 | 164.0 ± 6.7 |
| Opposite-sex twins | 1214 | 2441.5 ± 569.5 | 36.0 ± 2.9 | 29.2 ± 4.8 | 164.2 ± 6.4 |

**Table 4**

Proportional Change in Birthweight Per Unit Change in Independent Variables for Singletons and Twins

| | Singletons | (95%CI, *p*-value)* | Twins | (95%CI, *p*-value)+ |
|---|---|---|---|---|
| Gestational age wks[1] | 1.0324 | (1.0321–1.0328, $p < 0.001$) | 1.0212 | (1.0181–1.0244, $p < 0.001$) |
| male sex | 1.0435 | (1.0427–1.0445, $p < 0.001$) | 1.0459 | (1.0389–1.0532, $p < 0.001$) |
| maternal height cms[2] | 1.0037 | (1.0036–1.0038, $p < 0.001$) | 1.0043 | (1.0038–1.0049, $p < 0.001$) |
| maternal age years[3] | 1.0015 | (1.0014–1.0016, $p < 0.001$) | 1.0016 | (1.0009–1.0024, $p = 0.01$) |
| primiparous | 0.9667 | (0.9659–0.9677, $p < 0.001$) | 0.9609 | (0.9538–0.9680, $p < 0.001$) |
| opposite-sex | | | 1.0205 | (1.0128–1.0280, $p < 0.001$) |

Note: * Adjusted $R^2 = 0.51$.
+ Adjusted $R^2 = 0.76$.
1 = Gestational age — 40 complete weeks
2 = Maternal height —162 cm
3 = Maternal age — 25 years

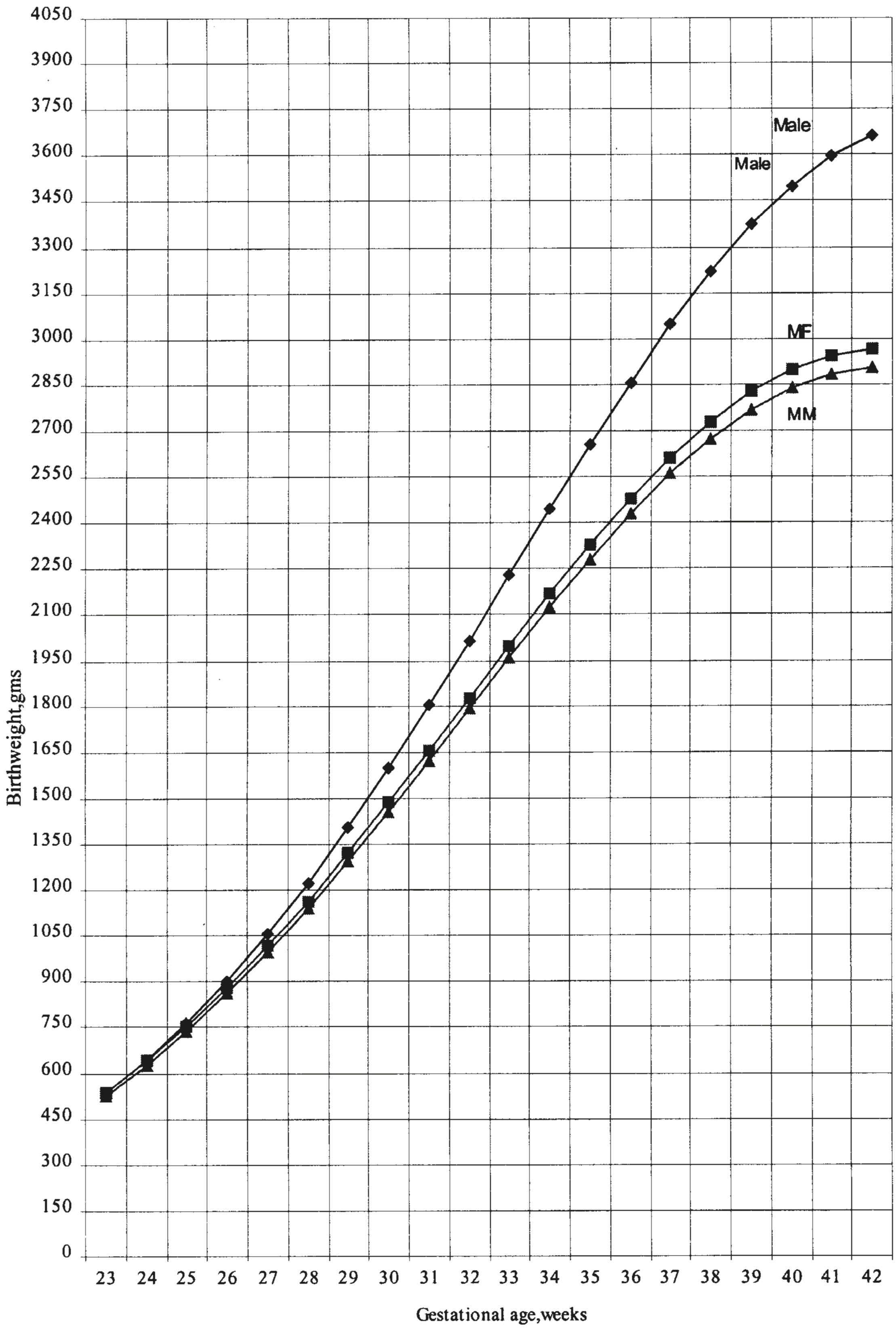


**Figure 1**

Predicted birth weight against gestational age for primiparous male singletons, and primiparous male twins by sex of their co-twin.



https://doi.org/10.1375/twin.5.6.529 Published online by Cambridge University Press

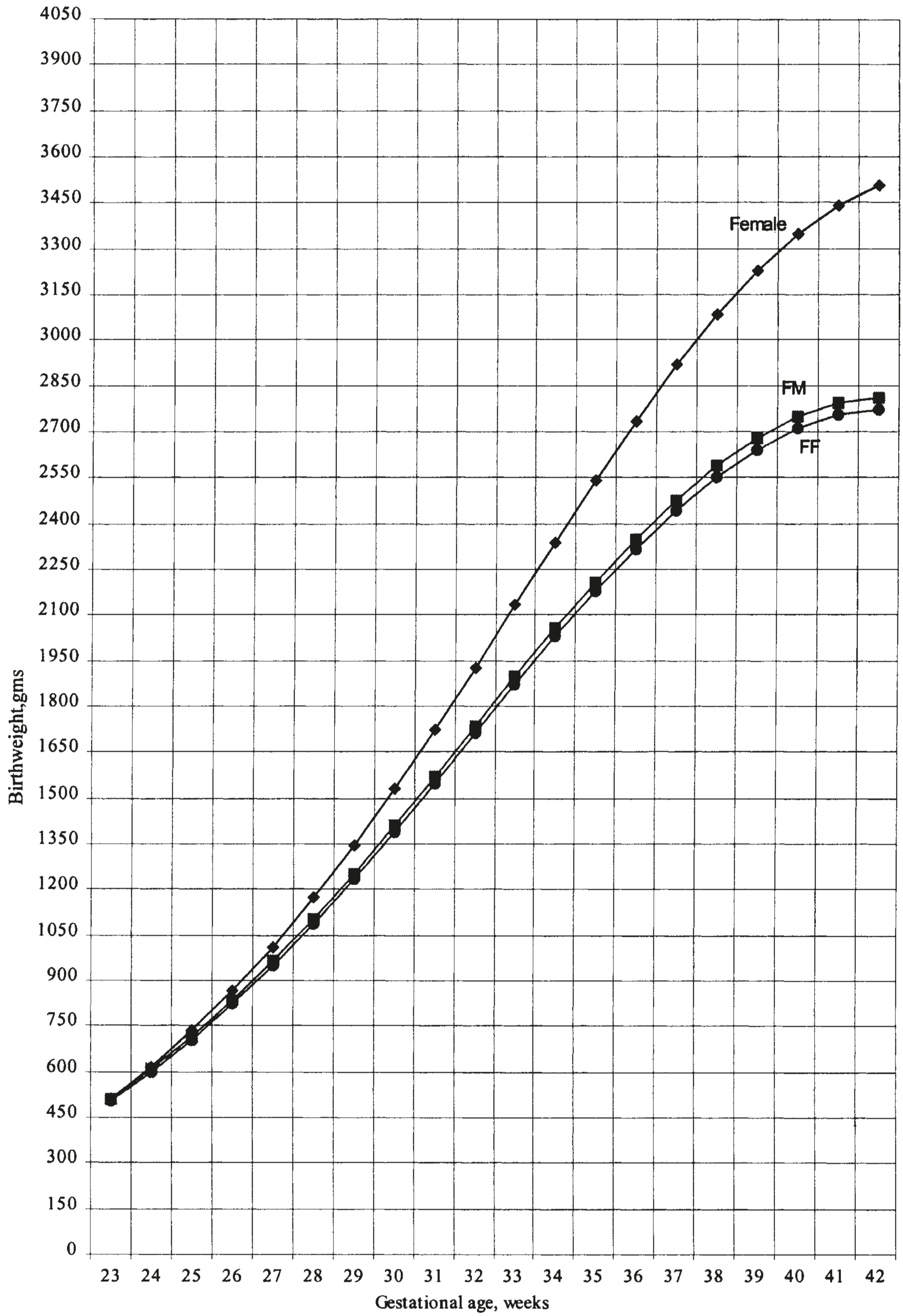


**Figure 2**

Predicted birth weight against gestational age for primiparous female singletons, and primiparous female twins by sex of their co-twin.

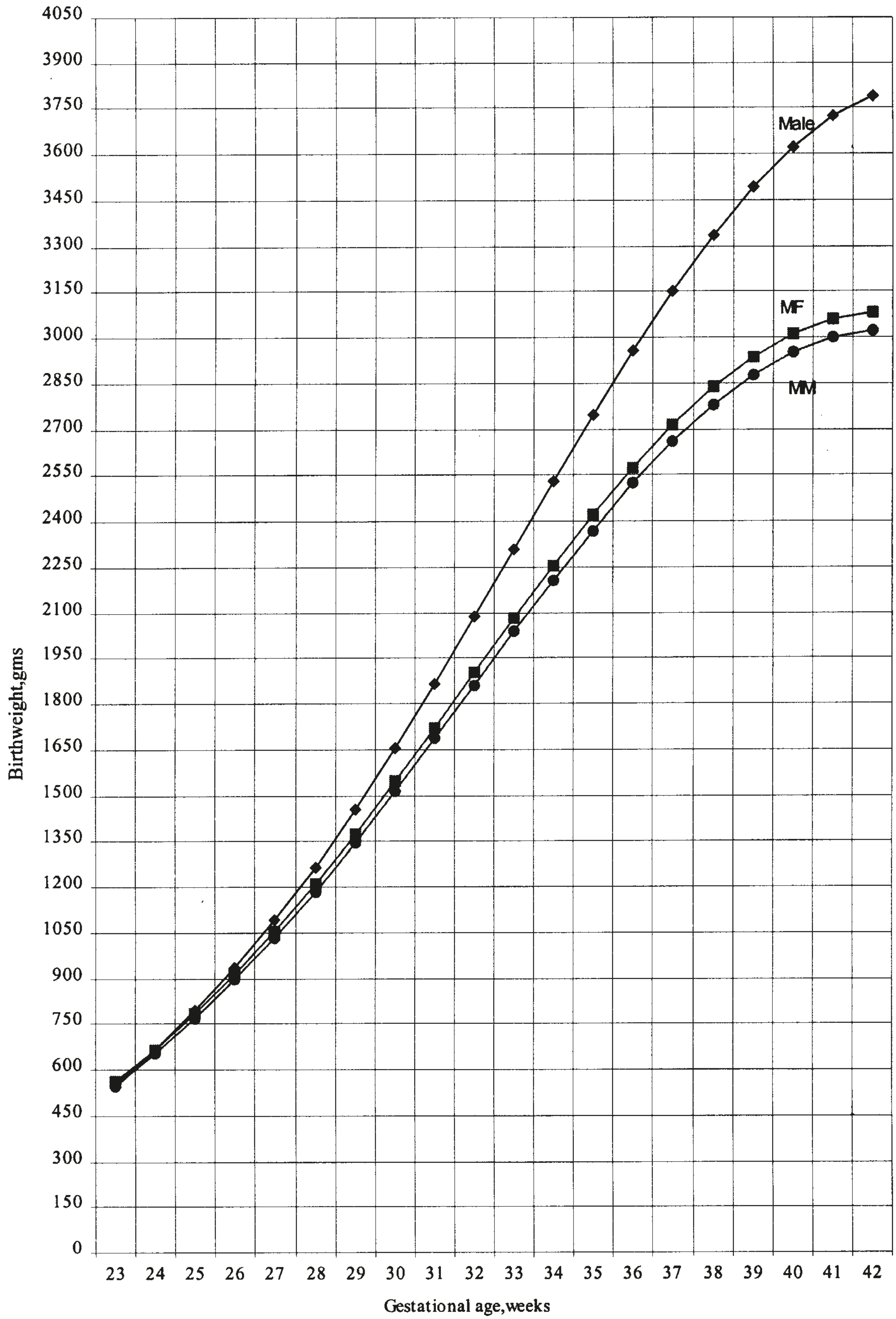


**Figure 3**

Predicted birth weight against gestational age for multiparous male singletons, and multiparous male twins by sex of co-twin.

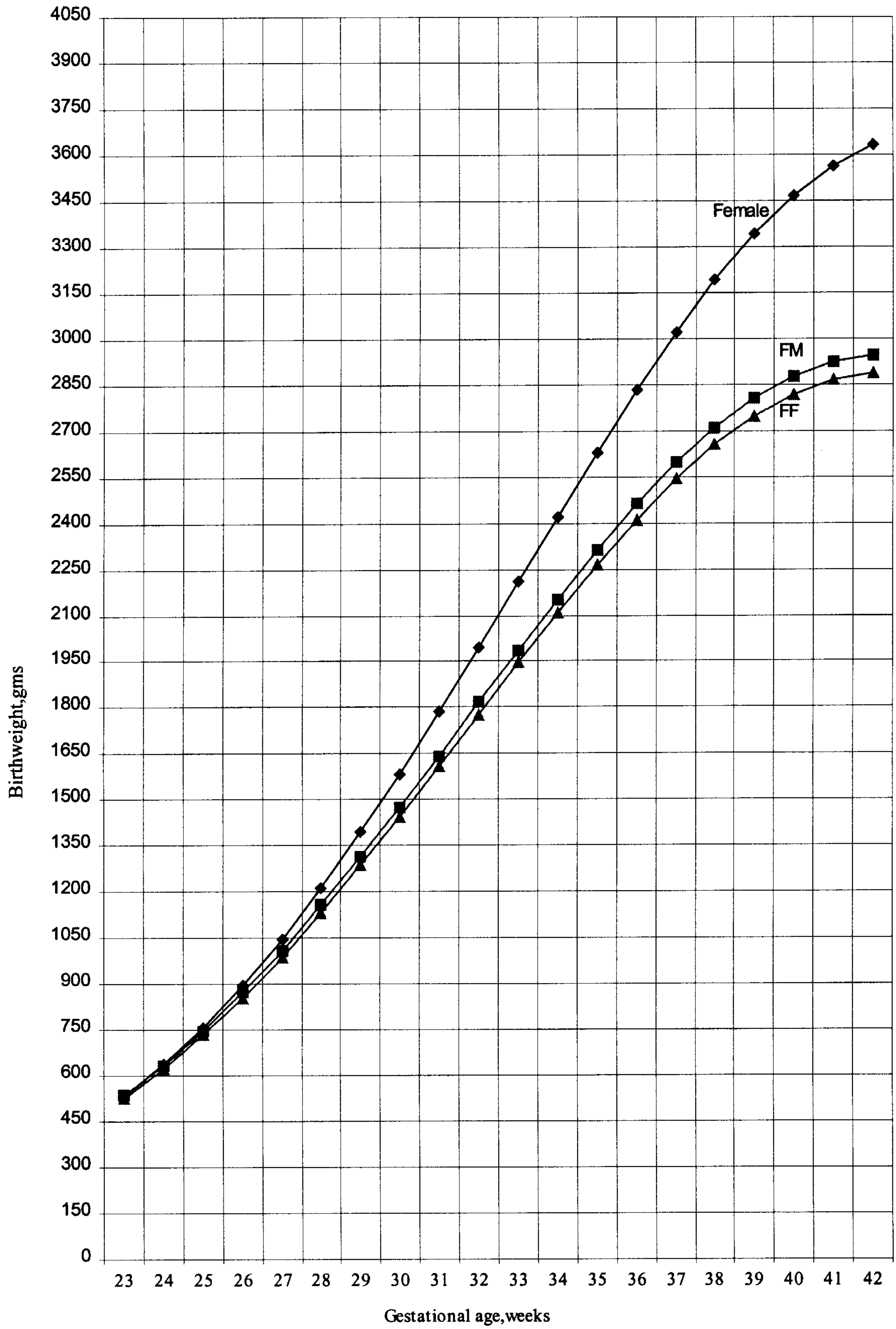


**Figure 4**

Predicted birth weight against gestational age for multiparous female singletons, and multiparous female twins by sex of co-twin.



https://doi.org/10.1375/twin.5.6.529 Published online by Cambridge University Press

growing faster than twins, and opposite-sex co-twins growing faster than like-sex co-twins. Singletons weighed about 40g more than opposite-sex co-twins at the 27th gestational week, but 700g more at the 42nd gestational week.

Moreover, the intrauterine growth rates of opposite-sex twins were consistently slightly higher than those of the same sex twins, the difference ranging from 13g to 22g at the 27th gestational weeks and 39g to 63g at the 42nd gestational week. Primiparous infants weighed less than their multiparous counterparts throughout gestation and the differences increased from about 20g in the 23rd gestational week to 120g in the 42nd gestational week.

## Discussion

In this study we have compared the effects of various determinants of intrauterine growth between twins and singletons. Three quarters (76%) of variation in mean birthweight for twins was predicted by selected variables compared with 51% for singletons. This suggests that determinants of fetal growth other than gestational age, gender, maternal age, maternal height and parity play a more important role for singletons than for twins.

The main strength of this study is that the large cohort is representative of the total population of livebirths with the same source of data and period of birth for both singletons and twins.

It would have been desirable to consider other known determinants of birthweight by including zygosity and chorionicity in the analysis and excluding women with pathological factors known to alter fetal growth rate such as maternal cigarette smoking, pre-eclampsia or diabetes. Unfortunately data pertaining to these factors were either not available or not sufficiently reliable.

As anticipated, twins grew more slowly than singletons from 26 weeks gestation, but the effects of maternal age and height were very similar. However, both parity and gender had a greater effect in twins than singletons and having a co-twin of the opposite-sex enhanced birthweight by a small but statistically significant amount. This advantage may be an effect of zygosity (Fakeye, 1986; Floos et al., 2001; Glinianaia et al., 1998). Twins of the opposite-sex are necessarily dizygotic and dichorionic with separate placental circulations; while twins of the same sex may or may not be dichorionic. If the negative effect on birthweight of being of the same sex estimated in this study is due to the monochorionicity of some portion of like sex twin pairs, the negative effect attributable to monochorionicity may be much greater than our estimated value of –2.1% for being like sex.

The male hormone may be responsible for stimulating increased growth both in the male (Snow, 1989) and in his female co-twin, resulting in the female co-twin of an opposite-sex pair growing faster than like-sex female pairs (Fakeye, 1986). Moreover, antigenic differences between mothers and male fetuses might be associated with enhanced male birthweight and the difference in fetal size is not apparent until the third trimester (Gewolb & Warshaw, 1983; Snow, 1989). On the other hand, Floos et al. (2001) suggested that the higher weight of male co-twin of an opposite-sex pair may be the result of longer gestations in pregnancies carrying female fetuses, but our study shows no association between gender and gestational duration.

Maternal uterine capacity constrains intrauterine growth once the total fetal mass reaches about 3000 grams, regardless of the number of fetuses (Gewolb & Warshaw, 1983). This explains why intrauterine growth patterns of singletons do not differ from twins until a certain gestational age. Our study suggests that the utero-placental constraints become operative at about the 26th gestational week.

After adjusting for other variables, infants born to multiparous women weighed more than those of primiparous women at all gestational ages for both singletons and twins. This may suggest that maternal capacity to nurture infants is improved in subsequent gestations (Blickstein et al., 2000; Järvelin et al., 1997; Seidman et al., 1988), although infant gender affects birthweight more strongly than parity (Glinianaia et al., 2000).

In conclusion, this population-based study has demonstrated that the impact of non-pathological factors on fetal growth was greater for twins than singletons, and twin pairs of opposite-sex consistently grew faster than those of same sex. The regression equations can be used to determine the appropriateness of intrauterine growth in twin pairs of various gender combinations.

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