Newborn Twin Outcome Predicted by Maternal Variables: Differentiation by Term and Sex

Marilyn L. Riese, Hallie M. Swift, and Steffany L. Barnes

Louisville Twin Study, Child Development Unit, Health Sciences Center, University of Louisville, Kentucky, USA

Predictive relations between maternal variables and outcome status for 199 pairs of newborn twins were evaluated. The maternal independent variables included pregravid weight, weight at end of pregnancy, weight gain, age, parity, height, socioeconomic status, years of education, and body mass index. The twin dependent variables included birthweight, birth length, 5-min Apgar score, number of days in an isolette, number of days in the hospital, weight at discharge, and chronological age at discharge. For stepwise multiple linear regression analyses, the newborn twins were grouped by term (fullterm/preterm) and sex (female/male). A combination of a larger number of independent variables acted as statistically significant predictors of twin outcome for the preterm twins than for the fullterm twins, and for the male twins than for the female twins. This was noted particularly for the anthropometric variables and for parity. Maternal weight gain, typically considered to be the critical variable related to infant birthweight, consistently had a significant outcome role for the preterm twins and male twins, but not for the fullterm twins or female twins. Demographic variables had a low rate of prediction for newborn outcome. This study has demonstrated that evaluating twins within groups separated by potential risk variables allows for a more accurate description of the influence of maternal variables on twin outcome than evaluating twins across groups as a single population.

Due to increased use of infertility treatments and, to a lesser extent, women delaying childbirth, the incidence of twin births has increased at a rapid rate (52% between 1981 and 1997) (Kogan et al., 2000; Luke, 1998). At present, twin births account for 3% of all live births, but account for much higher rates of perinatal morbidity, such as low birthweight (21%) and preterm birth (14%) (Kogan et al., 2000). In 1997, 55% of twins born in the United States were preterm (Kogan et al., 2000). At least part of the recent increase in rate of preterm delivery of twins may be associated with changing obstetrical practices (a review of morbidity and mortality for twins can be found in Luke, 1998). Both low birthweight and preterm birth increase the risk of infant morbidity and developmental problems. Because of the increase in risk variables related to twin gestation, the determination of maternal variables related to that risk may lead to changes in the management of twin pregnancies and, subsequently, may serve to alleviate negative outcome for the twin infants.

Maternal nutrition has been determined to be an important contributor to infant birthweight. In this regard, maternal pregravid weight and weight gain have been shown to be related to singleton birthweight (Kirchengast & Hartmann, 1998; review: Luke et al., 1992; review: MacGillivray, 1983; Tavares et al., 1996) and, recently suggested, to twin birthweight (Fenton & Thirsk, 1994; Luke & Leurgans, 1996; Pederson et al., 1989). Several areas of research, however, have indicated that additional maternal anthropometric, pregnancy-related, and demographic variables are also related to the developmental outcome of children. Additional variables observed for singleton pregnancies include maternal height (Kirchengast & Hartmann, 1998; MacGillivray, 1983; Tavares et al., 1996), pregravid body mass index (Kirchengast & Hartmann, 1998; Tavares et al., 1996), and maternal age (Kirchengast & Hartmann, 1998; Tavares et al., 1996). For twin pregnancies, additional variables include maternal age (Luke et al., 1997). In determining the importance of maternal input to newborn outcome for twins, therefore, it is informative to evaluate the contribution of these several areas of maternal variables. Outcome variables found to be associated with the maternal variables, in addition to birthweight, include length of hospital stay for twin offspring (Luke et al., 1992) and birth length for singleton offspring (Kirchengast & Hartmann, 1988). Because of the relatively small amount of relevant data available for twin pregnancies and twin outcome, it is useful to evaluate variables determined to be significant for singleton outcome in addition to those suggested to be significant for twin outcome.

Furthermore, the high rate of preterm delivery for twins, and differences in developmental outcome for preterm and fullterm infants, makes it necessary to determine if maternal variables exert similar influences on outcome for fullterm and preterm twins. The infant's sex also has been found to differentiate risk in development, suggesting an examination of outcome based on this variable. It is known, for example,

Address for correspondence: Marilyn L. Riese PhD, Child Development Unit, Health Sciences Center, University of Louisville, Louisville, Kentucky 40292-0001, USA. Email: mlriese@gatekeeper.lts.louisville.edu. or mlries01@gwise.louisville.edu

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that the female fetus and newborn are more mature neurologically than the male, a difference seen beginning at approximately 30 weeks conceptional age (Stratton, 1982; Tanner, 1974). The male fetus and newborn also are known to be more susceptible to adverse prenatal and perinatal variables than the female fetus and newborn (Maccoby & Jacklin, 1974).

Finally, other infant perinatal variables, such as 5-minute Apgar scores, number of days in an isolette, and weight and chronological age at hospital discharge, commonly are used as indicators of newborn status, suggesting their inclusion in addition to birthweight as outcome measures for twins. This study was designed to determine which of several maternal variables were the most important for predicting twin outcome, which perinatal outcome measures were predicted more frequently, and whether those findings would be applicable in similar ways for twins evaluated within the different groups.

Materials and Methods

Subjects

The sample included 199 women and their twins (89 fullterm pairs and 110 preterm pairs). Fullterm and preterm were defined by early ultrasound when available. Subjects were recruited between September 1984 and February 1996, however, so that ultrasound was not available for all twins. In those cases, other information from the medical charts was used for the medical determination of gestational age (such as first day of last menstrual period, Dubowitz, or Ballard).

This sample was a subset of a larger group participating in a study of infant development and included all twin pairs and mothers who had the complete data sets required for this study. Parents of virtually all twin pairs born in the county were approached to participate in the study; parents were not approached if there were too many twin pairs born simultaneously so that not all pairs could be scheduled for assessment before hospital discharge, or when twins were born with gross anomalies or life-threatening conditions (both of these situations were rare). No infants in the sample had either serious or minor malformations. Consent rate averaged over 80%. The full socioeconomic status distribution was represented in the total sample (Stevens & Featherman, 1981). Mothers consented to an interview and to a review of their and their infants' medical records for the relevant information.

The study was approved by the Human Studies Committee of the University and the Institutional Review Boards of the participating hospitals. Permission was received from the infants' physicians to assess the infants in the nursery. Informed, signed consent was obtained from each mother after the complete details of the study were explained to her, and this consent signature was witnessed by a member of the hospital staff.

Procedure

Independent and dependent variables, as well as grouping variables, were selected both from those determined from previous research in this lab and from the literature to be relevant to the purposes of this study. The maternal independent variables included pregravid weight, weight at end of pregnancy, weight gain, age, parity, height, socioeconomic status (SES), years of education, and body mass index (pregravid weight/height^2; BMI). To avoid having a statistically unreasonable number of maternal variables, those variables that previous research had determined were not related to outcome were not used; those include zygosity (which was not known for this entire sample), race, and marital status (for review, Pederson et al., 1989). The twin dependent variables included birthweight, birth length, 5-min Apgar score, number of days in an isolette, number of days in the hospital, and weight and chronological age when infants were medically stable and ready to be discharged from the hospital.

Maternal pregravid weight, weight at end of pregnancy, age, parity, height, SES, and years of education were obtained by interview and/or chart review. (Previous studies have reported high reliability and validity of self-reported variables such as height and weight; Luke et al., 1992). Information for all other variables was obtained from chart review or mathematical calculation. When grouped by term at birth, the twin variables were averaged for pairs. Descriptive statistics for the maternal and twin variables are presented in Table 1, grouped by term at birth and sex of twins within pairs.

Stepwise multiple linear regression analyses were computed to determine which maternal variables were the more important independent predictors of twin outcome measures. This procedure enters or removes one variable at a time in a stepwise manner, fitting a multiple linear regression equation to the data. Separate analyses were computed for each newborn dependant variable, grouping the twins by term at birth (fullterm: 38 to 41 weeks, and preterm: 29 to 37 weeks) and by sex (female and male).

Results

Within-group Differences

The means and standard deviations for the maternal and twin infant variables are presented in Table 1. Welch Equality of Means tests (Dixon, 1992), in which variances are not assumed to be equal, were computed between the sex-within-pairs groups for differences on the maternal and twin variables.

For group differences based on sex of twins within pairs, there were no significant differences observed for the maternal variables. For the twin variables, birthweight differences, and subsequently test weight differences, were obtained between groups. Female same sex twins weighed less than male same sex twins and unlike sex twins. This difference in weights was not accounted for by sex differences in gestational age, as there was not a significant difference in average gestational age (females = 36.4 weeks, males = 36.9 weeks). This finding is consistent with previously reported findings of lower birthweights for female twins and singletons than for male twins and singletons (Loos et al., 2001).

Predictors by Term

The results of the stepwise multiple linear regression analyses for the fullterm twins are presented in Table 2, and for

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Table 1

Means and Standard Deviations for Maternal and Twin Variables by Term at Birth and Sex of Twins Within Pairs

	Term				Sex					
Variables	Fullterm (*N* = 89)		Preterm (*N* = 110)		Female Same Sex (*N* = 156; 78prs)		Male Same Sex (*N* = 108; 54prs)		Unlike Sex (*N* = 134; 67prs)	
Maternal	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Pregravid weight (kg)	65.91	15.91	62.96	13.13	62.36	12.44	62.57	14.22	67.89	16.31
Weight at end (kg)	85.81	14.68	81.41	14.57	80.99	14.45	83.63	14.36	85.96	15.15
Weight gain (kg)	19.90	7.31	18.46	6.64	18.63	6.35	21.06	8.07	18.07	6.45
Age	28.05	4.76	27.41	5.91	27.59	5.45	26.83	5.51	28.51	5.28
Parity	1.02	1.02	0.92	0.95	0.95	0.98	0.76	0.67	1.15	1.16
Height (cm.)	165.97	6.30	164.54	6.81	165.39	6.75	163.78	6.62	166.06	6.33
SES[a]	43.39	19.93	39.64	16.92	40.81	18.83	40.33	17.99	42.70	18.33
Education (years)	13.98	2.62	13.40	2.17	13.68	2.25	13.26	2.40	13.96	2.54
BMI[b]	23.92	4.01	23.26	2.83	22.80	2.73	23.33	3.25	24.62	4.07
Twin										
Birthweight (g)	2889.43	412.67	2247.06	475.25	2414.90	477.95	2632.35	633.51	2594.44	535.29*
Birth length (cm.)	48.47	2.91	45.25	3.75	46.49	3.48	46.77	4.53	46.90	3.38
5-min Apgar	8.84	0.56	8.46	0.97	8.58	0.92	8.59	0.80	8.69	0.75
No days isolette	0.22	1.28	6.33	9.85	3.19	7.05	4.32	9.98	3.17	6.78
No days hospital	5.70	2.22	14.72	14.94	10.5	12.75	11.88	14.20	9.94	9.01
Discharge weight (g)	2757.19	362.60	2288.11	294.55	2373.59	351.46	2629.40	412.71	2536.63	407.38**
Discharge chronological age (day)	3.04	1.93	11.41	14.37	7.53	12.03	8.69	13.66	7.00	8.75

Note: * $p < .002$; ** $p < .0001$; [a] socioeconomic status; [b] body mass index.

the preterm twins in Table 3. A combination of a larger number of independent variables acted as statistically significant predictors of twin outcome for the preterm twins than for the fullterm twins. Risk, as defined by gestational age at birth, differentiated which maternal variables were more meaningful for the twins' outcome. Whereas the literature has suggested the importance of maternal weight gain for newborn outcome, these findings indicate that maternal weight gain has a consistently significant outcome role for preterm twins, but not for fullterm twins. The more weight gained by the mother during the pregnancy, the more favorable the outcome for preterm twins. For infants who were born prematurely, those infants whose mothers gained more weight had better outcome than those infants whose mothers gained less weight. Furthermore, maternal parity was significant for outcome for the preterm twins, with higher parity leading to a more favorable outcome. Similar findings were not observed for the fullterm twins.

Although maternal anthropometric variables did predict outcome for the fullterm group, the variables were not the same as those observed for the preterm group, and were not as consistent across newborn outcome variables as for the preterm group. Mother's height was the only variable predicting more than one outcome measure for the fullterm twins, demonstrating that taller mothers had twins with more favorable outcome than shorter mothers. Interestingly, infant birthweight, which typically is the variable considered most important for twin outcome, was predicted by maternal weight variables for both fullterm and preterm twins, but those maternal variables were not the same for the two groups, even though related.

Predictors by Sex

The results of the stepwise multiple linear regression analyses for the female twins are presented in Table 4, and for the male twins in Table 5. Similar to the findings when grouped by term, grouping by sex resulted in a combination of more independent variables predicting twin outcome for the group typically found to be at higher risk (i.e., males) than for those typically at lower risk (i.e., females). The differentiation of predictor variables grouped by sex was not as clear-cut, however, as when grouped by term. It is noteworthy that maternal weight gain again was found to differentiate between the two groups, with this variable being a consistent predictor of outcome for the higher risk group (males), but not predicting any outcome for the lower risk group (females). More prenatal weight gain by mothers, when compared with less prenatal weight gain, resulted in better outcome for the male twins.

In contrast to the findings for the lower risk fullterm twins when compared with the higher risk preterm twins, parity was found to be a significant predictor for several neonatal outcome measures for the lower risk females, although it was a significant predictor for all of the neonatal outcome variables for the higher risk male twins. Higher maternal parity was related to better outcome for both females and males.

Maternal height also differentiated between female and male twins, with being tall related to better outcome for the higher risk males. Maternal height did not predict any newborn outcome measures for the lower risk females. It will be recalled that maternal height was related to outcome measures for fullterm infants, but not for preterm infants.

Finally, some demographic variables were found to predict outcome in a very few areas, with more significant

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Table 2

Maternal Predictors of Newborn Outcome for Fullterm Twins

Dependent Variable (Pair N)	Step	Predictor	Multiple R	Partial *r*	Initial *r* with Criterion	*F* to Remove
Birthweight (89)	1	End Weight	.2924	—	.2924	8.13
	2	BMI[a]	.3874	–.2658	.0953	6.53
Birth Length (88)	1	Height	.2952	—	.2952	8.21
5-min Apgar (88)	1	SES[b]	.2415	—	.2415	5.33
Days in Isolette (88)	1	Height	.2203	—	–.2203	4.39
Days in Hospital (89)	0	—	—	—	—	—
Discharge Weight (89)	1	Height	.2797	—	.2797	7.39
Disch Chron Age (89)	0	—	—	—	—	—

Note: [a] body mass index; [b] socioeconomic status.

Table 3

Maternal Predictors of Newborn Outcome for Preterm Twins

Dependent Variable (Pair N)	Step	Predictor	Multiple R	Partial *r*	Initial *r* with Criterion	*F* to Remove
Birthweight (110)	1	Weight Gain	.3477	—	.3477	14.85
	2	Parity	.4137	.2391	.2129	6.49
	3	Pregravid Weight	.4487	.1907	.1382	4.00
Birth Length (104)	1	Weight Gain	.3390	—	.3390	13.25
5-min Apgar (110)	1	Weight Gain	.3169	—	.3169	12.06
Days in Isolette (96)	1	Parity	.2895	—	–.2895	8.60
	2	Weight Gain	.3834	–.2626	–.2490	6.89
Days in Hospital (110)	1	Weight Gain	.2371	—	–.2371	6.43
	2	Parity	.3328	–.2404	–.2258	6.56
Discharge Weight (110)	1	End Weight	.4013	—	.4013	20.74
	2	SES[a]	.4439	.2070	.1569	4.79
	3	Parity	.4786	.1996	.0984	4.40
Disch Chron Age (110)	1	Weight Gain	.2435	—	–.2435	6.81
	2	Parity	.3323	–.2331	–.2181	6.15

Note: [a] socioeconomic status.

relations for male twins than for female twins. For female twins, higher SES was related to higher birthweight and discharge weight; there were no predictor relations for SES for the male twins. More maternal education was related to higher 5-min Apgar scores and higher discharge weight for male twins, whereas maternal education did not predict any outcome measures for female twins.

Discussion

The most informative findings from this study were those for maternal weight gain, the variable that previously had been found to predict singleton birthweight and, in a few studies, twin birthweight. These results have indicated that maternal weight gain significantly and, for the most part, consistently, predicted twin outcome for the higher risk (preterm and male) twins, but not for the lower risk (fullterm and female) twins. When considering the importance of maternal weight gain for newborn twin outcome, therefore, the offspring of all twin pregnancies should not be viewed as belonging to the same group. Rather, the gestational age and sex of cotwins must be taken into account.

One possibility is that, because there is a range of birth gestational ages for the preterm group (i.e., 29 to 37 weeks), it might be assumed that weight gain increases with each week of pregnancy and, subsequently, a strong association between increased gestational age and improved infant prognosis would be expected. Several considerations argue against this possibility, however. First, for this sample, the correlation between weight gain and gestational age for the preterm group was $r = 0.24$. Although this correlation is significant at the .05 level, it is modest, indicating that the direct association between weight gain and gestational age is not strong. Furthermore, the correlation between conceptional age at discharge (birth gestational age plus chronological age) and weight gain is $r = 0.04$, basically a zero-order correlation, yet weight gain was a predictor for age at discharge.

Second, it has been indicated that weight gain occurs more quickly and earlier in twin gestations, actually before

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Table 4

Maternal Predictors of Newborn Outcome for Female Twins

Dependent Variable (N)	Step	Predictor	Multiple R	Partial *r*	Initial *r* with Criterion	*F* to Remove
Birthweight (223)	1	End Weight	.2995	—	.2995	21.78
	2	SES[a]	.3483	.1863	.1830	7.91
	3	Parity	.3847	.1743	.1097	6.86
	4	BMI[b]	.4156	–.1705	.1596	6.53
Birth Length (220)	1	End Weight	.2839	—	.2839	19.10
	2	BMI[b]	.3454	–.2052	.1134	9.54
5–min Apgar (223)	1	End Weight	.1753	—	.1753	7.01
Days in Isolette (211)	1	End Weight	.1863	—	–.1863	7.52
	2	Parity	.2602	–.1849	–.1713	7.36
Days in Hospital (223)	1	End Weight	.1422	—	–.1422	4.56
Discharge Weight (223)	1	End Weight	.2963	—	.2963	21.27
	2	SES[a]	.3430	.1810	.1781	7.45
	3	BMI[b]	.3756	–.1629	.1479	5.97
	4	Parity	.4073	.1700	.0867	6.48
Disch Chron Age (223)	1	End Weight	.1465	—	–.1465	4.85

Note: [a] socioeconomic status; [b] body mass index

Table 5

Maternal Predictors of Newborn Outcome for Male Twins

Dependent Variable (N)	Step	Predictor	Multiple R	Partial *r*	Initial *r*	*F* to Remove
Birthweight (175)	1	Weight Gain	.3077	—	.3077	18.10
	2	Parity	.4268	.3108	.2253	18.39
	3	Height	.4861	.2572	.2549	12.11
	4	End Weight	.5089	.1726	.2717	5.22
Birth Length (171)	1	Weight Gain	.2631	—	.2631	12.56
	2	Parity	.3733	.2745	.1963	13.69
	3	Height	.4329	.2263	.2338	9.87
5-min Apgar (173)	1	Parity	.2319	—	.2319	9.72
	2	Weight Gain	.3610	.2844	.2244	14.96
	3	Education	.4002	.1853	.1901	6.01
Days in Isolette (168)	1	Parity	.2652	—	–.2652	12.55
	2	Weight Gain	.4045	–.3169	–.2451	18.42
	3	Height	.4433	–.1982	–.1971	6.71
Days in Hospital (175)	1	Weight Gain	.2863	—	–.2863	15.44
	2	Parity	.4097	–.3059	–.2272	17.75
	3	Height	.4587	–.2262	–.2270	9.22
Discharge Weight (175)	1	End Weight	.3020	—	.3020	17.36
	2	BMI[a]	.3471	–.1795	.1310	5.73
	3	Parity	.3879	.1846	.1385	6.03
Disch Chron Age (175)	1	Education	.4134	.1551	.1568	4.19
	2	Parity	.4199	–.3235	–.2448	20.11
	3	Height	.4681	–.2278	–.2271	9.36

Note: [a] body mass index

the 20th week (Luke, 1998). Low maternal weight gains early in gestation are related to poor intrauterine growth, lowered birthweights, and higher morbidity among twins (Luke, 1998; Luke et al., 1997). These authors demonstrated that mid gestation (20 to 28 weeks) maternal weight gains are most highly related to birthweight, even though fetal weight gain is greatest after 28 weeks (Luke et al., 1997). They concluded that maternal weight gains before 28 weeks gestation are the most significant for intrauterine fetal growth and birthweight of twins (Luke et al., 1998). The association between earlier, and not overall, maternal weight gain and both twin growth and weight described in these studies thereby serves to abate concerns regarding an association between better prognosis for twins and improved maternal weight gain for the preterm sample. These findings, in fact, provide an explanation for the low

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and zero-order correlations found for this sample between weight gain and gestational age and between weight gain and conceptional age at discharge.

Third, this study has demonstrated that weight gain was a significant predictor for the higher-risk males, but not for the lower-risk females (with no differences in gestational age between males and females). This result provides further support for the conclusion that weight gain differentiates as a predictor by group risk. In fact, an examination (unpublished) of the predictive relations based on the size of the infants within twin pairs (i.e., whether the twin was the larger or the smaller infant), demonstrated that maternal weight gain was a significant predictor of birthweight and birth length for the smaller twins, but not for the larger twins. This finding provides additional support for the differentiation of risk groups by maternal weight gain. Information about the rates of maternal weight gain was not available for this population; such information might prove useful in future research to clarify this issue further.

It also was demonstrated that a higher number of maternal variables were associated with outcome for the higher risk preterm and male twins than for the lower risk fullterm and female twins. This was noted particularly for the anthropometric variables and for parity. Interestingly, the sociodemographic variables had a low incidence of association with twin outcome. As virtually all mothers in this study had prenatal care, these findings suggest the importance of care during the current pregnancy relative to demographics for twin outcome. Pregravid body mass index, which had been found to predict birthweight in some previous research, had some predictive input for birthweight in this study for the lower-risk fullterm and female twins, but not for the higher-risk preterm and male twins.

Knowing that different maternal variables influence outcome for fullterm and preterm twins could direct the management of twin pregnancies. For example, because higher weight gain is predictive of improved outcome for preterm twins, increased weight gain could be encouraged early in twin gestations because of the high incidence of preterm delivery in twin pregnancies. Recent advances in medical technology have made it possible to diagnose twin pregnancies early in the first trimester, allowing for nutritional advice to be provided during early fetal development. Similarly, increased weight gain might lead to improved outcome for male twins. These possibilities are consistent with the conclusion of Luke and colleagues (Luke et al., 1998) who recommended nutrition therapy early in twin pregnancies.

Furthermore, knowledge of background variables such as parity could affect anticipated outcome so that women with lower parity would be monitored for delivery of twins with potentially higher risk status than those with higher parity. In this regard, it is noteworthy that parity, and not maternal age, most consistently predicted outcome. It has been suggested (Luke et al., 1998) that higher parity, as well as older age, may be associated with high maternal body fat which, in turn, may be related to more adequate fetal growth and higher birthweight. Finally, these findings suggest that shorter women pregnant with male twins might be expected to have boys with less favorable outcome than taller women.

In sum, this study has demonstrated that evaluating influences on newborn outcome for all twins across groups as a single population, rather than separating twins by potential risk variables, does not allow for a completely accurate description of the association between maternal variables and newborn outcome. To determine if the variables found to have significant influence in this study remain significant for long term developmental outcome of twins, future research should be designed to assess that association for the twins by groups defined by relative risk.

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