

Supplemental Analyses

1.1 Clinical-level symptoms in the sample

There are no clinical cutoff scores for the CABI, so clinical levels of problems are not available at 5 years. At age 10, the clinical cutoffs for the CBCL suggest that 14.4% have clinical levels of social problems (T-score > 70), 18.3% for anxious/depressive problems, 6.2% for delinquent problems, and 11.7% for aggressive problems. In adolescence, 8.6% scored in the clinical range on the CBCL social problems scale, 14.5% on depressive symptoms, 13.0% on anxiety symptoms, 8.6% on aggressive problems, 2.5% on conduct problems, and 6.2% on oppositional defiant problems.

1.2 Correlations between parent and adolescent reports of problem behaviors

Parent report was used in the current analyses for consistency in the reporter across time. The following are correlations between adolescent (Youth Self Report) and parent report (CBCL) of problem behaviors in adolescence (all p s < .001): depressive ($r = 0.31$), anxiety ($r = 0.17$), aggressive ($r = 0.29$), oppositional defiant ($r = 0.27$), conduct ($r = 0.35$), and social problems ($r = 0.24$).

1.3 Correlations between 10y and adolescent behavior variables and CBCL composites

The externalizing variable we used at age 10 was correlated at $r = 0.93$, $p < .001$, with the CBCL externalizing composite variable, and the latent externalizing variable in adolescence was correlated at $r = 0.91$, $p < .001$, with the CBCL externalizing composite variable. The internalizing variable we used at age 10 was correlated at $r = 0.89$, $p < .001$, with the CBCL internalizing composite variable, and the internalizing variable we used in adolescence was correlated at $r = 0.88$, $p < .001$, with the CBCL internalizing composite. The social problems scale directly from the CBCL was used to assess social problems at 10y and adolescence.

2. Description of all models tested

Model number	Description of model being tested
Model 1	Mediation model with severity of iron deficiency as the main predictor of direct and indirect pathways to adolescent internalizing, externalizing, and social problems
Model 2	Moderation model testing the interaction between severity of iron deficiency at 12-18 months and maternal responsiveness in infancy predicting pathways to adolescent problems
Model 3	Moderation model testing the interaction between severity of iron deficiency at 12-18 months and maternal responsiveness at 5y predicting pathways to adolescent problems
Model 4a	Model 1 with dummy-coded iron status (iron deficiency anemia, iron deficiency without anemia, and iron sufficiency at 12-18 months) instead of severity of iron deficiency as the independent variable
Model 4b	Model 4a with iron status coded as iron deficiency with or without anemia vs. iron sufficiency at 12-18 months
Model 5	Model 2 with dummy-coded iron status (iron deficiency anemia, iron deficiency without anemia, and iron sufficiency at 12-18 months) as the independent variable instead of severity of iron deficiency
Model 6	Model 3 with dummy-coded iron status (iron deficiency anemia, iron deficiency without anemia, and iron sufficiency at 12-18 months) instead of severity of iron deficiency as the independent variable

3. Summary of Model 1 indirect effects

More severe iron deficiency at 12-18 months predicted higher levels of adolescent internalizing symptoms through the following indirect pathways: 1) iron deficiency at 12-18 months to age 5 externalizing symptoms to age 5 negative maternal responsiveness to age 10 internalizing symptoms to adolescent internalizing symptoms ($\beta = 0.012$, $SE = 0.006$, $z = 2.09$, $p = .036$). The association between severity of iron deficiency at 12-18 months and adolescent externalizing symptoms was indirectly mediated through the pathway from iron deficiency at 12-18 months to age 5 externalizing symptoms to age 5 negative maternal responsiveness to age 10 externalizing symptoms to age 16 externalizing symptoms ($\beta = 0.017$, $SE = 0.008$, $z = 2.11$, $p = .035$). There was also a direct effect between more severe iron deficiency in infancy and adolescent externalizing problems ($\beta = 0.09$, $SE = 0.03$, $z = 3.06$, $p = .002$). For adolescent social problems, there were three significant indirect pathways from more severe iron deficiency at 12-18 months to 1) age 5 externalizing symptoms to age 5 negative maternal responsiveness to age 10 internalizing symptoms to adolescent social problems ($\beta = 0.008$, $SE = 0.004$, $z = 2.01$, $p = 0.044$), 2) age 5 externalizing symptoms to age 5 negative maternal responsiveness to age 10 social problems to adolescent social problems ($\beta = 0.006$, $SE = 0.003$, $z = 1.98$, $p = .048$), and 3) age 5 externalizing symptoms to age 5 negative maternal responsiveness to age 10 externalizing symptoms to adolescent social problems ($\beta = 0.007$, $SE = 0.003$, $z = 1.98$, $p = .047$).

4. Data Analytic Plan for Supplemental Analyses

A total of 3 supplementary models were tested: Model 4) a mediation model with dummy-coded iron status at 12-18 months (iron deficiency anemia, iron deficiency without anemia, and iron sufficiency at 12-18 months; instead of severity of iron deficiency as in Model 1) predicting adolescent problems; Model 5) a moderation model testing the interaction between

dummy-coded iron status at 12-18 months (instead of severity of iron deficiency as in Model 2) and maternal responsiveness at 9 months predicting pathways to adolescent problems; Model 6) a moderation model testing the interaction between dummy-coded iron status at 12-18 months (instead of severity of iron deficiency as in Model 3) and maternal responsiveness at 5y predicting pathways to adolescent problems. Iron sufficiency was omitted and served as the reference group. Pairwise comparisons were assessed among the three classifications of iron status to determine whether effects differed for clinically relevant categories (e.g., iron deficiency anemia and iron deficiency without anemia). Thus, there were two exogenous variables in this second analysis: iron sufficiency versus iron deficiency without anemia, and iron sufficiency versus iron deficiency anemia. New parameters were specified that were derived from parameter estimates for the two dummy variables in order to compare the iron deficiency with and without anemia groups. The delta method was used to produce standard errors for these new parameters (Muthén, 2011). The resulting models 4-6 are identical to Models 1-3 except for iron deficiency severity being dummy-coded instead of analyzed as an ordinal variable.

Results

5.1. Model 4: Mediation model

5.1.1. Iron status category comparisons (Model 4a). Sensitivity analyses compared categories of iron status directly to determine whether effects were driven by iron deficiency anemia or if iron deficiency without anemia contributed to these pathways (paths shown in Figure S4; Table S5). The model demonstrated good fit to the data (CFI > 0.94, RMSEA < 0.05, SRMR < 0.06). Results indicated that compared to iron sufficiency, iron deficiency anemia did not predict greater 5y externalizing problems ($\beta = 0.08$, $SE = 0.04$, $z = 1.85$, $p = .06$), and iron deficiency without anemia did not predict 5y externalizing problems ($\beta = 0.09$, $SE = 0.05$, $z =$

1.93, $p = .053$). There were no differences between iron deficiency anemia and iron deficiency without anemia in predicting any of the endogenous variables, $p > .05$. Iron deficiency without anemia was directly associated with adolescent externalizing problems ($\beta = 0.10$, $SE = 0.03$, $z = 3.40$, $p = .001$). Iron deficiency anemia was not associated with adolescent externalizing problems ($\beta = 0.05$, $SE = 0.03$, $z = 1.76$, $p = .08$). Iron deficiency anemia was associated with greater adolescent social problems ($\beta = 0.06$, $SE = 0.03$, $z = 2.14$, $p = .03$), but iron deficiency without anemia was not, $p > .05$. The remainder of paths were highly similar to those in the model testing severity of iron deficiency as an ordinal variable (see Figure 1). Overall, the iron deficiency severity variable was a better predictor of 5y externalizing problems and pathways to adolescent problems than either the iron deficiency with and without anemia variables.

5.1.2. Iron deficiency with or without anemia vs. iron sufficiency (Model 4b). Due to the similar associations of 5y externalizing problems with iron deficiency anemia ($\beta = 0.08$) and iron deficiency without anemia ($\beta = 0.09$) and no significant difference between these groups predicting 5y externalizing problems, these two groups were combined to test whether iron deficiency without anemia was the threshold for associations with 5y externalizing problems (iron deficiency with or without anemia = 1, iron sufficiency = 0). These analyses revealed that iron deficiency with or without anemia was significantly associated with 5y externalizing problems compared to iron sufficiency ($\beta = 0.11$, $SE = 0.05$, $z = 2.35$, $p = .02$; Table S6) and significantly predicted six pathways to adolescent internalizing, externalizing, and social problems, suggesting that iron deficiency without anemia was the threshold for effects (see Table S6, Figure S5).

5.2 Moderation model: Maternal responsiveness at 9 months

Iron status category comparisons (Model 5). Sensitivity analyses compared categories of iron status (iron deficiency with or without anemia) directly to determine whether interactions were potentially driven by iron deficiency anemia or iron deficiency without anemia. The interaction between iron deficiency anemia at 12-18 months and maternal responsiveness at 9 months predicted 5y internalizing problems ($\beta = 0.15$, $SE = 0.06$, $z = 2.52$, $p = .01$), but the iron deficiency without anemia and maternal responsiveness interaction did not, $p > .05$. Simple slopes analyses revealed that maternal responsiveness was not associated with 5y internalizing problems in children who had iron deficiency anemia at 12-18 months, $p = .10$, but that more positive maternal responsiveness was associated with lower 5y internalizing problems for children who were iron sufficient or had iron deficiency without anemia, $p = .004$ (Figure 2). For more negative maternal responsiveness (1 SD below the mean), there was no difference in 5y internalizing symptoms between the children who had iron deficiency anemia at 12-18 months and those who did not. For more positive responsiveness (1 SD above the mean), children who had iron deficiency anemia at 12 or 18 months showed higher 5y internalizing problems than those without iron deficiency anemia. There were 2 indirect pathways by which the interaction between 12-18 month iron deficiency anemia and 9-month maternal responsiveness were associated with adolescent internalizing and social problems (see Table S7), both of which operated through 5y and 10y internalizing problems. However, iron deficiency anemia and iron deficiency without anemia did not interact with 9-month maternal responsiveness to predict 5y externalizing or social problems, $ps > .05$ (Table S8).

Summary of indirect effects. There were two indirect pathways by which the interaction between iron deficiency anemia at 12-18 months and maternal responsiveness in infancy was associated with adolescent outcomes (see Table S7): 1) 5y internalizing to 10y internalizing to

adolescent internalizing problems ($\beta = 0.015$, $SE = 0.007$, $z = 2.18$, $p = .03$), and 2) 5y internalizing to 10y internalizing to adolescent social problems ($\beta = 0.010$, $SE = 0.005$, $z = 2.15$, $p = .03$).

5.3. Moderation model: Maternal responsiveness at 5y

Iron status category comparisons (Model 6). The interaction between maternal responsiveness at 5y and iron deficiency at 12-18 months with anemia did not significantly predict 5y internalizing, externalizing, or social problems, $ps > .05$. The interactions between maternal responsiveness at 5y and iron deficiency without anemia at 12-18 months were also not significantly associated with 5y internalizing, externalizing, or social problems, $ps > .05$ (Table S9).

6. Mediation model with both maternal responsiveness at 9 months and 5y

To test whether alterations in maternal responsiveness in infancy may precede internalizing, externalizing, and social problems, we tested a mediation model from iron status at 12-18 months to maternal responsiveness in infancy to internalizing, externalizing, and social problems at 5 y, to maternal responsiveness at 5 y to internalizing, externalizing, and social problems at 10 y and then to adolescence. The maternal responsiveness measure (at 9 months) does precede the iron status assessment at 12-18 months, which makes the mediation model problematic. However, we conducted the model as a preliminary assessment of the directionality of associations between iron deficiency, maternal responsiveness, and behavior problems (assuming that maternal responsiveness does not change a great deal from 9 months to 18 months). This model indicated that there was no association between severity of iron deficiency at 12-18 months and maternal responsiveness at 9 months, $p = .81$. As a result, there were no significant paths from iron deficiency at 12-18 months to later behavior problems through

maternal responsiveness in infancy. Maternal responsiveness in infancy was associated with age 5 externalizing problems, $\beta = 0.15$, $SE = 0.06$, $p = .008$, but not internalizing or social problems, $ps > .24$. Future research is needed to tease apart the directionality of these associations more precisely, though our preliminary analyses suggest that alterations in maternal responsiveness in infancy do not directly follow iron deficiency at 12-18 months.

7. Sensitivity analyses

7.1. Iron status imputation. Sensitivity analyses were performed to ensure that model results were not due to imputation of 18-month iron status for a subgroup of infants. The model with the continuous variable of iron deficiency severity was tested only for individuals who had iron status measured directly at both 12 and 18 months. The direction and magnitude of associations in the model remained the same in this subgroup compared to the overall sample that included imputed 18-month iron status.

7.2. Chronic iron deficiency. To consider whether these findings were driven by a subgroup of individuals with chronic iron deficiency in infancy ($N = 115$; 12.3%), we created a variable such that participants who had iron deficiency with or without anemia at both 12 and 18 months received a score of 1, and participants who did not have iron deficiency with or without anemia at both 12 and 18 months received a 0. In the model, this chronic iron deficiency variable did not predict age 5 externalizing, internalizing, or social problems. To be sure that these findings were not driven by 7 individuals with chronic iron deficiency anemia in infancy, a second variable was created in which these participants received a score of 1, and all other participants, who did not have iron deficiency anemia at both 12 and 18 months, received a 0. In the model, this chronic iron deficiency anemia variable did not predict age 5 externalizing, internalizing, or social problems.

Table S1. Iron status Ns at 12 and 18 months.

		Iron Status at 18 months		
		Iron Sufficient	Iron Deficiency without Anemia	Iron Deficiency Anemia
Iron Status at 12 months	Iron Sufficient	512	65	5
	Iron Deficiency without Anemia	151	74	16
	Iron Deficiency Anemia	80	18	7

Note. Number of participants in each iron status group at 12 and 18 months. For 5 participants, there were concerns with 18-month iron imputation and so they were given a value of missing for 18-month iron status.

Table S2. Descriptive statistics by iron deficiency group.

	Iron Sufficient (N = 512)		Iron Deficiency Without Anemia (N = 294)		Iron Deficiency Anemia (N = 127)		Differences between iron deficiency groups		
	M or %	SD	M or %	SD	M or %	SD	Chi-square	F-test	P-value
Age at assessment (y)									
5y	5.5	0.05	5.5	0.03	5.5	0.04		$F(2, 599)=0.43$.65
10y	10.0	0.1	10.0	0.1	10.0	0.1		$F(2, 821)=1.80$.17
Adolescence	14.6	1.5	14.4	1.5	13.7	1.4		$F(2, 932)=17.95$	<.001***
Sex (% female)	51.8%	--	50.3%	--	29.9%	--	$\chi^2(2, N = 933) = 20.12$		<.001***
Maternal age at child's birth (y)	27.0	6.1	26.1	6.0	24.9	6.0		$F(2, 924)=6.17$.002**
Mother's education (y)	9.5	2.7	9.5	2.8	9.2	2.7		$F(2, 932)=0.43$.65
Graffar (SES)	26.7	6.1	27.5	6.5	28.6	6.9		$F(2, 929)=5.00$.007**
HOME score	30.7	4.7	30.1	4.7	30.6	4.7		$F(2, 928)=1.78$.17
Maternal stress (number)	4.7	2.6	4.5	2.8	4.8	2.5		$F(2, 911)=0.61$.55
Formula/milk intake (average mL/day)	433.0	211.5	414.5	206.0	356.8	186.0		$F(2, 863)=6.61$.001**
Supplementation group							$\chi^2(4, N = 866) = 138.9$		<.001***
High iron	54.1%	--	31.3%	--	11.5%	--			
Low iron	23.2%	--	26.3%	--	12.3%	--			
No added iron	22.7%	--	42.4%	--	76.2%	--			
Received medicinal iron in infancy	19.3%	--	9.9%	--	95.3%	--	$\chi^2(2, N = 933) = 350.8$		<.001***

Note. Values are *n* (%) for categorical variables and mean (SD) for continuous variables. Percentages calculated for those with non-missing data on each variable. Mean Graffar in this sample corresponds to middle SES class. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table S3. Estimates of direct pathways from severity of iron deficiency at 12-18 months to adolescent socioemotional problems with maternal responsiveness in infancy as a moderator (Model 2).

	β	95% CI
Severity of Iron Deficiency in Infancy		
High Iron Supplementation	-0.22***	-0.29, -0.15
Low Iron Supplementation	-0.09**	-0.15, -0.02
Hemoglobin at 6 months	-0.12***	-0.19, -0.06
Maternal Age at Birth	-0.10**	-0.16, -0.04
Received Medicinal Iron	0.29***	0.22, 0.37
Low Socioeconomic Status (Graffar)	0.08**	0.02, 0.14
Female Sex	-0.08**	-0.14, -0.03
5y Internalizing Problems		
Severity of Iron Deficiency in Infancy	0.02	-0.06, 0.09
Low Socioeconomic Status (Graffar)	0.17***	0.09, 0.24
Maternal Responsiveness in Infancy	-0.33*	-0.57, -0.06
Iron Deficiency x Maternal Responsiveness	0.29*	0.02, 0.53
5y Externalizing Problems		
Severity of Iron Deficiency in Infancy	0.09*	0.004, 0.18
Maternal Stress in Infancy	0.12**	0.04, 0.21
Maternal Responsiveness in Infancy	-0.18	-0.43, 0.08
Iron Deficiency x Maternal Responsiveness	0.04	-0.21, 0.28
5y Social Problems		
Severity of Iron Deficiency in Infancy	0.02	-0.06, 0.09
Low Socioeconomic Status (Graffar)	0.13**	0.06, 0.20
Maternal Responsiveness in Infancy	-0.20	-0.45, 0.07
Iron Deficiency x Maternal Responsiveness	0.18	-0.07, 0.41
10y Internalizing Problems		
Severity of Iron Deficiency in Infancy	0.03	-0.04, 0.09
5y Internalizing Problems	0.29***	0.19, 0.38
5y Externalizing Problems	0.22***	0.11, 0.32
5y Social Problems	0.15**	0.06, 0.24
Maternal Education	-0.12***	-0.18, -0.06
Female Sex	-0.07*	-0.12, -0.02
10y Externalizing Problems		
Severity of Iron Deficiency in Infancy	-0.02	-0.09, 0.04
5y Internalizing Problems	0.04	-0.07, 0.14
5y Externalizing Problems	0.55***	0.45, 0.65
5y Social Problems	0.03	-0.06, 0.11
Maternal Education	-0.13***	-0.18, -0.07

10y Social Problems

Severity of Iron Deficiency in Infancy	0.01	-0.06, 0.08
5y Internalizing Problems	0.07	-0.03, 0.17
5y Externalizing Problems	0.28***	0.18, 0.38
5y Social Problems	0.20***	0.11, 0.29
Maternal Education	-0.08**	-0.14, -0.02
Female Sex	0.10**	0.04, 0.16

Adolescent Internalizing Problems

Severity of Iron Deficiency in Infancy	0.02	-0.04, 0.07
10y Internalizing Problems	0.35***	0.27, 0.43
10y Externalizing Problems	0.08†	-0.002, 0.16
10y Social Problems	0.17***	0.10, 0.23
Maternal Education	-0.10**	-0.16, -0.05

Adolescent Externalizing Problems

Severity of Iron Deficiency in Infancy	0.08**	0.03, 0.13
10y Internalizing Problems	0.07†	-0.01, 0.15
10y Externalizing Problems	0.46***	0.38, 0.54
10y Social Problems	0.11**	0.04, 0.17
Maternal Education	-0.07*	-0.13, -0.02

Adolescent Social Problems

Severity of Iron Deficiency in Infancy	0.06*	0.004, 0.11
10y Internalizing Problems	0.23***	0.16, 0.30
10y Externalizing Problems	0.18***	0.10, 0.26
10y Social Problems	0.21***	0.14, 0.28
Female	0.10***	0.06, 0.15
Maternal Education	-0.07*	-0.12, -0.01
Formula/milk intake (average mL/day)	-0.05*	-0.09, -0.01

Note. All estimates reported are standardized estimates and 95% confidence intervals (CI) for each of the direct pathways to behavior problems. Dependent variables are in bold with independent variables and associated standardized (β) coefficients. *Note.* Covariates were included in the final model if they predicted the model variable at † $p < .10$. $p < .05$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table S4. Estimates of direct pathways from severity of iron deficiency at 12-18 months to adolescent socioemotional problems with maternal responsiveness at 5y as a moderator (Model 3).

	β	95% CI
Severity of Iron Deficiency in Infancy		
High Iron Supplementation	-0.22***	-0.28, -0.15
Low Iron Supplementation	-0.09**	-0.15, -0.02
Hemoglobin at 6 months	-0.12***	-0.18, -0.06
Maternal Age at Birth	-0.10**	-0.16, -0.04
Received Medicinal Iron	0.29***	0.22, 0.37
Low Socioeconomic Status (Graffar)	0.08**	0.02, 0.14
Female Sex	-0.08**	-0.14, -0.03
5y Internalizing Problems		
Severity of Iron Deficiency in Infancy	0.00	-0.07, 0.07
Low Socioeconomic Status (Graffar)	0.14***	0.07, 0.22
5y Maternal Responsiveness	-0.33**	-0.54, -0.11
Iron Deficiency x Maternal Responsiveness	0.00	-0.09, 0.09
5y Externalizing Problems		
Severity of Iron Deficiency in Infancy	0.08†	-0.0090909, 0.16
5y Maternal Responsiveness	-0.65***	-0.85, -0.45
Iron Deficiency x Maternal Responsiveness	0.06	-0.03, 0.14
5y Social Problems		
Severity of Iron Deficiency in Infancy	0.01	-0.07, 0.08
Low Socioeconomic Status (Graffar)	0.12**	0.04, 0.19
5y Maternal Responsiveness	-0.21†	-0.45, 0.03
Iron Deficiency x Maternal Responsiveness	-0.01	-0.11, 0.10
10y Internalizing Problems		
Severity of Iron Deficiency in Infancy	0.03	-0.04, 0.09
5y Internalizing Problems	0.29***	0.20, 0.38
5y Externalizing Problems	0.21***	0.11, 0.32
5y Social Problems	0.15**	0.06, 0.24
Maternal Education	-0.12***	-0.18, -0.06
Female Sex	-0.06*	-0.11, -0.01
10y Externalizing Problems		
Severity of Iron Deficiency in Infancy	-0.02	-0.09, 0.05
5y Internalizing Problems	0.03	-0.07, 0.13
5y Externalizing Problems	0.56***	0.46, 0.66
5y Social Problems	0.03	-0.06, 0.11
Maternal Education	-0.12***	-0.18, -0.06
10y Social Problems		

Severity of Iron Deficiency in Infancy	0.01	-0.05, 0.08
5y Internalizing Problems	0.07	-0.03, 0.17
5y Externalizing Problems	0.28***	0.18, 0.37
5y Social Problems	0.20***	0.11, 0.30
Maternal Education	-0.08*	-0.14, -0.02
Female Sex	0.10**	0.04, 0.16
Adolescent Internalizing Problems		
Severity of Iron Deficiency in Infancy	0.02	-0.04, 0.07
10y Internalizing Problems	0.35***	0.27, 0.42
10y Externalizing Problems	0.08†	0.00, 0.16
10y Social Problems	0.17***	0.10, 0.23
Maternal Education	-0.10***	-0.16, -0.05
Adolescent Externalizing Problems		
Severity of Iron Deficiency in Infancy	0.08**	0.02, 0.13
10y Internalizing Problems	0.07†	-0.01, 0.15
10y Externalizing Problems	0.46***	0.38, 0.54
10y Social Problems	0.11**	0.04, 0.17
Maternal Education	-0.07*	-0.13, -0.02
Adolescent Social Problems		
Severity of Iron Deficiency in Infancy	0.06*	0.01, 0.11
10y Internalizing Problems	0.23***	0.16, 0.31
10y Externalizing Problems	0.17***	0.10, 0.25
10y Social Problems	0.21***	0.14, 0.28
Female	0.11***	0.07, 0.15
Maternal Education	-0.07*	-0.12, -0.01
Low Iron Supplementation	-0.05*	-0.09, -0.01

Note. All estimates reported are standardized estimates and 95% confidence intervals (CI) for each of the direct pathways to behavior problems. Dependent variables are in bold with independent variables and associated standardized (β) coefficients. *Note.* Covariates were included in the final model if they predicted the model variable at $p < .05$. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table S5. Estimates of direct pathways from iron deficiency with and without anemia (dummy-coded) at 12-18 months to adolescent socioemotional problems (Model 4a; iron deficiency anemia vs. iron deficiency without anemia vs. iron sufficiency).

	<i>B</i>	<i>95% CI</i>
Iron Deficiency Anemia in Infancy		
Hemoglobin at 6 months	-0.08**	-0.13, -0.02
Maternal Age at Birth	-0.09**	-0.14, -0.04
Received Medicinal Iron	0.59***	0.54, 0.64
Female Sex	-0.11***	-0.15, -0.06
Iron Deficiency Without Anemia in Infancy		
High Iron Supplementation	-0.30***	-0.37, -0.22
Low Iron Supplementation	-0.12**	-0.20, -0.05
Hemoglobin at 6 months	-0.08**	-0.14, -0.03
Received Medicinal Iron	-0.40***	-0.46, -0.34
5y Internalizing Problems		
Iron Deficiency Anemia in Infancy	0.02	-0.06, 0.09
Iron Deficiency Without Anemia in Infancy	0.03	-0.05, 0.11
Low Socioeconomic Status (Graffar)	0.15***	0.07, 0.22
5y Externalizing Problems		
Iron Deficiency Anemia in Infancy	0.08†	-0.005, 0.17
Iron Deficiency Without Anemia in Infancy	0.09†	-0.001, 0.19
Maternal Stress in Infancy	0.11*	0.03, 0.19
5y Social Problems		
Iron Deficiency Anemia in Infancy	0.02	-0.05, 0.10
Iron Deficiency Without Anemia in Infancy	0.01	-0.08, 0.10
Low Socioeconomic Status (Graffar)	0.10**	0.03, 0.18
Maternal Education	-0.08*	-0.15, -0.01
5y Maternal Responsiveness		
Iron Deficiency Anemia in Infancy	-0.07	-0.22, 0.06
Iron Deficiency Without Anemia in Infancy	0.05	-0.10, 0.18
5y Internalizing Problems	-0.16*	-0.31, -0.02
5y Externalizing Problems	-0.65***	-0.78, -0.49
5y Social Problems	-0.11†	-0.23, 0.02
Maternal Stress in Infancy	-0.12**	-0.21, -0.03
10y Internalizing Problems		
Iron Deficiency Anemia in Infancy	-0.02	-0.13, 0.08
Iron Deficiency Without Anemia in Infancy	0.04	-0.07, 0.13
5y Maternal Responsiveness	-0.54***	-0.65, -0.39
Female Sex	-0.07*	-0.12, -0.01
Maternal Education	-0.13***	-0.19, -0.06

10y Externalizing Problems

Iron Deficiency Anemia in Infancy	-0.06	-0.17, 0.04
Iron Deficiency Without Anemia in Infancy	0.03	-0.08, 0.12
5y Maternal Responsiveness	-0.61***	-0.69, -0.48
Maternal Education	-0.12***	-0.18, -0.06

10y Social Problems

Iron Deficiency Anemia in Infancy	-0.02	-0.12, 0.07
Iron Deficiency Without Anemia in Infancy	0.03	-0.06, 0.12
5y Maternal Responsiveness	-0.46***	-0.56, -0.33
Female Sex	0.10**	0.04, 0.16
Maternal Education	-0.09**	-0.15, -0.03

Adolescent Internalizing Problems

Iron Deficiency Anemia in Infancy	0.01	-0.05, 0.06
Iron Deficiency Without Anemia in Infancy	0.03	-0.03, 0.09
10y Internalizing Problems	0.34***	0.26, 0.42
10y Externalizing Problems	0.08†	-0.003, 0.16
10y Social Problems	0.17***	0.10, 0.23
Maternal Education	-0.10***	-0.16, -0.05

Adolescent Externalizing Problems

Iron Deficiency Anemia in Infancy	0.05†	-0.01, 0.11
Iron Deficiency Without Anemia in Infancy	0.10**	0.04, 0.16
10y Internalizing Problems	0.08†	-0.004, 0.16
10y Externalizing Problems	0.45***	0.37, 0.53
10y Social Problems	0.10**	0.04, 0.17
Maternal Education	-0.07*	-0.13, -0.02

Adolescent Social Problems

Iron Deficiency Anemia in Infancy	0.06*	0.01, 0.11
Iron Deficiency Without Anemia in Infancy	0.04	-0.02, 0.10
10y Internalizing Problems	0.23***	0.16, 0.30
10y Externalizing Problems	0.18***	0.10, 0.25
10y Social Problems	0.21***	0.14, 0.28
Female	0.11***	0.07, 0.15
Maternal Education	-0.06*	-0.12, -0.01

Note. All estimates reported are standardized estimates and 95% confidence intervals (CI) for each of the direct pathways to behavior problems. Dependent variables are in bold with independent variables and associated standardized (β) coefficients. *Note.* Covariates were included in the final model if they predicted the model variable at $p < .05$. † $p < .10$. * $p < .05$.

** $p < .01$. *** $p < .001$.

Table S6. Estimates of direct pathways from iron deficiency with or without anemia at 12-18 months to adolescent socioemotional problems (Model 4b; iron deficiency with and without anemia vs iron sufficiency).

	β	95% CI
Iron Deficiency With or Without Anemia in Infancy		
High Iron Supplementation	-0.31***	-0.38, -0.25
Low Iron Supplementation	-0.13***	-0.20, -0.07
Hemoglobin at 6 months	-0.13***	-0.19, -0.07
Maternal Age at Birth	-0.09**	-0.15, -0.03
Low Socioeconomic Status (Graffar)	0.08*	0.02, 0.14
5y Internalizing Problems		
Iron Deficiency With or Without Anemia	0.03	-0.05, 0.11
Low Socioeconomic Status (Graffar)	0.14***	0.07, 0.22
5y Externalizing Problems		
Iron Deficiency With or Without Anemia	0.11*	0.02, 0.19
Maternal Stress in Infancy	0.11*	0.03, 0.19
5y Social Problems		
Iron Deficiency With or Without Anemia	0.02	-0.06, 0.10
Low Socioeconomic Status (Graffar)	0.11**	0.03, 0.18
Maternal Education	-0.08*	-0.15, -0.01
5y Maternal Responsiveness		
Iron Deficiency With or Without Anemia	0.00	-0.15, 0.13
5y Internalizing Problems	-0.16*	-0.31, -0.02
5y Externalizing Problems	-0.65***	-0.78, -0.48
5y Social Problems	-0.12†	-0.24, 0.02
Maternal Stress in Infancy	-0.13**	-0.21, -0.04
10y Internalizing Problems		
Iron Deficiency With or Without Anemia	0.02	-0.09, 0.11
5y Maternal Responsiveness	-0.54***	-0.65, -0.39
Maternal Education	-0.13***	-0.19, -0.06
10y Externalizing Problems		
Iron Deficiency With or Without Anemia	-0.01	-0.11, 0.08
5y Maternal Responsiveness	-0.60***	-0.68, -0.48
Maternal Education	-0.12***	-0.18, -0.06
10y Social Problems		
Iron Deficiency With or Without Anemia	0.01	-0.08, 0.10
5y Maternal Responsiveness	-0.46***	-0.55, -0.33
Female Sex	0.12***	0.06, 0.17
Maternal Education	-0.09**	-0.15, -0.03

Adolescent Internalizing Problems

Iron Deficiency With or Without Anemia	0.03	-0.03, 0.08
10y Internalizing Problems	0.34***	0.26, 0.43
10y Externalizing Problems	0.08†	-0.004, 0.16
10y Social Problems	0.17***	0.10, 0.23
Maternal Education	-0.10***	-0.16, -0.05

Adolescent Externalizing Problems

Iron Deficiency With or Without Anemia	0.10***	0.04, 0.15
10y Internalizing Problems	0.08†	-0.005, 0.16
10y Externalizing Problems	0.45***	0.37, 0.53
10y Social Problems	0.11**	0.04, 0.17
Maternal Education	-0.07*	-0.13, -0.02

Adolescent Social Problems

Iron Deficiency With or Without Anemia	0.06*	0.003, 0.11
10y Internalizing Problems	0.23***	0.16, 0.30
10y Externalizing Problems	0.18***	0.10, 0.25
10y Social Problems	0.21***	0.14, 0.28
Female	0.10***	0.06, 0.15
Maternal Education	-0.06*	-0.12, -0.01

Note. All estimates reported are standardized estimates and 95% confidence intervals (CI) for each of the direct pathways to behavior problems. Dependent variables are in bold with independent variables and associated standardized (β) coefficients. *Note.* Covariates were included in the final model if they were associated with the model variable at $p < .05$. † $p < 0.10$, * $p < .05$. ** $p < .01$. *** $p < .001$.

Table S7. Summary of significant indirect pathways between iron deficiency at 12-18 months and adolescent socioemotional problems (Models 4 and 5).

	β	95% CI
Model 4: Mediation of ID With or Without Anemia		
ID→5y Externalizing→5y Maternal Responsiveness→10y Internalizing→Adolescent Internalizing	.013*	.002, .025
ID→5y Externalizing→5y Maternal Responsiveness→10y Social→Adolescent Internalizing	.005*	.001, .011
ID→5y Externalizing→5y Maternal Responsiveness→10y Externalizing→Adolescent Externalizing	.018*	.003, .037
ID→5y Externalizing→5y Maternal Responsiveness→10y Social→Adolescent Externalizing	.003†	.000, .008
ID→5y Externalizing→5y Maternal Responsiveness→10y Internalizing→Adolescent Social	.009*	.001, .018
ID→5y Externalizing→5y Maternal Responsiveness→10y Social→Adolescent Social	.007*	.001, .014
ID→5y Externalizing→5y Maternal Responsiveness→10y Externalizing→Adolescent Social	.007*	.001, .015
Model 5: Moderation of IDA by Infancy Maternal Responsiveness		
IDA x Infancy Maternal Responsiveness→5y Internalizing→10y Internalizing→Adolescent Internalizing	.015*	.003, .030
IDA x Infancy Maternal Responsiveness→5y Internalizing→10y Internalizing→Adolescent Social	.010*	.002, .020

Note. All estimates are standardized estimates and 95% confidence intervals for each of the indirect pathways in the model. ID = iron deficiency. IDA = iron deficiency anemia. IDA x Infancy Maternal Responsiveness signifies the interaction between these two variables. † $p < .10$, * $p < .05$. ** $p < .01$. *** $p < .001$.

Table S8. Estimates of direct pathways from iron deficiency with and without anemia (dummy-coded) at 12-18 months to adolescent socioemotional problems with maternal responsiveness at 9 months as a moderator (Model 5; iron deficiency anemia vs. iron deficiency without anemia vs. iron sufficiency).

	β	95% CI
Iron Deficiency Anemia in Infancy		
Hemoglobin at 6 months	-0.08**	-0.13, -0.02
Maternal Age at Birth	-0.09**	-0.15, -0.04
Received Medicinal Iron	0.59***	0.54, 0.64
Female Sex	-0.11***	-0.15, -0.06
Iron Deficiency without Anemia in Infancy		
High Iron Supplementation	-0.30***	-0.37, -0.22
Low Iron Supplementation	-0.12**	-0.20, -0.05
Hemoglobin at 6 months	-0.08**	-0.14, -0.03
Received Medicinal Iron	-0.40***	-0.46, -0.34
5y Internalizing Problems		
Iron Deficiency Anemia in Infancy	0.02	-0.06, 0.09
Iron Deficiency without Anemia in Infancy	0.02	-0.06, 0.10
Maternal Responsiveness in Infancy	-0.12	-0.26, 0.03
Iron Deficiency Anemia x Maternal Responsiveness	0.15*	0.03, 0.27
Iron Deficiency without Anemia x Maternal Responsiveness	-0.01	-0.15, 0.12
Low Socioeconomic Status (Graffar)	0.16***	0.08, 0.23
5y Externalizing Problems		
Iron Deficiency Anemia in Infancy	0.07	-0.02, 0.16
Iron Deficiency without Anemia in Infancy	0.09†	0.001, 0.19
Maternal Responsiveness in Infancy	-0.16*	-0.30, -0.01
Iron Deficiency Anemia x Maternal Responsiveness	0.00	-0.11, 0.11
Iron Deficiency without Anemia x Maternal Responsiveness	0.03	-0.10, 0.17
Maternal Stress in Infancy	0.13**	0.05, 0.21
5y Social Problems		
Iron Deficiency Anemia in Infancy	0.02	-0.06, 0.10
Iron Deficiency without Anemia in Infancy	0.00	-0.08, 0.09
Maternal Responsiveness in Infancy	-0.07	-0.20, 0.08
Iron Deficiency Anemia x Maternal Responsiveness	0.08	-0.03, 0.18
Iron Deficiency without Anemia x Maternal Responsiveness	0.03	-0.11, 0.17

Maternal Responsiveness		
Low Socioeconomic Status (Graffar)	0.12**	0.04, 0.19
Maternal Education	-0.08*	-0.15, -0.01
10y Internalizing Problems		
Iron Deficiency Anemia in Infancy	0.02	-0.04, 0.09
Iron Deficiency without Anemia in Infancy	0.01	-0.05, 0.08
5y Internalizing Problems	0.29***	0.19, 0.39
5y Externalizing Problems	0.20***	0.09, 0.31
5y Social Problems	0.15**	0.06, 0.24
Maternal Education	-0.11***	-0.18, -0.05
Female Sex	-0.06*	-0.11, -0.01
Maternal Stress in Infancy	0.06*	0.01, 0.12
10y Externalizing Problems		
Iron Deficiency Anemia in Infancy	-0.02	-0.09, 0.05
Iron Deficiency without Anemia in Infancy	-0.02	-0.09, 0.05
5y Internalizing Problems	0.03	-0.07, 0.13
5y Externalizing Problems	0.55***	0.45, 0.65
5y Social Problems	0.03	-0.06, 0.11
Maternal Education	-0.13***	-0.18, -0.07
10y Social Problems		
Iron Deficiency Anemia in Infancy	0.01	-0.06, 0.08
Iron Deficiency without Anemia in Infancy	0.01	-0.06, 0.08
5y Internalizing Problems	0.07	-0.03, 0.17
5y Externalizing Problems	0.26***	0.16, 0.36
5y Social Problems	0.21***	0.11, 0.30
Maternal Education	-0.07*	-0.14, -0.01
Female Sex	0.10**	0.04, 0.16
Maternal Stress in Infancy	0.08*	0.02, 0.14
Adolescent Internalizing Problems		
Iron Deficiency Anemia in Infancy	0.01	-0.05, 0.06
Iron Deficiency without Anemia in Infancy	0.03	-0.03, 0.09
10y Internalizing Problems	0.35***	0.27, 0.43
10y Externalizing Problems	0.08†	-0.002, 0.16
10y Social Problems	0.17***	0.10, 0.23
Maternal Education	-0.10***	-0.16, -0.05
Adolescent Externalizing Problems		
Iron Deficiency Anemia in Infancy	0.05†	-0.01, 0.11
Iron Deficiency without Anemia in Infancy	0.10**	0.04, 0.16
10y Internalizing Problems	0.07†	-0.01, 0.15
10y Externalizing Problems	0.45***	0.38, 0.53

10y Social Problems	0.11**	0.04, 0.17
Maternal Education	-0.07*	-0.13, -0.02
Adolescent Social Problems		
Iron Deficiency Anemia in Infancy	0.06*	0.01, 0.11
Iron Deficiency without Anemia in Infancy	0.04	-0.02, 0.10
10y Internalizing Problems	0.23***	0.16, 0.30
10y Externalizing Problems	0.17***	0.10, 0.25
10y Social Problems	0.21***	0.14, 0.28
Female	0.11***	0.07, 0.15
Maternal Education	-0.06*	-0.12, -0.01

Note. All estimates reported are standardized estimates and 95% confidence intervals (CI) for each of the direct pathways to behavior problems. Dependent variables are in bold with independent variables and associated standardized (β) coefficients. *Note.* Covariates were included in the final model if they predicted the model variable at $p < .05$. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

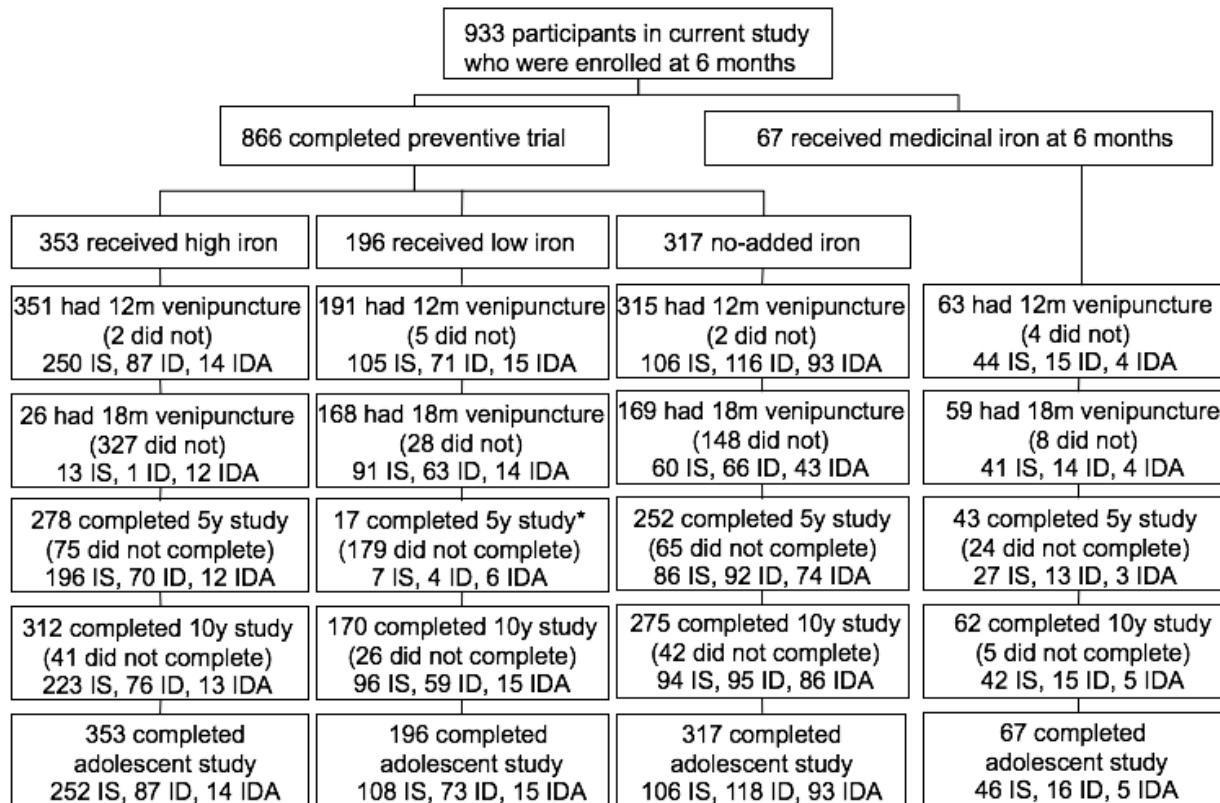
Table S9. Estimates of direct pathways from iron deficiency with and without anemia (dummy-coded) at 12-18 months to adolescent socioemotional problems with maternal responsiveness at 5y as a moderator (Model 6; iron deficiency anemia vs. iron deficiency without anemia vs. iron sufficiency).

	β	95% CI
Iron Deficiency Anemia in Infancy		
Hemoglobin at 6 months	-0.08**	-0.13, -0.02
Maternal Age at Birth	-0.09**	-0.15, -0.04
Received Medicinal Iron	0.59***	0.54, 0.64
Female Sex	-0.11***	-0.15, -0.06
Iron Deficiency without Anemia in Infancy		
High Iron Supplementation	-0.30***	-0.37, -0.22
Low Iron Supplementation	-0.12**	-0.20, -0.05
Hemoglobin at 6 months	-0.08**	-0.14, -0.03
Received Medicinal Iron	-0.40***	-0.46, -0.34
5y Internalizing Problems		
Iron Deficiency Anemia in Infancy	-0.01	-0.08, 0.07
Iron Deficiency without Anemia in Infancy	0.03	-0.05, 0.11
Maternal Responsiveness at 5y	-0.31***	-0.42, -0.19
Iron Deficiency Anemia x Maternal Responsiveness	0.00	-0.09, 0.09
Iron Deficiency without Anemia x Maternal Responsiveness	-0.04	-0.14, 0.06
Low Socioeconomic Status (Graffar)	0.15***	0.07, 0.22
5y Externalizing Problems		
Iron Deficiency Anemia in Infancy	0.06	-0.03, 0.14
Iron Deficiency without Anemia in Infancy	0.09†	-0.002, 0.18
Maternal Responsiveness at 5y	-0.57***	-0.70, -0.45
Iron Deficiency Anemia x Maternal Responsiveness	0.05	-0.04, 0.13
Iron Deficiency without Anemia x Maternal Responsiveness	0.04	-0.11, 0.19
5y Social Problems		
Iron Deficiency Anemia in Infancy	0.00	-0.07, 0.08
Iron Deficiency without Anemia in Infancy	0.00	-0.08, 0.09
Maternal Responsiveness at 5y	-0.23***	-0.35, -0.10
Iron Deficiency Anemia x Maternal Responsiveness	-0.02	-0.13, 0.09
Iron Deficiency without Anemia x Maternal Responsiveness	0.01	-0.11, 0.14

Low Socioeconomic Status (Graffar)	0.11**	0.03, 0.18
Maternal Education	-0.08*	-0.15, -0.01
10y Internalizing Problems		
Iron Deficiency Anemia in Infancy	0.03	-0.04, 0.09
Iron Deficiency without Anemia in Infancy	0.01	-0.05, 0.08
5y Internalizing Problems	0.29***	0.20, 0.38
5y Externalizing Problems	0.22***	0.11, 0.32
5y Social Problems	0.15***	0.06, 0.24
Maternal Education	-0.11***	-0.17, -0.05
Female Sex	-0.07*	-0.12, -0.02
10y Externalizing Problems		
Iron Deficiency Anemia in Infancy	-0.02	-0.09, 0.05
Iron Deficiency without Anemia in Infancy	-0.02	-0.09, 0.05
5y Internalizing Problems	0.04	-0.07, 0.14
5y Externalizing Problems	0.56***	0.46, 0.66
5y Social Problems	0.03	-0.06, 0.11
Maternal Education	-0.12***	-0.18, -0.06
10y Social Problems		
Iron Deficiency Anemia in Infancy	0.01	-0.05, 0.08
Iron Deficiency without Anemia in Infancy	0.01	-0.06, 0.07
5y Internalizing Problems	0.07	-0.03, 0.17
5y Externalizing Problems	0.27***	0.18, 0.37
5y Social Problems	0.21***	0.11, 0.30
Maternal Education	-0.07*	-0.14, -0.01
Female Sex	0.10**	0.04, 0.16
Maternal Stress in Infancy	0.06*	0.004, 0.13
Adolescent Internalizing Problems		
Iron Deficiency Anemia in Infancy	0.02	-0.04, 0.07
Iron Deficiency without Anemia in Infancy	0.03	-0.03, 0.09
10y Internalizing Problems	0.36***	0.28, 0.44
10y Externalizing Problems	0.08†	-0.002, 0.16
10y Social Problems	0.16***	0.09, 0.22
Female	0.07*	0.01, 0.13
Maternal Education	-0.10***	-0.16, -0.05
Adolescent Externalizing Problems		
Iron Deficiency Anemia in Infancy	0.06*	0.002, 0.12
Iron Deficiency without Anemia in Infancy	0.10**	0.04, 0.16
10y Internalizing Problems	0.08*	0.002, 0.16
10y Externalizing Problems	0.46***	0.38, 0.53
10y Social Problems	0.10**	0.03, 0.16

Female	0.05*	0.001, 0.11
Maternal Education	-0.07*	-0.13, -0.02
Adolescent Social Problems		
Iron Deficiency Anemia in Infancy	0.06*	0.01, 0.12
Iron Deficiency without Anemia in Infancy	0.04	-0.02, 0.10
10y Internalizing Problems	0.24***	0.17, 0.31
10y Externalizing Problems	0.18***	0.10, 0.25
10y Social Problems	0.20***	0.14, 0.27
Female	0.15***	0.10, 0.21
Maternal Education	-0.07*	-0.12, -0.01
Formula/milk intake (average mL/day)	-0.05*	-0.09, -0.004

Note. All estimates reported are standardized estimates and 95% confidence intervals (CI) for each of the direct pathways to behavior problems. Dependent variables are in bold with independent variables and associated standardized (β) coefficients. *Note.* Covariates were included in the final model if they predicted the model variable at $p < .05$. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.



*The 5-year follow-up: low-iron group was largely not assessed due to budgetary constraints except for 17 participants who are included the current analyses.
 Participants in the preventive trial who developed IDA at 12 or 18 months received medicinal iron. All measures in the current study were completed by both preventive trial participants and the participants who received medicinal iron.
 IS = iron sufficient, ID = iron deficiency without anemia, ID = iron deficiency anemia.

Figure S1. Flow chart of study participants.

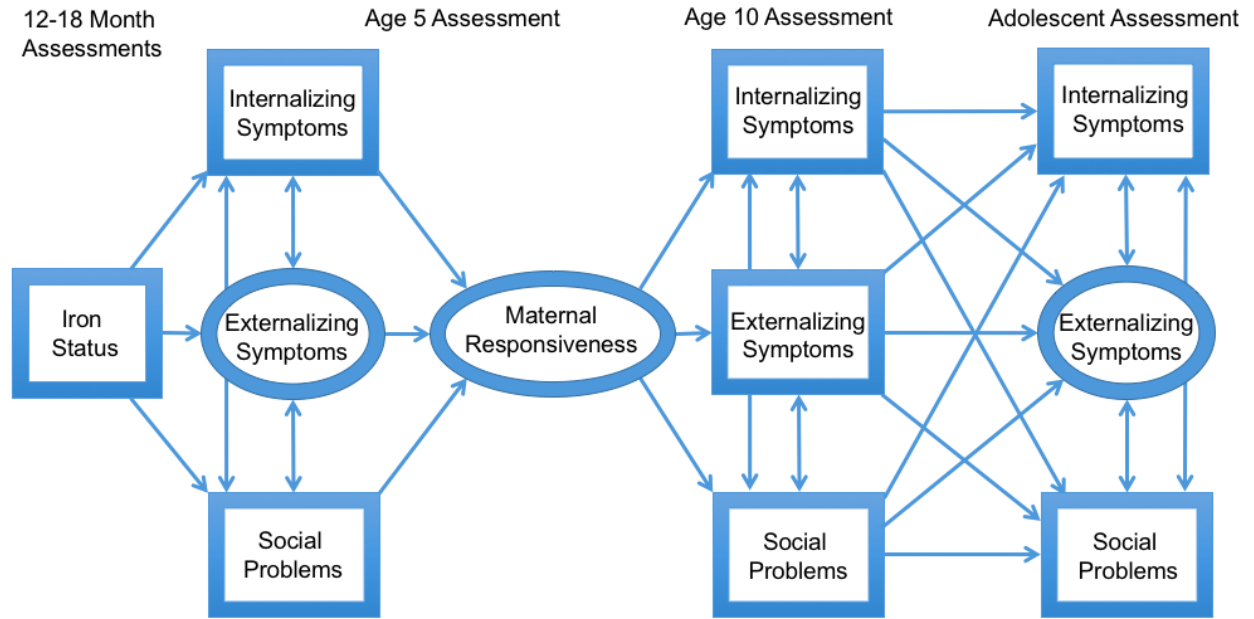


Figure S2. Hypothesized model of effects stemming from poorer iron status in infancy to subsequent internalizing, externalizing, and social problems (Model 1). All paths shown were included in tests of the model, as well as the direct paths from at 12- to 18-month iron status to 10-year and adolescent outcomes.

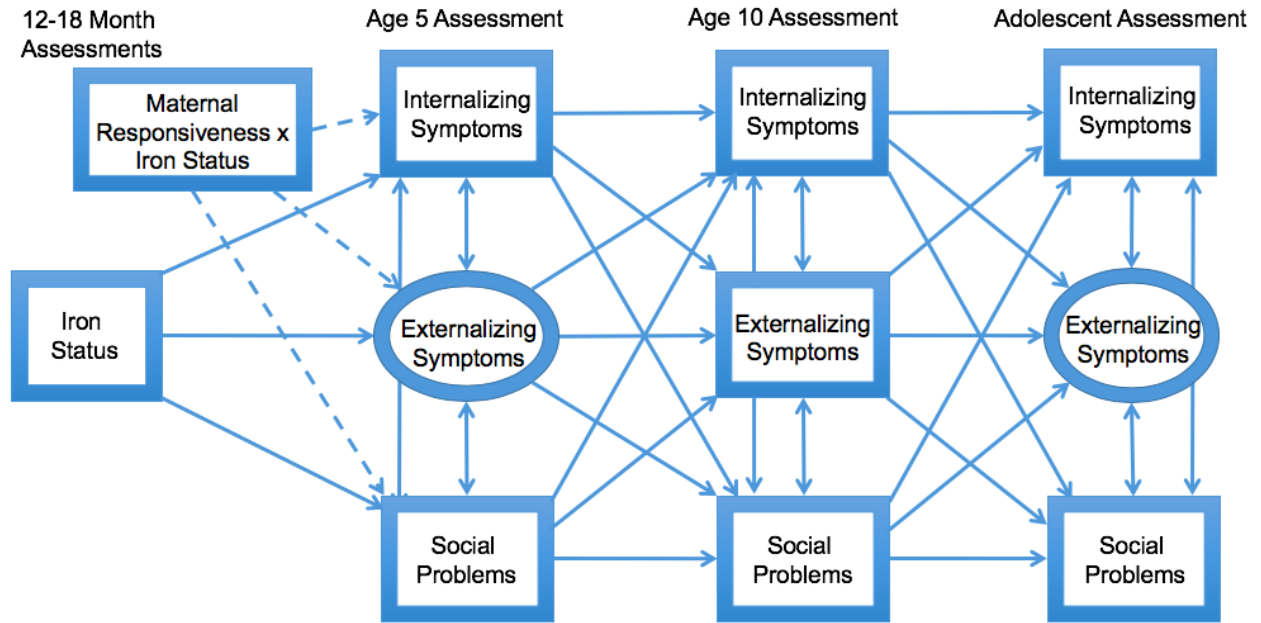


Figure S3. Hypothesized model of effects stemming from poorer iron status in infancy to subsequent internalizing, externalizing, and social problems, including the interaction between iron status in infancy and maternal responsiveness at infancy and 5y (tested in separate models: Models 2 and 3). All paths shown were included in tests of the model, as well as the direct paths from at 12- to 18-month iron status to 10-year and adolescent outcomes.

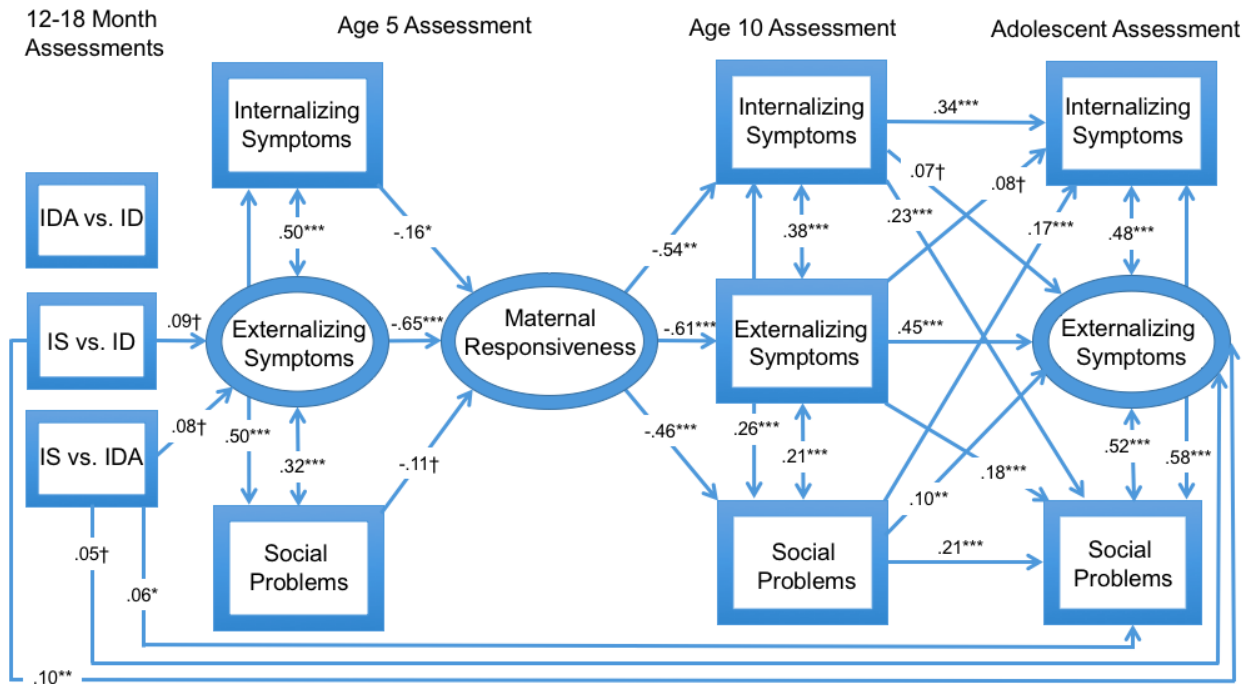


Figure S4. Model 4a results (comparing the 3 iron status groups: iron deficiency anemia, iron deficiency without anemia, and iron sufficiency) showing standardized estimates (β). The standardized estimates indicate the amount of change in Y per standard deviation unit of X. † $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$. Only paths with a significance level of $p < 0.10$ are shown (see Table S5).

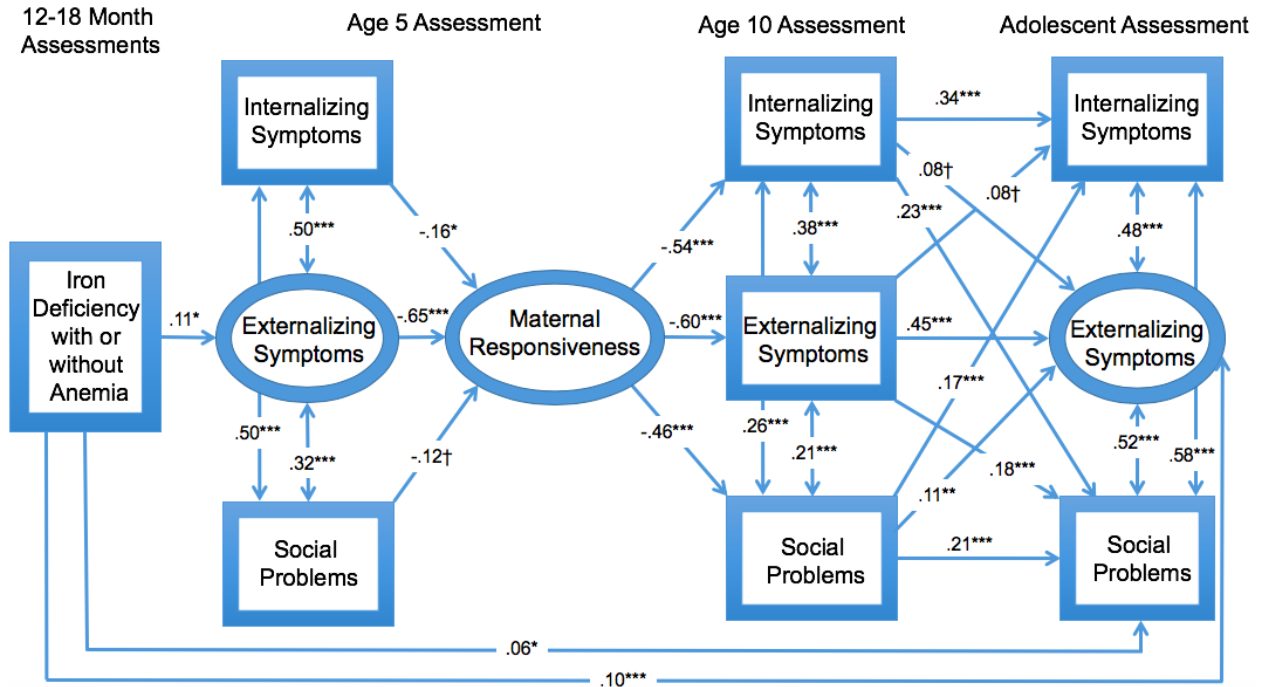


Figure S5. Model 4b results (iron deficiency with or without anemia vs. iron sufficiency) showing standardized estimates (β). The standardized estimates indicate the amount of change in Y per standard deviation unit of X. † $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$. Only paths with a significance level of $p < 0.10$ are shown (see Table S6).

References

Muthén, B. (2011). Applications of causally defined direct and indirect effects in mediation analysis using SEM in Mplus. *Technical report*. www.statmodel.com, 1-110.