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Effects of Nurse Home-Visiting on Maternal Life Course and Child Development: Age 6 Follow-Up Results of a Randomized Trial

David L. Olds, PhD*; Harriet Kitzman, RN, PhD‡; Robert Cole, PhD‡; JoAnn Robinson, PhD§; Kimberly Sidora, MPH‡; Dennis W. Luckey, PhD‖; Charles R. Henderson, Jr¶; Carole Hanks, RN, DrPH#; Jessica Bondy, MS‖; and John Holmberg, PsyD*

ABSTRACT. *Objective.* **To test, with an urban, primarily black sample, the effects of prenatal and infancy home visits by nurses on mothers' fertility and economic self-sufficiency and the academic and behavioral adjustment of their children as the children finished kindergarten, near their sixth birthday.**

Methods. **We conducted a randomized, controlled trial of a program of prenatal and infancy home-visiting in a public system of obstetric and pediatric care in Memphis, Tennessee. A total of 743 primarily black women at <29 weeks of gestation, with no previous live births and with ≥2 sociodemographic risk characteristics (unmarried, <12 years of education, or unemployed), were randomly assigned to receive nurse home visits or comparison services. Outcomes consisted of women's number and timing of subsequent pregnancies, months of employment, use of welfare, food stamps, and Medicaid, educational achievement, behavioral problems attributable to the use of substances, rates of marriage and cohabitation, and duration of relationships with partners and their children's behavior problems, responses to story stems, intellectual functioning, receptive language, and academic achievement.**

Results. **In contrast to counterparts assigned to the comparison group, women visited by nurses had fewer subsequent pregnancies and births (1.16 vs 1.38 pregnancies and 1.08 vs 1.28 births, respectively), longer intervals between births of the first and second children (34.28 vs 30.23 months), longer relationships with current partners (54.36 vs 45.00 months), and, since the previous follow-up evaluation at 4.5 years, fewer months of using welfare (7.21 vs 8.96 months) and food stamps (9.67 vs 11.50 months). Nurse-visited children were more likely to have been enrolled in formal out-of-home care between 2 and 4.5 years of age (82.0% vs 74.9%). Children visited by nurses demonstrated higher intellectual functioning and receptive vocabulary scores (scores of 92.34 vs 90.24 and 84.32 vs 82.13, respectively) and fewer behavior problems in the borderline or clinical range (1.8% vs 5.4%). Nurse-visited children born to mothers with low levels of psychologic resources had higher arithmetic achievement test scores (score of 88.61 vs 85.42) and expressed less aggression (score of 98.58 vs 101.10) and incoherence (score of 20.90 vs 29.84) in response to story stems. There were no statistically significant program effects on women's education, duration of employment, rates of marriage, being in a partnered relationship, living with the father of the child, or domestic violence, current partner's educational level, or behavioral problems attributable to the use of alcohol or drugs.**

Conclusion. **This program of prenatal and infancy home-visiting by nurses continued to improve the lives of women and children at child age 6 years, 4 years after the program ended.** *Pediatrics* **2004;114:1550–1559;** ***nurse, home visits, pregnancy, welfare, child development.***

ABBREVIATIONS. MSSB, McArthur Story Stem Battery; KABC, Kaufman Assessment Battery for Children; PPVT-III, Peabody Picture Vocabulary Test; CBCL, Child Behavior Checklist.

For decades, federal, state, and local governments have attempted to reduce the rates of welfare dependence, child abuse and neglect, and crime with a variety of preventive interventions. With the passage of the federal welfare reform law in 1996, which imposed significant time limits on the use of welfare,[1] it has become especially important for states to identify strategies that enable them to improve family economic self-sufficiency and simultaneously to promote child health and development. Women who leave welfare but fail to find jobs in which their income and benefits increase have children who are more likely to suffer academically and behaviorally.[2] A program of prenatal and infancy home-visiting by nurses that was tested with a primarily white sample in semirural Elmira, New York, demonstrated promise as a means of improving families' economic self-sufficiency and reducing child abuse and neglect, children's arrests, and children's emerging use of alcohol.[3–8]

A replication of the Elmira trial with a primarily unmarried, low-income sample of black subjects in Memphis produced effects consistent with earlier findings. Many beneficial effects of the Elmira program on qualities of parental caregiving, childhood injuries, and maternal life course were replicated while the Memphis program was in operation (from pregnancy through the first 2 years after the birth),[9] with effects on maternal life course during a 2.5-year period after the end of the program (child age: 24-54 months).[10] The next major questions are whether the

From the Departments of *Pediatrics, §Psychiatry, and ‖Preventive Medicine and Biometrics, University of Colorado, Denver, Colorado; ‡University of Rochester School of Nursing, Rochester, New York; ¶Department of Human Development, Cornell University, Ithaca, New York; and #Baylor University School of Nursing, Waco, Texas.

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Reprint requests to (D.L.O.) University of Colorado Health Sciences Center, 1825 Marion St, Suite 200, Denver, CO 80218. E-mail: olds.david@tchden.org

effects of the Memphis program on maternal life course endure and whether children exhibit reduced risks of antisocial behavior and improved school readiness at age 6, which is the focus of the current report.

In addition to examining conventional aspects of maternal life course (eg, fertility, education, work, and relationships with partners) and child development (cognition, language, and academic achievement), we examined whether the program produced lasting effects on indicators of children's emerging antisocial behavior, as reflected in parent and teacher reports of maladaptive behavior and in children's narrative responses to story stems (incomplete stories that children are asked to finish). Children's responses to story stems can be coded to indicate the degree to which their internalized models of conflict resolution reflect poorly regulated strategies, such as dysregulated aggression, or well-regulated strategies, such as expressions of empathy and affiliation, in meeting challenges.[11,12] These features of children's narrative responses, as well as story incoherence, have been associated with child problem behaviors[13,14] and child maltreatment,[15] and linked theoretically with the development of antisocial behavior.[16]

We hypothesized that the program would produce enduring effects, consistent with those observed in the Elmira trial, on the rates and timing of subsequent pregnancy, maternal participation in the workforce, use of welfare, and paternal involvement in the family. We found no statistically significant effects of the program in Elmira on children's cognitive and language development and parents' reports of behavior problems at child age 4 for the sample as a whole,[6] and we did not examine children's narrative responses to story stems or conduct assessments of children or families at age 6 in that study. However, given program effects on children's injuries and behavior in the first 2 years of life in the Memphis trial,[9] we expected to observe program effects on child outcomes during the current phase of follow-up assessment. We predicted that program benefits for children would be concentrated on those born to mothers with low levels of psychologic resources (limited intellectual functioning, mental health, and sense of control over their life circumstances), because the program effects on childhood injuries and behavior at younger ages in the Memphis and Elmira trials were greater for that group.[3,9]

METHODS

We assessed the children and their mothers in the study offices near the child's sixth birthday (mean age: 77.0 months; SD: 3.8 months). We also obtained teachers' (primarily first grade) reports of children's classroom behavior. The details of the study design and its implementation were reported previously[9,10] and are summarized here. Table 1 provides the numbers of eligible patients invited to participate, randomized, and evaluated at each follow-up assessment. As Table 1 indicates, among the randomized cases in which there was no fetal or child death, follow-up assessments were completed for 91% of the mothers and 88% of the children in the current phase of follow-up monitoring.

Participants

Between June 1990 and August 1991, we invited 1290 patients who met study inclusion criteria and were examined consecutively at the obstetric clinic of the Regional Medical Center in Memphis, Tennessee, to participate. We actively recruited women who were of low income and unmarried, because this group was found to benefit the most in the Elmira trial. Women at <29 weeks of gestation were recruited if they had no previous live births, no specific chronic illnesses thought to contribute to fetal growth retardation or preterm delivery, and at least 2 of the following sociodemographic risk conditions: unmarried, <12 years of education, or unemployed. Eighty-eight percent of the 1290 eligible women (1139 women) completed informed consent forms and were randomized to 1 of 4 treatment conditions described below. Ninety-two percent of the women enrolled were black, 98% were unmarried, 64% were ≤18 years of age at registration, and 85% came from households with incomes at or below the federal poverty level.

Statistical Power and Assignment Ratios

Sample sizes were established when the trial was first designed, on the basis of power calculations conducted for pregnancy and

TABLE 1. Sample Composition With Time, According to Treatment

	Treatment Group				Total
	1	2	3	4	
No. of eligible patients invited to participate					1290
No. of refusals					151
No. of randomized					1139
No. allocated to treatment	166	515	230	228	1139
No. of postrandomization drops*	1	4	4	4	13
Average no. of completed prenatal home visits (range, SD)			7 (0–18, 4.0)	7 (0–18, 4.0)	14
Average no. of completed postnatal home visits (range, SD)				26 (0–71, 14.7)	26
No. of miscarriages	6	19	6	8	39
No. of stillbirths	0	5	3	2	10
No. of infant/child deaths	2	7	2	1	12
No. available for follow-up	NA	480	NA	213	693
No. of 6-y maternal interviews completed	NA	444	NA	197	641
No. of 6-y child assessments completed	NA	425	NA	190	615

Unless otherwise specified, the difference between the numbers of cases randomized and assessed is attributable to missed assessments. NA indicates not applicable.

* Eleven of the 13 women who dropped out involved cases in which the mother refused participation after randomization. One case (assigned to treatment 2) was dropped from the study when it was learned that the woman was registered and randomized a second time after an earlier registration and miscarriage; a second case (assigned to treatment 1) was not monitored because of a clerical error after a staff member identified the woman as not meeting the inclusion criteria.

infancy outcomes. For all power calculations, we set $\alpha = .05$ and $\beta = .20$ and specified 2-tailed tests. We chose to enroll fewer women in the postnatal phase of this trial than in the prenatal phase because treatment effects (in SD units) were larger for postnatal outcomes than for prenatal outcomes in the Elmira trial. These calculations also indicated that, with very little loss of statistical power for normally distributed dependent variables, we could assign half as many women to the relatively expensive nurse visitation intervention as to the comparison condition. These calculations led to a total target sample of 750 for the postnatal phase of the study, with the assumption of 20% attrition, and 743 subjects were enrolled. The differences in prenatal and postnatal sample sizes and in proportions assigned to nurse and comparison conditions were accomplished by assigning participants disproportionately to 4 treatment conditions, as outlined below.

Given the sample enrolled and retained at the 6-year follow-up assessment and assuming that, for normally distributed variables, 10% of the variance is accounted for by other terms in the model, we estimated the smallest detectable treatment main effects for key postnatal outcomes as follows: mean decrease in the rate of subsequent pregnancy from 1.38 to 1.16 pregnancies (SD: 0.95), mean decrease in the number of months of welfare use from 8.96 months to 7.92 months for the 4.5- to 6-year period (SD: 7.92 months), and increase in the marriage rate from 15% to 24% married. Details of the design and assignment ratios are presented elsewhere.[9]

Randomization

After completion of baseline interviews, identifying information on the participants was sent to the University of Rochester, where it was entered into a computer program that randomized individual women to 4 treatment conditions, with methods that are extensions of those described by Soares and Wu.[17] This procedure concealed the randomization from individuals directly involved with the participants in Memphis. The randomization was conducted within strata from a model with 5 classification factors, ie, maternal race (black versus nonblack), maternal age (<17 years, 17–18 years, or ≥19 years), gestational age at enrollment (<20 vs ≥20 weeks), employment status of head of household (employed versus unemployed), and geographic region of residence (4 regions). Women randomized to the home-visitation groups were assigned randomly to a nurse home visitor.

Treatment Conditions

Women in treatment 1 ($n = 166$) were provided with free, round-trip, taxicab transportation for scheduled prenatal care appointments; they did not receive any postpartum services or assessments. Women in treatment 2 ($n = 515$) were provided with the free transportation for scheduled prenatal care appointments plus developmental screening and referral services for the child at 6, 12, and 24 months of age. Women in treatment 3 ($n = 230$) were provided with the same services as in treatment 1 plus intensive nurse home-visiting services during pregnancy, 1 postpartum visit in the hospital before discharge, and 1 postpartum visit in the home. Women in treatment 4 ($n = 228$) were provided with the same services as in treatment 3; in addition, they continued to be visited by nurses through the child's second birthday. For evaluation of postnatal outcomes, treatment 2 was compared with treatment 4. Only these 2 groups were assessed after delivery of the child, to limit the cost of the study.

Program Plan and Implementation

The experimental home-visiting program was conducted by the Memphis/Shelby County Health Department. The nurses completed a mean of 7 home visits (range: 0–18 visits) during pregnancy and 26 home visits (range: 0–71 visits) during the first 2 years after the birth. They followed detailed visit-by-visit guidelines in their efforts (1) to improve the outcomes of pregnancy by promoting women's healthy prenatal behaviors, (2) to improve the health and development of children by promoting parents' competent care of their children, and (3) to enhance parents' life-course development by encouraging parents to plan subsequent pregnancies, complete their education, and find work. The nurses helped families make use of needed health and human services and attempted to involve other family members and friends (particularly the children's fathers and grandmothers) in the pregnancy, birth, and early care of the child. Program protocols were grounded in epidemiologic findings and theories of human ecology, human attachment, and self-efficacy.[18,19] Details of the program design and implementation are reported elsewhere.[9,10]

Masking

Interviews and assessments of the children were conducted by staff members who were masked with respect to the women's and children's treatment assignments. Although the principal investigators and statisticians had access to subjects' treatment assignments, all decisions about coding of interview responses and construction of variables were made explicitly without this information.

Assessments and Definitions of Variables

Assessments for the current phase of follow-up monitoring were conducted after children had completed at least 7 months of kindergarten (through March). Teacher reports and school data were derived primarily from the children's first grade teachers ($n = 486$), although a small number of reports came from kindergarten ($n = 33$), second grade ($N = 42$), and special education ($n = 3$) teachers. Previous interviews with participating women were conducted at registration (before their assignment to treatments), at the 36th week of pregnancy, and at the 6th, 12th, 24th, and 54th months of the child's life. Interview and child-testing data for the current report were derived primarily from the intake and 6-year assessments.

Baseline Assessments

Baseline assessments were described in previous reports.[9,10] A variable was created to index women's psychologic resources measured at registration. The variable was based on the mean z scores for the women's intelligence,[20] mental health,[21] and sense of mastery[22] plus self-efficacy (women's confidence in their ability to behave in accordance with the major behavioral objectives of the program).[19] The psychologic resource variable was standardized to a mean of 100 and SD of 10 and then dichotomized at values of ≤100 vs >100.

Maternal Life Course

Women were interviewed near the child's sixth birthday, for assessment of the number and timing of subsequent pregnancies and births, the use of substances, behavioral problems attributable to the use of substances (such as traffic violations, poor performance at work, or compromised care of the child), educational achievements, number of months worked, occupational status of the job,[23] and the number of months enrolled in welfare, food stamps, and Medicaid. To reduce error in recall, we limited the time frame for which the women needed to recall their employment and welfare, food stamp, and Medicaid use to the period since their firstborn child was 54 months of age (the last interview date). We assessed fertility outcomes for the entire 6-year period, because recall regarding pregnancies and births is not as susceptible to error. The 6-year interviews also assessed rates of marriage and cohabitation, duration of women's current partnered relationships, current partner's education, employment, and social class (based on their occupational codes),[23] domestic violence since the birth of the first child, and whether the current male partner was the biological father of the child. At the interview conducted at 54 months after the birth, we assessed whether children attended Head Start, preschool programs, licensed day care, or early intervention programs; we created a dichotomous variable indicating whether children attended any of these programs in the preschool period.

Child Assessments

The children's mothers completed the Achenbach Child Behavior Checklist (CBCL).[24] Maternal reports of child behavior problems were classified according to whether children were in the borderline/clinical range of the following types of behavior problems: internalizing (anxious/depressed, withdrawn/depressed, or somatic complaints), externalizing (rule-breaking and aggressive behavior), and total problems (internalizing problems, exter-

nalizing problems, social problems, thought problems, attention problems, or other maladaptive behaviors). Scores that exceed the borderline or clinical cutoff values are indications that the children's behavior is maladjusted.[24]

Children's first grade teachers completed the Hightower Teacher-Child Rating Scale.[25] Teachers' reports of children's classroom behavior were summarized into 2 scales derived from principal-components analysis, 1 that reflected the degree to which children were engaged with school (Cronbach's $\alpha = .96$), and 1 that reflected their classroom socioemotional adjustment (Cronbach's $\alpha = .92$).

Children's responses to 8 story beginnings (stems) from the McArthur Story Stem Battery (MSSB)[26] were videotaped and coded for a series of content themes, observable affective expressions, and coherence in completing the stories.[27] The coding scheme and constructs were adapted explicitly for low-income black children with a combination of theory, prior research, and factor analysis to characterize children's representations of dysregulated aggressive behavior and parental warmth/empathy themes in their stories and whether each story completion was incoherent.[11] Codes were averaged for all stories, and components were standardized before aggregation. The development of specific constructs through aggregation of codes from the MSSB has varied among investigations.[12]

The dysregulated aggression index was created through aggregation of the following observational codes: aggression, personal injury, dishonesty, danger, destruction, inappropriate child power, and negative parenting representations in the narrative responses. Because aggression is the central construct in this measure, it was weighted 1.0, with all other factors being weighted 0.5 (Cronbach's $\alpha = .67$, interobserver Pearson correlation coefficient = 0.83). This variable was standardized to a mean of 100 and an SD of 10.

The warmth/empathy variable was derived through aggregation of codes for representations of parents as warm or supportive, as well as empathy, affiliation, affection, and expressions of reparation and guilt among story characters. In this construct, parental warmth is the central variable and was weighted 1.0, with the other factors being weighted 0.5 (Cronbach's $\alpha = .68$, interobserver Pearson correlation coefficient = 0.68). Like dysregulated aggression, the warmth/empathy variable was standardized to a mean of 100 and an SD of 10.

Each of the 8 narrative responses was evaluated to determine whether it was incoherent, ie, whether the narrative had an illogical sequence of events or incoherent emotional shifts. The incoherence variable consisted of the percentage of stories that were incoherent (interobserver Pearson correlation coefficient = 0.76).

Although it was not explicitly hypothesized before the beginning of this research, we became particularly interested in children's ability to maintain story coherence in the presence of strongly expressed affect, ie, the degree to which children lose coherence and become dysregulated as emotional expressions increase. Each story was coded to indicate the degree to which joy, fear, anger, concern, and sadness were expressed; those scores were aggregated to create an index that reflected the degree of emotional expression (Cronbach's $\alpha = .49$, interobserver Pearson correlation coefficient = 0.68). Story coherence was then examined in the context of emotional expression.

The variables created in these ways have both construct and predictive validity; they are uniquely related to children's achievement and behavior, as revealed in their school records for grades 1 through 3, after controlling for children's intellectual functioning, and parent and teacher reports of behavior problems at age 6 years. Others working with the MSSB have reported similar findings.[26–30] Children's cognitive and language skills were assessed with the Kaufman Assessment Battery for Children (KABC)[31] and the Peabody Picture Vocabulary Test (PPVT-III).[32]

Statistical Models and Methods of Analysis

Data analyses were conducted and reported for all cases randomized, insofar as outcome data were available. The primary statistical model consisted of a 2-level treatment factor (treatment 2 vs treatment 4) and 3 covariates (household income, housing density, and maternal childrearing attitudes associated with child maltreatment), to adjust for nonequivalence ($P < .10$) among treatment groups assessed at the current follow-up evaluation. Separate analyses of child outcomes were conducted for the sample defined by the mothers' having low levels of psychologic resources. The model for child outcomes considered the gender of the child as a classification factor with and without interactions, but gender was not included after it was determined that the gender of the child did not interact with treatments and that adjustment of estimates for gender had little effect on estimates or conclusions.

All dependent variables were examined with respect to their distributional characteristics. Continuous dependent variables that did not violate the normality assumption were analyzed with the general linear model; dichotomous outcomes, such as rates of cohabitation, were analyzed with the logistic-linear model (with the assumption of binomial distribution). For dichotomous correlated outcomes, such as counts of subsequent low birth weight newborns, we used generalized estimating equations[33,34] with a logit link function and assumption of an exchangeable (compound symmetry) correlation structure. The timing of the first subsequent birth was examined with proportional-hazards analysis[35] with the primary model specified above, after confirmation that the proportionality assumption was satisfied.

Estimates and tests were adjusted for all covariates. Homogeneity of regressions was tested for all covariates.[36] Regressions of children's story coherence on their level of emotional expression were tested for homogeneity by treatments, with adjustment for the standard 3 covariates. Tables that present child outcomes show treatment main effects and effects for the group defined by mothers' having low levels of psychologic resources.

RESULTS

Baseline Equivalence of Treatment Groups

As shown in Table 2, the treatment groups were similar with respect to background characteristics for the participants for whom 6-year follow-up assessments were conducted, with the following exceptions: at intake, nurse-visited women (treatment 4) had higher scores for childrearing attitudes associated with child maltreatment and lived in households with less discretionary income and higher housing densities than did women in the comparison group (treatment 2). These differences suggest that the nurse-visited group had a greater proportion of at-risk families at child age 6 years, although the proportions of families for whom assessments were conducted were large and nearly equivalent across treatment conditions, as shown in Table 1.

Maternal Life Course

As indicated in Table 3, nurse-visited women had fewer subsequent pregnancies and births than did women in the comparison group (1.16 vs 1.38 pregnancies, $P = .01$, and 1.08 vs 1.28 births, $P = .01$, respectively) and longer intervals between the births of the first and second children (34.28 vs 30.23 months, $P = .01$). Figure 1 plots the time until the birth of the first subsequent child for nurse-visited and comparison group women; the curves are different ($P = .01$). Nurse-visited women also had longer relationships with their current partners (54.36 vs 45.00 months, $P = .02$). Between children's 54th and 72nd months of life, nurse-visited women had fewer months of using welfare and food stamps (7.21 vs 8.96 months, $P = .01$, and 9.67 vs 11.50 months, $P = .004$, respectively). As shown in Table 3, nurse-visited children were more likely to have been enrolled in formal out-of-home care (Head Start, preschool, licensed day care, or early intervention) between 2 and 4.5 years of age (82.0% vs 74.9%, $P = .05$). There were no statistically significant program effects on

TABLE 2. Background Characteristics of Participants for Whom 6-Year Assessments Were Completed

Background Variable	Sample	Proportion, %	
		Comparison (N = 444)	Nurse-Visited (N = 197)
Married	Whole	1.6	1.0
	Low-resource	0.4	1.9
Maternal race, nonblack	Whole	6.1	8.6
	Low-resource	5.2	7.5
Head of household employed	Whole	56.4	50.0
	Low-resource	52.0	49.5
Drank Alcohol in past 14 d	Whole	4.3	4.6
	Low-resource	5.7	6.6
Smoked cigarettes in past 3 d	Whole	8.4	10.2
	Low-resource	8.7	11.3
Used marijuana in past 14 d	Whole	1.6	1.0
	Low-resource	1.7	1.9
Used cocaine in past 2 wk	Whole	0.2	0.0
	Low-resource	0.4	0.0
Any drug use (screen)	Whole	4.2	4.2
	Low-resource	7.4	5.8
Any sexually transmitted disease, prerandomization*	Whole	33.4	37.6
	Low-resource	33.6	40.6

		Comparison		Nurse-Visited	
		Mean	SD	Mean	SD
Maternal age, y	Whole	18.03	3.19	18.08	3.21
	Low-resource	18.05	3.28	18.26	3.90
Gestational age at randomization, wk	Whole	16.58	5.78	16.60	5.68
	Low-resource	16.33	5.82	16.75	5.58
Psychologic resources index	Whole	100.03	10.07	99.56	10.72
	Low-resource	92.23	5.80	91.69	6.81
Highest grade completed, mother	Whole	10.24	1.87	10.14	2.03
	Low-resource	9.87	1.88	9.66	2.10
Discretionary household income, $†	Whole	1658.00	6976	−127.60	6650
	Low-resource	−135.10	6443	−1098.00	6471
% of census tract below poverty	Whole	34.78	21.37	35.93	20.09
	Low-resource	36.80	21.05	35.99	21.29
Housing density	Whole	0.94	0.50	1.03	0.57
	Low-resource	1.04	0.54	1.13	0.52
Conflict with mother‡§	Whole	99.79	10.35	100.47	9.16
	Low-resource	101.89	12.66	101.38	10.14
Conflict with partner‡§	Whole	99.75	10.14	100.56	9.68
	Low-resource	101.07	11.43	102.31	11.42
Attitudes toward childrearing predictive of child abuse	Whole	99.43	9.62	101.28	10.72
	Low-resource	102.56	9.02	104.71	9.44

* Diagnosis of either *Chlamydia trachomatis*, *Trichomonas vaginalis*, or *Neisseria gonorrhoeae* in current pregnancy prior to randomization.
† Annual household discretionary income based on income subsistence standards for Medicaid eligibility, reported household income, and number of individuals in household at registration. The low value in treatment group 4 is accurate.
‡ Standardized so that mean (SD) value of 100 (10).
§ A scale was developed for this study that assessed the degree to which an individual provided emotional and material support to the mother.

women's mastery, mental health, education, employment, marriage, being in a partnered relationship, living with the father of the child, outcomes of subsequent pregnancies, current partner's education or socioeconomic status, use of marijuana, behavioral problems attributable to the use of alcohol or drugs, or domestic violence.

Child Outcomes

Table 4 shows that nurse-visited children had higher scores on tests of intellectual functioning and receptive language (92.34 vs 90.24, $P = .03$, and 84.32 vs 82.13, $P = .04$, respectively) and were reported by their mothers to have fewer problems in the borderline or clinical range of the CBCL Total Problems scale (1.8% vs 5.4%, $P = .04$). Nurse-visited children born to mothers with low psychologic resources had higher arithmetic achievement test scores (88.61 vs 85.42, $P = .04$) and, in their responses to story stems, expressed less dysregulated aggression (98.58 vs 101.10, $P = .04$) and told fewer incoherent stories (20.90 vs 29.84, $P = .006$).

Figure 2 shows the fitted regressions of the percentage of coherent stories children told on their degree of emotional expression, fitted separately for nurse-visited and control group children. For both the entire sample and children born to mothers with low psychologic resources, the regressions were significantly different by treatment ($P = .048$ and $P = .041$, respectively). Children's story coherence disintegrated in the presence of high levels of emotional expression to a greater degree in the control group, compared with children visited by nurses. There were no statistically significant program effects on parents' reports of their children's internalizing or externalizing behavior problems, on children's rep-

TABLE 3. Adjusted Estimate of Program Effects on Maternal Life Course

	Comparison		Nurse-Visited		Comparison vs Nurse	
	LS Mean	SE	LS Mean	SE	*P* Value	Effect Size
No. of subsequent pregnancies (birth to 72 mo)	1.38	0.05	1.16	0.07	.01	−0.22
No. of subsequent children (birth to 72 mo)	1.28	0.04	1.08	0.07	.01	−0.22
Months between births of 1st and 2nd children	30.23	0.85	34.38	1.33	.01	0.26
Mastery*[22]	99.79	0.46	100.46	0.70	.43	0.07
Mental health*[21]	99.92	0.48	100.18	0.71	.76	0.03
Months mother employed (54–72 mo)	9.99	0.31	9.96	0.47	.97	−0.003
SES of current job (mother)†	13.06	0.90	14.01	1.35	.56	0.05
Months of AFDC (54–72 mo)	8.96	0.36	7.21	0.54	.01	−0.22
Months of food stamps (54–72 mo)	11.50	0.35	9.67	0.53	.004	−0.24
Months of Medicaid (54–72 mo)	13.08	0.34	11.98	0.52	.08	−0.15
Months with current partner	45.00	2.17	54.36	3.23	.02	0.24
Highest grade current partner completed	12.05	0.08	12.16	0.12	.45	0.07
SES of partner's current job†	31.63	1.15	30.83	1.71	.70	−0.04
	Proportion, %		Proportion, %		*P* Value	Odds Ratio
Mother graduated from high school/earned GED diploma	65.9		68.5		.54	1.12
Married	15.0		11.9		.18	1.36
Has current partner	76.7		78.4		.64	1.10
Lives with father of study child	10.0		12.0		.45	1.23
Subsequent miscarriage‡	5.2		3.4		.50	0.75
Subsequent abortion‡	5.0		3.5		.42	0.70
Subsequent low birth weight newborn§	15.7		11.4		.16	0.69
Subsequent NICU/special care admission§	22.7		17.5		.14	0.72
Currently using marijuana	3.4		4.6		.47	1.37
Moderate/heavy drinker (≥3 drinks ≥3 times/mo)	2.6		5.2		.11	2.03
Behavioral problems attributable to substance use	4.1		3.9		.88	0.94
Any domestic violence, birth to age 6 y	39.5		38.8		.87	0.97
Child attended Head Start, preschool, day care, or early intervention, age 24–54 mo	74.9		82.0		.05	1.53

AFDC indicates Aid to Families With Dependent Children; GED, General Educational Development; NICU, neonatal intensive care unit; LS, least-squares.
* Standardized to mean = 100, SD = 10.
† Socioeconomic status (SES) derived from percentile rankings of US Bureau of Census occupation codes, based on median income and median education associated with occupations.[23]
‡ Rate per subsequent pregnancy.
§ Rate per subsequent birth.

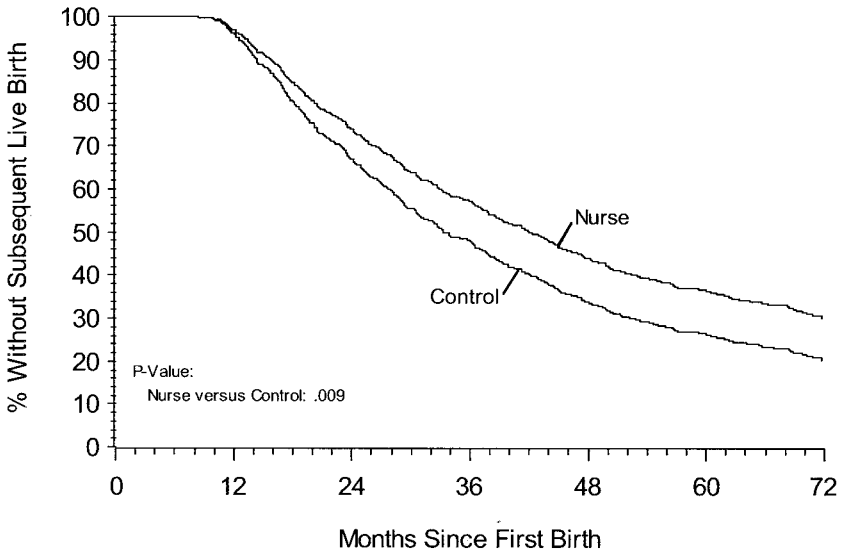

Fig 1. Proportional-hazards model for time until first subsequent live birth.

resentations of empathy in their story stem responses, on children's reading achievement, or on teachers' reports of child behavior.

DISCUSSION

Four years after the end of the program at child age 2 years, it continued to produce effects in the lives of urban black women and their children. Nurse-visited women had fewer subsequent pregnancies and births, less use of welfare, longer relationships with their partners, and greater enrollment of their children in some form of preschool or licensed day care. Nurse-visited children demonstrated higher IQs and language scores and fewer

TABLE 4. Adjusted Estimate of Program Effects on Child Development Outcomes

	Sample	Comparison		Nurse-Visited		Comparison vs. Nurse	
		LS Mean	SE	LS Mean	SE	*P* Value	Effect Size
Academically engaged (teacher report)*	Whole	6.86	1.08	6.16	1.63	.72	−0.03
	Low-resource	4.23	1.54	4.74	2.33	.86	0.02
Classroom social skills (teacher report)*	Whole	24.53	0.59	24.93	0.89	.71	0.03
	Low-resource	22.92	0.82	24.54	1.23	.27	0.14
Dysregulated aggression (story stems)†‡	Whole	100.26	0.49	99.24	0.74	.26	−0.10
	Low-resource	101.10	0.67	98.58	1.00	.04	−0.25
Warmth/empathy (story stems)†‡	Whole	99.51	0.49	100.86	0.73	.13	0.14
	Low-resource	98.98	0.66	100.30	0.99	.27	0.13
% incoherent stories (story stems)†	Whole	25.22	1.23	21.15	1.84	.07	−0.16
	Low-resource	29.84	1.78	20.90	2.68	.006	−0.34
Mental processing composite (KABC)	Whole	90.24	0.54	92.34	0.82	.03	0.18
	Low-resource	87.64	0.72	90.49	1.10	.03	0.25
Arithmetic achievement (KABC)	Whole	88.61	0.62	89.75	0.92	.30	0.09
	Low-resource	85.42	0.84	88.61	1.27	.04	0.25
Reading achievement (KABC)	Whole	93.56	0.62	93.79	0.93	.84	0.02
	Low-resource	90.87	0.86	92.07	1.29	.44	0.09
Receptive vocabulary (PPVT-III)	Whole	82.13	0.59	84.32	0.89	.04	0.17
	Low-resource	79.08	0.81	81.75	1.22	.07	0.21
		Proportion, %		Proportion, %		*P* Value	Odds Ratio
Internalizing problems (borderline/clinical)§	Whole	14.7		12.6		.50	0.84
	Low-resource	16.5		20.4		.40	1.30
Externalizing problems (borderline/clinical)§	Whole	20.2		17.4		.43	0.83
	Low-resource	24.2		21.7		.63	0.87
Total problems (borderline/clinical)§	Whole	5.4		1.8		.04	0.32
	Low-resource	6.6		3.7		.31	0.55

LS indicates least-squares.
* Derived from factor analysis of Hightower Teacher-Child Rating Scale.
† Derived from children's narrative responses to McArthur Story Stem Battery.
‡ Standardized to mean = 100, SD = 10.
§ Based upon Achenbach Child Behavioral Problems Checklist.

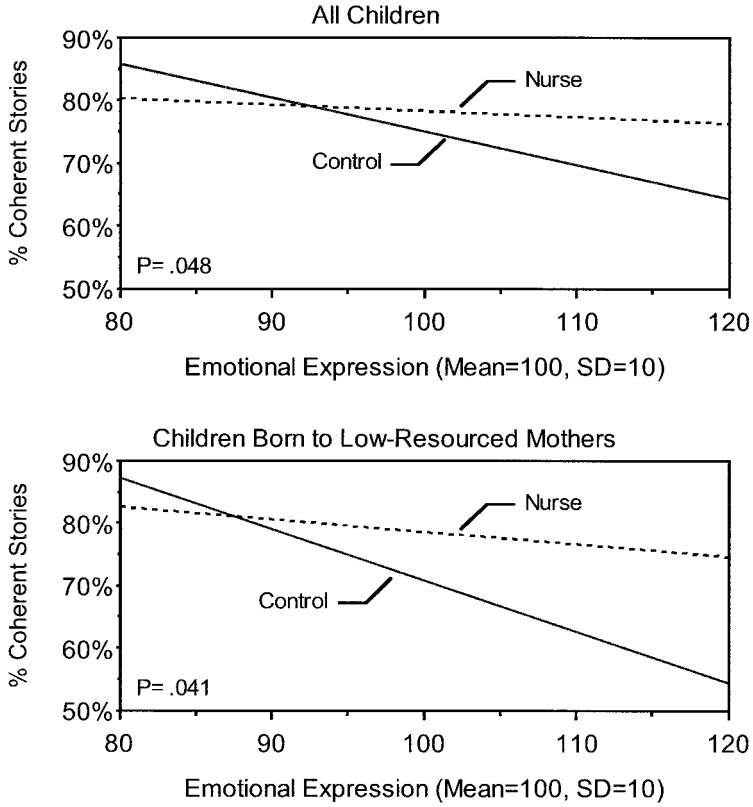

Fig 2. Fitted regressions of percentage of coherent stories on emotional expression (with mean = 100 and SD = 10), specified separately for control and nurse-visited children, for all children and those born to low-resource mothers.

behavioral problems in the borderline or clinical range. Moreover, nurse-visited children born to mothers with low psychologic resources revealed less dysregulated aggression and story incoherence in their narrative responses to the story stems. Children in the control group had more difficulty main-

taining story coherence in the presence of high levels of emotional expression than did nurse-visited children. These results support the conclusion that this program can improve maternal life course and aspects of children's functioning that may increase their academic and behavioral adjustment to elementary school.

With 3 trials of this program having been conducted with different populations, in different contexts and at different points in our nation's history, we are in a position to examine the extent to which the program produces comparable effects across context and time. Its effects on rates and timing of subsequent pregnancies and births among subjects in Memphis are consistent with those observed among white subjects in Elmira, New York,[4,7,37] and among a more ethnically diverse sample in Denver at child age 4 years,[38] giving us confidence in the reliability and generalizability of these findings. Although the effect of the program on the use of welfare in Memphis is consistent with findings from the Elmira trial, both of these interventions were completed before welfare reform, which may account for the absence of a corresponding effect in Denver.

The effects of the program on children's intellectual and language functioning, although relatively small (ie, 0.17–0.25 SD, depending on measure and whether the effect was estimated for the whole sample or children born to low-resource mothers), were similar in Memphis (child age 6 years) and Denver (child age 4 years), although the effect in Denver was limited to children with low-resource mothers.[38] The Elmira effect at child age 4 years was not statistically significant, probably because of limited power, but was of similar magnitude (0.19 SD points on the Stanford-Binet IQ test).[6]

The impact of the program on the duration of partner relationships also is consistent with effects observed in Elmira at child age 4 years[37] and with increases in the rates of marriage among women in Elmira who had been unmarried at registration.[39] No corresponding effects were observed in Denver at child age 4 years, although nurse-visited women in Denver reported lower rates of domestic violence in the 6-month period before the 4-year interview.[38] The absence of a corresponding effect on domestic violence in Memphis might be related to the longer period (6 years) for which women in Memphis were asked to report on violent behaviors by their partners.

It is reasonable to ask whether the nurse-visited children's higher rate of enrollment in preschool, Head Start, and licensed day care accounted for their superior functioning. Although there is some evidence that children in the control group who attended these programs demonstrated superior socioemotional adjustment in elementary school and better cognitive functioning, compared with their counterparts who did not (data not shown), parents who sent their children to such programs were also at lower risk for poor outcomes than were those who did not. Moreover, the relatively small difference in the rates of attendance (82% vs 75%) is not likely, by itself, to account for the program effects on child functioning observed here. The nurse visitation program thus produced improvements in children's functioning despite high levels of participation in preschool programs among both the control and nurse-visited groups. In addition, it is important to note that nurse-visited children born to low-resource mothers in the Denver trial had better language and executive functioning at age 4 years than did their control group counterparts, despite lower rates of enrollment in Head Start, preschool, and day care.[38]

How does this program compare in its impact with center-based preschool programs? Some model center-based programs for preschoolers examined in randomized trials >30 years ago produced large effects on children's cognitive performance at school entry (typically ranging in effect size from 0.5 to 0.75 SD units),[40] but those small trials have not been replicated in the current social and economic environment, with larger representative samples of participants. Moreover, the effects of those programs on IQ and language gradually decreased, whereas the effects observed in this trial, although modest, have increased with time.

What might account for this program's growing impact on children's cognitive and language development? In interpreting the program's impact on children's development, it is important to note that the combination of compromised neurologic development attributable to poor prenatal health and harsh punitive parenting can be particularly damaging to children's cognitive and behavioral development[41,42] and this program affected these earlier risks.[9] Moreover, closely spaced subsequent pregnancies and lack of financial resources are associated with compromised child development.[43,44] We have hypothesized that the beneficial effects of the program on child outcomes are attributable to the combination of improved prenatal health, improved parental caregiving, and improved maternal life course.[18] Preliminary analyses suggest that parental caregiving (qualities of the home environment, maternal attitudes associated with child maltreatment, and injuries recorded in the children's medical records in the first 2 years of life) and maternal life course (interbirth intervals, duration of relationships with current partners, and use of welfare) are likely to play important roles in explaining the enduring effect of the Memphis program on children's cognitive functioning and behavioral adjustment (data not shown).

Despite these encouraging findings, the beneficial effects of the program on children's intellectual and language functioning emerged only after statistical control for biasing baseline conditions. Although results adjusted for covariates reflect the best estimates of the long-term program impact, program effects on IQ and language were significant only as trends ($P < .10$) until biasing baseline conditions were controlled.

Moreover, maternal outcomes and children's behavior problems were assessed with maternal reports. Although we have no administrative data with which to compare maternal reports of welfare use in the current study, in a recent report from this trial in which we had both self-report and administrative

data on the use of welfare and food stamps, analyses of program effects produced virtually identical results irrespective of whether maternal report or administrative data were used as outcomes.[10] Given the short 18-month period during which the women recalled employment and the use of welfare, the accuracy of recall is likely to be good. Although the program effects on child behavior problems also were based on maternal reports, its effects on children's representations of dysregulated aggression and incoherence were based on the children's narrative responses to story stems. It is unlikely that children's responses could be affected by their knowledge of their treatment assignments. The nurse-visited children's superior performance on tests of intellectual functioning and language is consistent with the parents' reports of child behavior.

It is important to note, however, that the reduction in total behavioral problems on the CBCL was not corroborated by teachers' reports of child behavior. The teacher report measure consists of continuous scores and does not have a clinical cutoff value, which may account for this failure of corroboration. Moreover, the continuous version of the CBCL, based on parent reports, did not produce statistically significant treatment differences. Although these inconsistencies raise questions about the clinical significance of the CBCL findings, it is reasonable to interpret these results as indicating that the program prevented only the most seriously dysregulated behavior, which might be assessed more reliably with the clinical and borderline cutoff values of the CBCL.

Finally, the use of the MSSB to assess children's internal models of conflict resolution is still in an experimental phase. However, each of the variables used in this study demonstrated construct and predictive validity with this sample. In general, the effects of the program observed through child age 6 years increase the likelihood that nurse-visited children will adjust more effectively as they proceed through elementary school than will children in the control group.

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STUDY FINDS CARBON MONOXIDE CAN TRIGGER BRAIN-DAMAGING ATTACK BY IMMUNE SYSTEM

"Carbon monoxide's reputation as a stealth toxin goes beyond its odorless, colorless properties. The gas can also surreptitiously cause delayed permanent brain damage, an effect that scientists have been unable to explain. But now they are no longer in the dark. A new study reveals that the damage arises from overactivation of immune cells that attack proteins that help insulate nerves. The findings were published in the September 1 online issue of the *Proceedings of the National Academy of Sciences USA* (www.pnas.org). . . . Stephen Thom, MD, PhD, of the University of Pennsylvania in Philadelphia, has been studying carbon monoxide's 2nd effect—permanent brain damage, which can become evident between 4 days and 3 weeks following exposure. Thom and colleagues have found that this effect occurs because carbon monoxide exposure modifies myelin basic protein, found in the insulating cells around neurons."

Hampton T. Navigating the body's water channels, scientists gain insights into disease. *JAMA*. 2004; 292:1537–1538

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Effects of Nurse Home-Visiting on Maternal Life Course and Child Development: Age 6 Follow-Up Results of a Randomized Trial

David L. Olds, Harriet Kitzman, Robert Cole, JoAnn Robinson, Kimberly Sidora, Dennis W. Luckey, Charles R. Henderson, Jr, Carole Hanks, Jessica Bondy and John Holmberg

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