Original Investigation

Associations of Housing Mobility Interventions for Children in High-Poverty Neighborhoods With Subsequent Mental Disorders During Adolescence

Ronald C. Kessler, PhD; Greg J. Duncan, PhD; Lisa A. Gennetian, PhD; Lawrence F. Katz, PhD; Jeffrey R. Kling, PhD; Nancy A. Sampson, BA; Lisa Sanbonmatsu, PhD; Alan M. Zaslavsky, PhD; Jens Ludwig, PhD

IMPORTANCE Youth in high-poverty neighborhoods have high rates of emotional problems. Understanding neighborhood influences on mental health is crucial for designing neighborhood-level interventions.

OBJECTIVE To perform an exploratory analysis of associations between housing mobility interventions for children in high-poverty neighborhoods and subsequent mental disorders during adolescence.

DESIGN, SETTING, AND PARTICIPANTS The Moving to Opportunity Demonstration from 1994 to 1998 randomized 4604 volunteer public housing families with 3689 children in high-poverty neighborhoods into 1 of 2 housing mobility intervention groups (a low-poverty voucher group vs a traditional voucher group) or a control group. The low-poverty voucher group (n=1430) received vouchers to move to low-poverty neighborhoods with enhanced mobility counseling. The traditional voucher group (n=1081) received geographically unrestricted vouchers. Controls (n=1178) received no intervention. Follow-up evaluation was performed 10 to 15 years later (June 2008-April 2010) with participants aged 13 to 19 years (0-8 years at randomization). Response rates were 86.9% to 92.9%.

MAIN OUTCOMES AND MEASURES Presence of mental disorders from the *Diagnostic and Statistical Manual of Mental Disorders* (Fourth Edition) within the past 12 months, including major depressive disorder, panic disorder, posttraumatic stress disorder (PTSD), oppositional-defiant disorder, intermittent explosive disorder, and conduct disorder, as assessed post hoc with a validated diagnostic interview.

RESULTS Of the 3689 adolescents randomized, 2872 were interviewed (1407 boys and 1465 girls). Compared with the control group, boys in the low-poverty voucher group had significantly increased rates of major depression (7.1% vs 3.5%; odds ratio (OR), 2.2 [95% CI, 1.2-3.9]), PTSD (6.2% vs 1.9%; OR, 3.4 [95% CI, 1.6-7.4]), and conduct disorder (6.4% vs 2.1%; OR, 3.1 [95% CI, 1.7-5.8]). Boys in the traditional voucher group had increased rates of PTSD compared with the control group (4.9% vs 1.9%, OR, 2.7 [95% CI, 1.2-5.8]). However, compared with the control group, girls in the traditional voucher group had decreased rates of major depression (6.5% vs 10.9%; OR, 0.6 [95% CI, 0.3-0.9]) and conduct disorder (0.3% vs 2.9%; OR, 0.1 [95% CI, 0.0-0.4]).

CONCLUSIONS AND RELEVANCE Interventions to encourage moving out of high-poverty neighborhoods were associated with increased rates of depression, PTSD, and conduct disorder among boys and reduced rates of depression and conduct disorder among girls. Better understanding of interactions among individual, family, and neighborhood risk factors is needed to guide future public housing policy changes.

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Author Affiliations: Department of Health Care Policy, Harvard Medical School, Boston, Massachusetts (Kessler, Sampson, Zaslavsky); School of Education, University of California Irvine, Irvine (Duncan); National Bureau of Economic Research, Cambridge, Massachusetts (Gennetian, Katz, Kling, Sanbonmatsu, Ludwig); Department of Economics, Harvard University, Cambridge, Massachusetts (Katz); Congressional Budget Office, Washington, DC (Kling); Harris School of Public Policy, University of Chicago, Chicago, Illinois (Ludwig).

Corresponding Author: Ronald C. Kessler, PhD, Department of Health Care Policy, Harvard Medical School, 180 Longwood Ave, Boston, MA 02115 (kessler@hcp.med.harvard.edu).

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Observational studies have consistently found that youth in high-poverty neighborhoods have high rates of emotional problems even after controlling for individual-level risk factors.[1] These findings raise the possibilities that neighborhood characteristics affect emotional functioning[2] and neighborhood-level interventions may reduce emotional problems. Available data from observational studies are unclear and subject to selection bias and the possibility of reverse causality (ie, families with emotional problems end up in poorer neighborhoods). Despite this uncertainty, presumptive neighborhood effects have been characterized,[3] causal pathways have been hypothesized,[4] and interventions have been implemented.[5]

It is important to evaluate these causal claims regarding neighborhood effects experimentally. The US Department of Housing and Urban Development (HUD) enacted a housing mobility experiment known as the Moving to Opportunity for Fair Housing Demonstration by randomizing volunteer low-income public housing families with children to receive vouchers to move to lower-poverty neighborhoods.[6,7] An interim evaluation 4 to 7 years after randomization showed that the intervention caused families to move to better neighborhoods with lower poverty and crime rates and increased social ties with more affluent people.[8] Significant reductions in psychological distress and depression were also found among adolescent girls in the intervention group vs the control group but increased behavior problems were found among adolescent boys in the intervention group vs the control group.[9-11] Given the importance of these sex differences, clinically significant mental disorders were included in a long-term (10-15 years after randomization) follow-up assessment. Prior long-term follow-up reports documented effects on improved neighborhood characteristics,[12,13] reduced adult extreme obesity and diabetes,[14] and improved adult subjective well-being.[13] No detectable effects on economic self-sufficiency were found.[13] Although long-term evaluation found significantly reduced psychological distress among adolescent girls,[15] measures of mental disorders were not examined in previous reports.

The primary objectives of the Moving to Opportunity study were to move families to lower-poverty neighborhoods and increase educational achievement and economic self-sufficiency. Mental disorders were measured as post hoc outcomes. The current report presents the first exploratory analyses evaluating long-term associations of housing mobility randomization with mental disorders among participants who were in early childhood at randomization and adolescence at follow-up.

Methods

Study Design

Families (n=4604) in the Moving to Opportunity study were recruited by public housing authorities from 1994 to 1998.[16] Families had to reside in public or project-based assisted housing in high-poverty census tracts (>40% of families in poverty) in Baltimore, Boston, Chicago, Los Angeles, or New York; be eligible for Section 8 housing; and have 1 or more children age younger than 18 years. Census tracts contain 2500 to 8000 people and are defined by the US Census Bureau to be "homogeneous with respect to population characteristics, economic status, and living conditions."[17] Housing authorities sent recruitment letters, held information sessions, and asked families to complete applications within 4 weeks of the invitation. Signed consents and baseline questionnaires were obtained during intake sessions prior to randomization. Families were then randomized into 1 of 3 groups using a computerized random-number generator: a low-poverty voucher group, a traditional voucher group, or a control group. In the low-poverty voucher group, families were offered a standard rent-subsidy voucher restricted to low-poverty census tracts (<10% of families in poverty). Vouchers provided subsidies for private-market housing equal to the difference between a rent threshold and the family's rent contribution (30% of income, identical to public housing).[18] Families remained eligible for vouchers as long as they met income and other criteria. Families also received short-term housing counseling during their initial housing search.[6,7] After 1 year, families in the low-poverty voucher group could use their voucher to relocate to a different tract, including those with higher-poverty rates, or could remain in the tract where they originally moved even if the poverty rate of that tract fell out of the low-poverty range. In the traditional voucher group, families were offered a standard rent-subsidy voucher without restriction on location as well as standard mobility counseling.[6,7] In the control group, families were offered no new assistance. Enhanced mobility counseling was offered to low-poverty voucher group families because of restrictions on where they could move. The protocol was approved by the Office of Management and Budget and HUD. Twenty-three percent of invited families applied,[6] and ultimately 48% of low-poverty voucher families and 63% of traditional voucher families used their vouchers to move.[7]

Interim (4-7 years after randomization) and long-term (10-15 years after randomization) evaluation surveys were carried out with household heads and residents who were children at baseline randomization and adolescents at follow-up. Most adolescents in the interim evaluation were in middle childhood or early adolescence (ages 9-16 years) at randomization, whereas most adolescents in the long-term evaluation were in early childhood (ages 0-8 years) at randomization. Long-term assessments were performed June 2008 through April 2010 by interviewers blinded to group assignment. All adolescents from households with 1 to 3 baseline children and 3 randomly selected adolescents from households with 4 or more baseline children were targeted for interview. Large households were purposely undersampled to reduce household burden.

Recruitment for long-term assessment began with telephone tracking and networking to locate hard-to-recruit participants. Potential respondents were offered $50 for completing interviews. Although most interviews were performed face-to-face, some were performed by telephone. Of

the hard-to-recruit nonrespondents, 35% were randomly selected for intensive recruitment with increased financial incentives.[19(p64)] Written informed parental consent and adolescent assent were obtained before interviews. These procedures were approved by the Office of Management and Budget, HUD, and the institutional review boards of the National Bureau of Economic Research, University of Chicago, University of Michigan, and Northwestern University.

Measures

Baseline head-of-household questionnaires focused largely on sociodemographics and neighborhood experiences (eg, social networks and crime victimization). Mental disorders were not assessed. Item-level missing data on the variables assessed was less than 5% for all but 5 variables (low birth weight; hospitalization before first birthday; baseline health problems that restricted normal activities; parent educational level; whether someone read to the child more than once daily during his/her early childhood; 5.5% to 11.2% missing). There were no missing values on the intervention variables. Item-level missing data were imputed using multiple imputation[20] using SAS software.[21]

The long-term assessment included the Composite International Diagnostic Interview (CIDI),[22] a widely used psychiatric diagnostic evaluation tool known to have good concordance with clinical diagnoses of mental disorders based on the *Diagnostic and Statistical Manual of Mental Disorders* (Fourth Edition) (*DSM-IV*).[23] The CIDI questions were read word-for-word and responses recorded in prespecified (mostly yes/no) format. Diagnoses were generated by CIDI algorithms operationalizing *DSM-IV* inclusion criteria. Diagnoses were made for *DSM-IV* disorders present within the past 12 months. Item-level missing data were less than 1% for each symptom question and were recoded conservatively to assume the symptom was absent. We focused on 6 *DSM-IV*/CIDI disorders: mood (major depression), anxiety (panic, posttraumatic stress), and disruptive behavior (oppositional-defiant, intermittent explosive, conduct). Bipolar disorder was also assessed, but was not analyzed due to low prevalence and insufficient statistical power to detect meaningful associations (eTable 1 in the Supplement).

Statistical Analysis

Sample size was determined by the Moving to Opportunity study budget ($70 million Congressional authorization, additional vouchers from local housing authorities, and counseling donated by nonprofit agencies). Randomization was designed to yield equal numbers of families within cities using vouchers in each intervention group. The number of families in the control group invited was set to equal the mean number invited in the 2 intervention groups. As voucher use percentages were determined only after randomization, proportions randomized across groups were modified during the study to adjust for observed rates of voucher use. The HUD determined that this design would yield 80% power to detect an effect of $2000 in increased earnings in each intervention group with a one-sided α of .05.[6(pE-4,exhibit,E4)] Post hoc power calculations showed that the long-term follow-up sample of adolescents had at least 80% power to detect an odds ratio (OR) for each of the 6 mental disorders considered herein of 1.4-1.8 (eTable 1 in the Supplement).

Intention-to-treat[24] logistic regression analysis[25] was used to estimate associations of the interventions with the outcomes. Across-time variation in the intervention vs control group selection ratios from 1994 to 1998 was corrected for by weighting. Case-level multiple imputation based on 20 pseudosamples was used to adjust for the fact that not all baseline participants completed follow-up interviews. The Taylor series method[26] implemented in SUDAAN[27] was used to adjust for weighting and clustering (cities, housing projects, families). The significance of sex differences was assessed by estimating a logistic regression equation to predict each disorder that included dummy variables for each intervention, a dummy variable for sex, and 2 dummy variables for the interactions of interventions with sex. A 2-degree-of-freedom χ^2 test was used to evaluate the significance of the interactions. In cases for which the test was significant, associations of the interventions with the disorder were considered separately for each sex. The evaluation of sex differences was carried out because significant sex differences had been found in previous interim evaluations.[9-11] The 6 mental disorders were considered separately because risk factors vary across these disorders.[28,29] The Benjamini-Hochberg method[30] was used to adjust significance tests across outcomes for the false discovery rate.

Logistic regression coefficients and standard errors were exponentiated to create ORs and 95% confidence intervals. Mental disorder prevalence estimates in the intervention and control groups were used to calculate absolute risk (AR) and absolute risk reduction (ARR). The jack-knife repeated replications method in SAS[26] was used to generate confidence intervals for the estimates of AR and ARR. Statistical significance was evaluated using a 2-sided α of .05.

Results

Response Rates

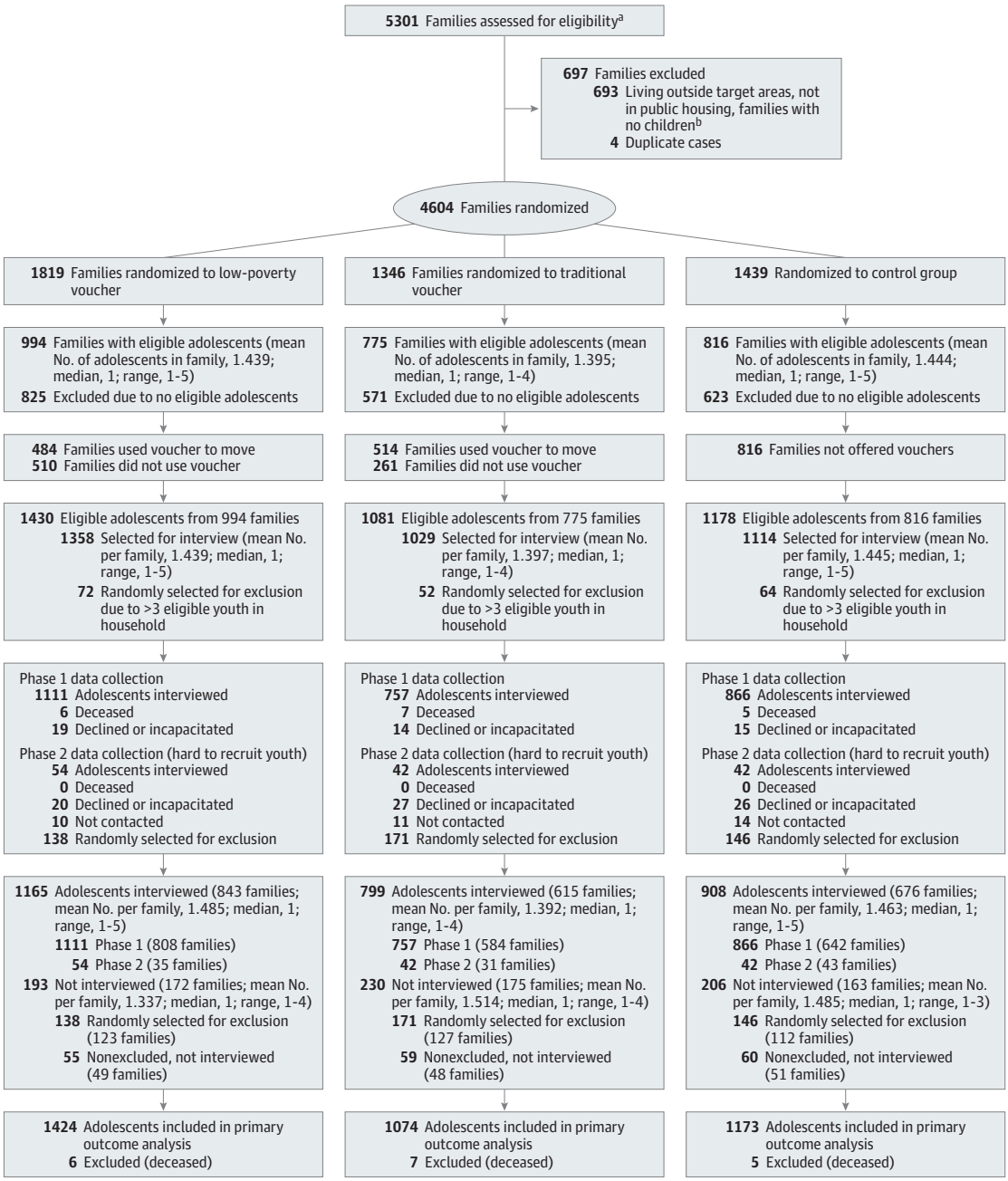
The 3689 adolescents assessed were aged 0 through 8 years (median age, 4 years) at baseline and aged 13 through 19 years (median age, 16 years) at the time of long-term follow-up interviews. A total of 2872 adolescents were interviewed (1407 boys and 1465 girls from 2134 families), including 1165 in the low-poverty voucher group (843 families), 799 in the traditional voucher group (615 families), and 908 in the control group (676 families), out of the 3689 eligible in the baseline sample (77.8% participation rate). An additional 643 adolescents were randomly excluded (188 from families with >4 eligible respondents and 455 due to difficult recruitment) and 174 were lost to follow-up (including 18 deceased) (**Figure**). The weighted response rates were 92.9% (low-poverty voucher group), 86.9% (traditional voucher group), and 89.4% (control group) using the American Association of Public Opinion Research definition.[31(p51)] Respondents were more likely to be girls and non-Hispanic black but did not

differ significantly from nonrespondents on other baseline personal, family, and neighborhood characteristics (eTable 2 in the Supplement).

Sample Characteristics

Baseline sociodemographic characteristics of adolescents were largely comparable across the 3 groups for both boys (**Table 1**)

Figure. Study Flow of the Moving to Opportunity Long-term Follow-up Evaluation of Adolescents



[a] Target respondents for the adolescent long-term evaluation included all baseline residents of randomized households who were aged 0 through 8 years at randomization from 1994 to 1998, aged 13 through 17 years at selection in December 2007, and aged 13 through 19 years at interview from June 2008 to April 2010. All adolescents in the eligible age range who lived at baseline in households containing 3 or fewer youth between 10 and 20 years were targeted for follow-up, whereas a random 3 were targeted from baseline households with 4 or more youth. A weight of n/3, for which n equals the number of eligible youths in the baseline household, was used to adjust for the undersampling of youths from baseline households containing more than 3 eligible youth. *Phase 1* data collection refers to the efforts made to contact and interview all target respondents until the end of the field period, at which point a random 35% of eligible target respondents (those who had not yet been interviewed, were not deceased or incapacitated, had not declined to participate) were selected for a more intensive *Phase 2* data collection effort that included expanded tracing efforts and increased financial incentives. A weight of 1/.35 was used to adjust for the undersampling of the *Phase 2* hard-to-recruit youths who were interviewed.

[b] For the 693 families excluded before randomization, the number excluded for each reason listed above is not known.

Table 1. Baseline Characteristics of the Moving to Opportunity Adolescent Boy Long-term Evaluation Sample Groups

	Voucher Group[a]								
	Low Poverty (n = 713)			Traditional (n = 533)			Control Group (n = 604)		
	Number[b]	Estimate (95% CI)	*P* Value[c]	Number[b]	Estimate (95% CI)	*P* Value[c]	Number[b]	Estimate (95% CI)	*P* Value[d]
Respondent Characteristics									
Age at baseline, y[e]									
0-5	602	82.2 (77.9 to 86.5)	.72	421	82.9 (79.0 to 86.8)	.99	502	83.0 (78.4 to 87.5)	.81
Mean		3.6 (3.4 to 3.9)	.82		3.6 (3.4 to 3.9)	.95		3.6 (3.5 to 3.9)	.91
Median		4.0 (0 to 7)			4.0 (0 to 8)			4.0 (0 to 8)	
Required special medicine/equipment	69	9.8 (7.0 to 12.7)	.97	64	11.2 (8.4 to 13.9)	.40	57	9.7 (7.2 to 12.3)	.68
Race/ethnicity									
Hispanic (any race)	184	27.7 (19.7 to 35.7)	.34	178	30.3 (21.5 to 39.1)	.83	197	31.0 (23.9 to 38.0)	.45
White (non-Hispanic)	14	2.0 (−0.2 to 4.1)	.85	9	1.8 (−0.2 to 3.7)	.97	12	1.8 (0.4 to 3.2)	.90
African American (non-Hispanic)	483	66.2 (56.7 to 75.6)	.59	322	63.3 (53.2 to 73.4)	.99	372	64.3 (56.3 to 72.3)	.83
Other race (non-Hispanic)	31	4.2 (2.0 to 6.4)	.26	23	4.6 (1.4 to 7.9)	.18	21	3.0 (1.4 to 4.6)	.17
Baseline characteristics of the sample adults									
High school diploma	297	40.8 (36.9 to 44.8)	.95	207	40.5 (34.3 to 46.6)	.96	248	40.6 (35.6 to 45.7)	.99
Currently in school	111	15.5 (12.1 to 18.9)	.15	102	18.3 (14.9 to 21.8)	.98	108	18.4 (14.4 to 22.4)	.37
Employed	156	22.0 (17.6 to 26.3)	.79	114	20.1 (15.5 to 24.7)	.69	127	21.3 (16.8 to 25.7)	.97
Never married	485	67.4 (61.7 to 73.2)	.40	354	67.6 (60.4 to 74.8)	.46	416	70.4 (65.1 to 75.6)	.38
<18 y at birth of first child	217	29.6 (24.1 to 35.1)	.35	165	31.7 (25.5 to 37.8)	.12	160	26.3 (20.1 to 32.5)	.17
Single mother	613	85.5 (81.2 to 89.8)	.49	463	86.9 (82.2 to 91.6)	.95	521	87.1 (83.7 to 90.4)	.64
Baseline Household Characteristics									
Income, $									
≤7000	130	17.0 (11.5 to 22.6)	.85	83	16.6 (10.1 to 23.2)	.73	96	17.5 (11.1 to 24.0)	.76
7001-9000	117	16.5 (12.3 to 20.6)	.90	107	19.6 (15.5 to 23.8)	.31	102	16.8 (13.2 to 20.4)	.70
9001-12 000	148	20.6 (16.3 to 24.9)	.33	147	27.5 (20.9 to 34.1)	.26	143	23.1 (18.9 to 27.4)	.87
12 001-17 000	164	23.5 (19.0 to 28.0)	.05	84	15.8 (11.7 to 19.8)	.28	119	18.2 (14.2 to 22.1)	.36
≥17 001	152	22.4 (17.8 to 27.0)	.43	109	20.5 (15.9 to 25.1)	.20	142	24.3 (19.8 to 28.8)	.21
Receives AFDC	596	83.5 (79.8 to 87.3)	.08	435	82.3 (77.5 to 87.1)	.24	476	79.1 (74.8 to 83.5)	.08
Household size									
1-2	67	9.9 (6.9 to 13.0)	.50	55	8.7 (5.8 to 11.6)	.90	54	8.4 (5.7 to 11.2)	.61
3	153	21.7 (18.0 to 25.3)	.01	139	25.1 (20.6 to 29.6)	.31	166	27.9 (23.6 to 32.3)	.03
4	196	28.0 (24.0 to 32.0)	.05	131	25.2 (20.3 to 30.1)	.36	135	22.6 (19.0 to 26.1)	.07
≥5	297	40.4 (35.4 to 45.5)	.85	208	41.0 (36.2 to 45.7)	.98	249	41.1 (36.6 to 45.5)	.90

Abbreviation: AFDC, Aid to Families with Dependent Children.

[a] Based on multiply imputation data (described in the text) to adjust for the fact that 22.2% of eligible baseline respondents did not participate in the long-term evaluation survey.

[b] Mean number of respondents in the group with the outcome averaged across the 20 multiply imputed pseudosamples.

[c] Compared with controls.

[d] Compared with both intervention groups combined.

[e] Age at long-term follow-up interview had a median age of 16 years for both the low-poverty voucher group and Traditional Voucher Group, and a median age of 17 years in the control group. The range was 13 to 19 years for all three groups.

and girls (**Table 2**). Most respondents were non-Hispanic black (61.8%-66.2% of groups) or Hispanic (27.7%-33.2% of groups). The majority of respondents were ages 0 through 5 years at baseline (82.2%-87.9% of groups), with mean age of 3.6 years in each group and range of 0 through 7 years in the low-poverty voucher group and 0 through 8 years in traditional voucher and control groups. The majority of baseline families received Aid to Families with Dependent Children (79.1%-85.1% of groups). Mean baseline neighborhood poverty rates were 53.6% to 54.9% (**Table 3**).

Mental Disorder Prevalence Within the Past 12 Months

The most prevalent mental disorders within the past 12 months were found to be intermittent explosive disorder (14.2% of boys and 16.0% of girls) and oppositional-defiant disorder (6.8% of boys and 8.4% of girls), followed by major depressive disorder (5.5% of boys and 7.9% of girls), post-traumatic stress disorder (PTSD) (4.4% of boys and 6.6% of girls), conduct disorder (4.3% of boys and 1.6% of girls), and panic disorder (4.1% of boys and 3.7% of girls) (eTable 3 in the Supplement).

Table 2. Baseline Characteristics of the Moving to Opportunity Adolescent Girl Long-term Follow-up Evaluation Sample Groups

	Voucher Group[a]								
	Low Poverty (n = 711)			Traditional (n = 541)			Control Group (n = 569)		
	Number[b]	% (95% CI)	*P* value[c]	Number[b]	% (95% CI)	*P* value[c]	Number[b]	% (95% CI)	*P* Value[d]
Respondent Characteristics									
Age at baseline, y[e]									
0-5	613	83.8 (79.8 to 87.9)	.86	457	87.9 (84.4 to 91.4)	.02	479	83.5 (79.6 to 87.3)	.20
Mean		3.6 (3.4 to 3.9)	.76		3.5 (3.2 to 3.7)	.06		3.7 (3.4 to 3.9)	.22
Median		4.0 (0 to 8)			4.0 (0 to 8)			4.0 (0 to 8)	
Required special medicine/equipment	60	8.1 (5.7 to 10.4)	.53	38	6.6 (3.9 to 9.4)	.89	39	6.9 (3.7 to 10.1)	.75
Race/ethnicity									
Hispanic (any race)	215	33.2 (24.7 to 41.7)	.74	163	28.2 (20.7 to 35.6)	.25	194	32.0 (24.6 to 39.4)	.75
White (non-Hispanic)	11	2.2 (−0.4 to 4.7)	.66	12	2.0 (− 0.3 to 4.2)	.48	15	2.8 (0.9 to 4.6)	.57
African American (non-Hispanic)	464	61.8 (51.9 to 71.6)	.89	341	65.7 (56.6 to 74.8)	.32	341	62.3 (53.8 to 70.8)	.72
Other race (non-Hispanic)	19	2.9 (0.8 to 4.9)	.94	24	4.2 (1.7 to 6.6)	.32	19.0	2.9 (1.2 to 4.7)	.62
Baseline characteristics of the sample adult									
High school diploma	278	38.4 (32.2 to 44.7)	.63	195	35.8 (29.0 to 42.5)	.82	212	36.7 (32.1 to 41.2)	.86
Currently in school	135	19.4 (15.2 to 23.6)	.48	93	16.8 (13.0 to 20.7)	.79	94	17.6 (13.7 to 21.4)	.75
Employed	151	22.3 (18.6 to 25.9)	.93	109	18.8 (15.3 to 22.3)	.19	127	22.1 (18.3 to 25.9)	.49
Never married	483	67.3 (62.6 to 72.0)	.33	370	69.5 (64.2 to 74.8)	.86	390	70.2 (64.4 to 75.9)	.51
<18 y at birth of first child	216	28.0 (22.9 to 33.1)	.19	164	31.1 (25.3 to 36.9)	.90	177	31.5 (26.7 to 36.2)	.35
Single mother	633	87.8 (84.2 to 91.5)	.48	470	87.1 (83.3 to 91.0)	.28	504	89.3 (86.2 to 92.4)	.32
Baseline Household Characteristics									
Income, $									
≤7000	143	17.6 (12.0 to 23.2)	.22	74	14.9 (8.3 to 21.5)	.80	79	15.7 (9.9 to 21.5)	.68
7001-9000	134	19.5 (15.4 to 23.7)	.31	125	22.9 (17.3 to 28.5)	.09	99	16.9 (13.7 to 20.1)	.13
9001-12 000	174	25.3 (20.2 to 30.3)	.98	138	25.7 (20.1 to 31.3)	.91	150	25.4 (20.5 to 30.2)	.96
12 001-17 000	144	20.3 (15.5 to 25.2)	.55	109	19.4 (15.6 to 23.2)	.31	127	22.3 (17.8 to 26.7)	.38
≥17 001	113	17.2 (13.5 to 20.9)	.31	93	17.0 (12.9 to 21.1)	.25	112	19.8 (16.0 to 23.5)	.21
Receives AFDC	598	82.9 (78.9 to 86.9)	.23	453	85.1 (81.3 to 89.0)	.07	449	80.2 (76.4 to 83.9)	.08
Household size									
1-2	72	10.8 (7.8 to 13.9)	.16	54	9.6 (6.8 to 12.4)	.62	54	8.7 (6.7 to 10.7)	.22
3	186	27.4 (23.3 to 31.4)	.52	132	24.3 (19.5 to 29.2)	.70	150	25.6 (21.4 to 29.9)	.87
4	191	26.4 (22.7 to 30.1)	.75	128	22.9 (18.6 to 27.3)	.38	144	25.4 (21.6 to 29.2)	.81
≥5	262	35.4 (30.1 to 40.8)	.20	227	43.1 (36.6 to 49.6)	.50	221	40.2 (34.6 to 45.8)	.67

Abbreviation: AFDC; Aid to Families With Dependent Children.

[a] Based on multiple imputation data (described in the text) to adjust for the fact that 22.2% of eligible baseline respondents did not participate in the long-term evaluation survey.

[b] Mean number of respondents in the group with the outcome averaged across the 20 multiply imputed pseudosamples.

[c] Compared with controls.

[d] Compared with both intervention groups combined.

[e] Age at long-term follow-up interview had a median age of 16 years for both the low-poverty voucher group and traditional voucher group, and a median age of 17 years in the control group. The range was 13 to 19 years for all 3 groups.

Associations of Interventions With Mental Disorders Among Boys and Girls Combined

Adjusting for the false discovery rate, respondents in the low-poverty voucher group had significantly elevated prevalence of PTSD (7.2% [95% CI, 5.7%-8.6%]; OR, 1.8 [95% CI, 1.2-2.7]) compared with the control group (4.2% [95% CI, 3.2%-5.2%]) (**Table 4**). None of the other 11 comparisons of low-poverty or traditional voucher groups with the control group was significant. Odds ratios comparing the low-poverty voucher group with the control group were in the range 0.7-1.6 (P = .13-.84). Odds Ratios comparing the traditional voucher group with the control group were in the range of 0.9-1.1 (P = .70).

After adjusting for the false discovery rate, the ORs comparing the low-poverty and traditional voucher groups with the control group varied significantly by respondent sex for 3 of the 6 outcomes: major depression (χ^2_2 = 14.1, P = .007), PTSD (χ^2_2 = 9.0, P = .03), and conduct disorder (χ^2_2 = 11.7, P = .01). Odds ratios were not significantly different by sex for panic disorder (χ^2_2 = 6.2, P = .08), oppositional-defiant disorder (χ^2_2 = 4.4, P = .16), or intermittent explosive disorder (χ^2_2 = 1.3, P = .60). Based on these results, the remaining analyses focused on major depression, PTSD, and conduct disorder separately for boys and girls.

Table 3. Baseline Moving to Opportunity Neighborhood Characteristics

Baseline Neighborhood Characteristics, %[a]	Voucher Group: Low Poverty Number[b]	Low Poverty % (95% CI)	Low Poverty P Value[c]	Voucher Group: Traditonal Number[b]	Traditonal % (95% CI)	Traditonal P Value[c]	Control Group (n = 569) Number[b]	Control Group % (95% CI)	Control Group P Value[d]
Boys									
Family member victimized past 6 mo	293	40.8 (36.9 to 44.7)	.13	235	44.0 (37.8 to 50.1)	.81	264	44.8 (40.2 to 49.4)	.29
Lived in neighborhood ≥5 y	383	52.4 (47.2 to 57.6)	.57	307	57.4 (52.1 to 62.7)	.30	325	54.3 (49.2 to 59.4)	.91
Moved >3 times in 5 y	75	10.9 (7.9 to 13.9)	.19	51	10.0 (6.8 to 13.3)	.10	90	14.6 (10.5 to 18.7)	.10
Family in neighborhood	447	64.9 (57.4 to 72.4)	.38	321	59.9 (54.3 to 65.4)	.68	377	61.7 (54.8 to 68.6)	.75
Mean poverty rate[e]		53.8 (49.3 to 58.4)	.79		54.9 (50.1 to 59.7)	.67		54.2 (49.7 to 58.7)	.94
City									
Baltimore	78	11.9 (5.5 to 18.3)	.84	71	13.3 (6.0 to 20.6)	.61	76	12.5 (6.2 to 18.9)	.99
Boston	125	17.4 (9.7 to 25.2)	.50	103	20.1 (11.0 to 29.1)	.77	128	19.2 (11.1 to 27.4)	.74
Chicago	215	23.2 (9.9 to 36.5)	.78	109	25.4 (10.9 to 39.8)	.49	108	22.2 (10.8 to 33.5)	.62
Los Angeles	148	24.8 (12.4 to 37.2)	.61	126	23.0 (12.2 to 33.7)	.85	170	23.4 (11.3 to 35.5)	.78
New York City	147	22.6 (15.0 to 30.2)	.99	124	18.3 (11.8 to 24.8)	.15	122	22.7 (14.7 to 30.6)	.47
Girls									
Family member victimized past 6 mo	324	45.8 (40.3 to 51.2)	.26	207	37.9 (32.3 to 43.5)	.44	232	41.5 (34.9 to 48.1)	.84
Lived in neighborhood ≥5 y	359	49.3 (44.8 to 53.8)	.04	287	51.2 (44.6 to 57.8)	.21	310	55.7 (51.1 to 60.4)	.05
Moved >3 times in 5 y	66	9.3 (7.0 to 11.6)	.12	62	12.9 (8.7 to 17.2)	.68	70	11.9 (9.1 to 14.8)	.52
Family in neighborhood	435	64.6 (58.6 to 70.6)	.65	354	65.6 (60.5 to 70.8)	.47	364	63.1 (56.5 to 69.7)	.52
Mean poverty rate[e]		53.7 (49.0 to 58.3)	.93		53.7 (49.4 to 57.9)	.94		53.6 (49.4 to 57.7)	.93
City									
Baltimore	74	10.9 (3.5 to 18.3)	.59	79	14.3 (5.8 to 22.9)	.02	58	10.1 (2.9 to 17.3)	.12
Boston	146	21.7 (13.2 to 30.3)	.47	92	17.7 (10.1 to 25.3)	.46	125	19.9 (12.0 to 27.8)	.97
Chicago	219	23.7 (11.7 to 35.8)	.56	110	24.7 (13.7 to 35.7)	.35	102	22.3 (11.8 to 32.9)	.40
Los Angeles	140	23.5 (12.5 to 34.5)	.92	121	21.6 (10.4 to 32.9)	.47	161	23.2 (11.3 to 35.1)	.80
New York City	132	20.1 (13.6 to 26.7)	.09	139	21.6 (15.2 to 28.0)	.36	123	24.5 (16.7 to 32.3)	.13

[a] Based on multiply imputation data (described in the text) to adjust for the fact that 22.2% of eligible baseline respondents did not participate in the long-term evaluation survey.

[b] Mean number of respondents in the group with the outcome averaged across the 20 multiply imputed pseudosamples.

[c] Compared with controls.

[d] Compared with both intervention groups.

[e] The mean poverty rate in census tract is the fraction of residents living below the poverty threshold in the household's baseline census tract. The poverty rate is linearly interpolated from the 1990 and 2000 decennial censuses. See http://www.census.gov/hhes/www/poverty/about/overview/measure.html for information on how the Census Bureau defines the poverty threshold.

Associations of Interventions With Mental Disorders Among Boys

Adjusting for the false discovery rate, boys had significantly elevated rates of major depression in the low-poverty voucher group (7.1% [95% CI, 4.1%-10.1%]; OR, 2.2 [95% CI, 1.2-3.9]) compared with the control group (3.5% [95% CI, 2.3%-4.6%]), elevated rates of PTSD in both the low-poverty voucher group (6.2% [95% CI, 4.7%-7.7%]; OR, 3.4 [95% CI, 1.6-7.4]) and the traditional voucher group (4.9% [95% CI, 3.0%-6.8%]; OR, 2.7 [95% CI, 1.2-5.8]) compared with the control group (1.9% [95% CI, 0.9%-2.9%]), and of conduct disorder in the low-poverty voucher group (6.4% [95% CI, 4.7%-8.1%]; OR, 3.1 [95% CI, 1.7-5.8]) compared with the control group (2.1% [95% CI, 1.1%-3.2%]) (**Table 5**). Neither of the other 2 comparisons between intervention and control groups was significantly different, with ORs in the range 1.7-2.0 (P = .23).

Associations of Interventions With Mental Disorders Among Girls

Adjusting for the false discovery rate, girls in the traditional voucher intervention group had significantly reduced rates of major depression (6.5% [95% CI, 4.5%-8.4%]; OR, 0.6 [95% CI, 0.3-0.9]) compared with the control group (10.9% [95% CI, 8.4%-13.4%]) and reduced rates of conduct disorder in the traditional voucher group (0.3% [95% CI, 0.0%-0.7%]; OR, 0.1 [95% CI, 0.0-0.4]) compared with the control group (2.9% [95% CI, 1.1%-4.7%]) (Table 5). The number needed to treat (NNT) (inverse of ARR) among girls was 23 for major depression and 38 for conduct disorder. None of the other 4 comparisons between intervention and control groups was significantly different, with ORs in the range 0.5-1.2 (P = .06-0.40).

Discussion

Our post hoc exploratory analysis found that interventions to encourage moving out of high-poverty neighborhoods were associated with increased depression, PTSD, and conduct disorder among adolescent boys and reduced depression and conduct disorder among adolescent girls randomized at ages 0 through 8 years. These sex differences were broadly consistent with interim follow-up results.[8,9,11] Qualitative evidence

Table 4. Associations of the Interventions With Mental Disorders in the Long-term Follow-up Sample of Adolescent Boys and Girls Combined

	Estimate (95% CI)[a]		
	Voucher Group		
	Low Poverty (n = 1424)	Traditional (n = 1074)	Control Group (n = 1173)
Major depressive disorder			
Absolute risk, %	6.8 (−12.0 to 25.6)	6.1 (−20.1 to 32.4)	7.1 (−21.8 to 35.9)
Absolute risk reduction, %	0.3 (−27.0 to 27.6)	1.0 (−30.7 to 32.7)	
Odds ratio	1.0 (0.6 to 1.4)	0.9 (0.6 to 1.3)	1 [Reference]
P value[b]	.84	.70	
No. of respondents[c]	98	66	84
Panic disorder			
Absolute risk, %	3.1 (2.2 to 4.1)	4.1 (2.8 to 5.3)	4.7 (3.2 to 6.1)
Absolute risk reduction, %	1.5 (−0.2 to 3.3)	0.6 (−1.6 to 2.8)	
Odds ratio	0.7 (0.4 to 1.1)	0.9 (0.5 to 1.5)	1 [Reference]
P value[b]	.17	.70	
No. of respondents[c]	52	44	58
Posttraumatic stress disorder			
Absolute risk, %	7.2 (5.7 to 8.6)	4.7 (3.6 to 5.8)	4.2 (3.2 to 5.2)
Absolute risk reduction, %	−3.0 (−4.5 to −1.5)	−0.5 (−1.9 to 1.0)	
Odds ratio	1.8 (1.2 to 2.7)	1.1 (0.7 to 1.8)	1 [Reference]
P value[b]	.03	.70	
No. of respondents[c]	105	54	48
Oppositional-defiant disorder			
Absolute risk, %	6.2 (4.8 to 7.6)	8.8 (7.5 to 10.0)	8.2 (6.3 to 10.1)
Absolute risk reduction, %	1.9 (−0.1 to 4.0)	−0.6 − 2.8 to 1.6)	
Odds ratio	0.7 (0.5 to 1.1)	1.1 (0.8 to 1.5)	1 [Reference]
P value[b]	.17	.70	
No. of respondents[c]	97	89	98
Intermittent explosive disorder			
Absolute risk, %	13.6 (11.5 to 15.8)	15.4 (13.4 to 17.3)	16.7 (14.9 to 18.6)
Absolute risk reduction, %	3.1 (−0.2 to 6.4)	1.3 (−1.3 to 4.0)	
Odds ratio	0.8 (0.6 to 1.0)	0.9 (0.7 to 1.2)	1 [Reference]
P value[b]	.13	.70	
No. of respondents[c]	202	161	96
Conduct disorder			
Absolute risk, %	3.9 (3.0 to 4.9)	2.2 (1.0 to 3.4)	2.5 (1.5 to 3.5)
Absolute risk reduction, %	−1.4 (−2.7 to −0.1)	0.3 (−1.2 to 1.8)	
Odds ratio	1.6 (1.0 to 2.6)	0.9 (0.5 to 1.7)	1 [Reference]
P value[b]	.13	.70	
No. of respondents[c]	55	21	28

[a] Based on a series of logistic regression equations comparing respondents in the low-poverty and traditional voucher intervention groups with respondents in the control group, ignoring whether intervention families used their vouchers. The equations are based on multiply-imputed data (described in the text) to adjust for the fact that 22.2% of eligible baseline respondents did not participate in the long-term evaluation survey.

[b] The *P* values evaluate the significance of odds ratios using the Benjamini-Hochberg method[30] to adjust for the false discovery rate. These *P* values are higher than those implied by the 95% CIs, as the latter are based on models for separate outcomes.

[c] Mean number of respondents in the group with the outcome averaged across the 20 multiply imputed pseudosamples.

suggested these differences were due to girls profiting more than boys from moving to better neighborhoods because of sex differences in both neighborhood experiences and in the social skills needed to capitalize on the new opportunities presented by their improved neighborhoods.[32-34] The magnitudes of the protective associations of the interventions with mental disorders among girls were modest in the intention-to-treat analyses, although these estimates would be larger if the analysis was restricted to movers. However, the ORs are comparable in size with those published in studies of risk factors considered to be of high policy significance. For example, the elevated ORs of PTSD found among boys were comparable with the ORs found between combat exposure and PTSD in epidemiological studies of the military,[35] whereas the reduced ORs of major depression found among girls was comparable with the inverse of the ORs found in previous research between sexual assault and major depression in epidemiological studies of young women.[36] Furthermore, it is important to recognize that these associations were evaluated 10 to 15 years after randomization. It is not clear if the magnitudes of the associations were stable over this entire time, but if so, they would be substantial despite the relatively high NNT. For example, ARR for major depression among girls would be 58.3 person-years per 100 respondents over 15 years if ORs were temporally stable over the entire time.

Table 5. Associations of the Interventions With Mental Disorders in the Long-term Follow-up Sample of Adolescent Boys vs Girls Separately

	Estimate (95% CI)[a]		
	Voucher Group		
	Low Poverty	Traditional	Control Group
Boys, No.	713	533	604
Major depressive disorder			
Absolute risk, %	7.1 (4.1 to 10.1)	5.7 (3.8 to 7.7)	3.5 (2.3 to 4.6)
Absolute risk reduction, %	−3.7 (−6.9 to −0.4)	−2.3 (−4.5 to −0.1)	
Odds ratio	2.2 (1.2 to 3.9)	1.7 (0.9 to 3.4)	1 [Reference]
P value[b]	.03	.23	
No. of respondents[c]	52	30	22
Posttraumatic stress disorder			
Absolute risk, %	6.2 (4.7 to 7.7)	4.9 (3.0 to 6.8)	1.9 (0.9 to 2.9)
Absolute risk reduction, %	−4.3 (−6.1 to −2.5)	−3.0 (−5.0 to −1.0)	
Odds ratio	3.4 (1.6 to 7.4)	2.7 (1.2 to 5.8)	1 [Reference]
P value[b]	.007	.05	
No. of respondents[c]	44	26	10
Conduct disorder			
Absolute risk, %	6.4 (4.7 to 8.1)	4.2 (1.9 to 6.5)	2.1 (1.1 to 3.2)
Absolute risk reduction, %	−4.2 (−6.4 to −2.1)	−2.1 (−4.5 to 0.4)	
Odds ratio	3.1 (1.7 to 5.8)	2.0 (0.8 to 5.1)	1 [Reference]
P value[b]	<.001	.23	
No. of respondents[c]	42	19	13
Girls, No.	711	541	564
Major depressive disorder			
Absolute risk, %	6.5 (4.7 to 8.3)	6.5 (4.5 to 8.4)	10.9 (8.4 to 13.4)
Absolute risk reduction, %	4.4 (1.5 to 7.3)	4.4 (1.3 to 7.5)	
Odds ratio	0.6 (0.3 to 1.0)	0.6 (0.3 to 0.9)	1 [Reference]
P value[b]	.06	.04	
No. of respondents[c]	46	35	61
Posttraumatic stress disorder			
Absolute risk, %	8.2 (6.1 to 10.2)	4.5 (3.2 to 5.7)	6.7 (4.8 to 8.5)
Absolute risk reduction, %	−1.5 (−3.8 to 0.9)	2.2 (0.0 to 4.4)	
Odds ratio	1.2 (0.8 to 2.1)	0.7 (0.3 to 1.2)	1 [Reference]
P value[b]	.40	.33	
No. of respondents[c]	60	28	38
Conduct disorder			
Absolute risk, %	1.5 (0.8 to 2.1)	0.3 (0.0 to 0.7)	2.9 (1.1 to 4.7)
Absolute risk reduction, %	1.4 (−0.5 to 3.3)	2.6 (0.7 to 4.5)	
Odds ratio	0.5 (0.2 to 1.4)	0.1 (0.0 to 0.4)	1 [Reference]
P value[b]	.20	.02	
No. of respondents[c]	11	2	15

[a] Based on a series of logistic regression equations comparing respondents in the low-poverty and traditional voucher intervention groups with respondents in the control group, ignoring whether intervention families used their vouchers. The equations are based on multiply-imputed data (described in the text) to adjust for the fact that 22.2% of eligible baseline respondents did not participate in the long-term evaluation survey.

[b] The *P* values evaluate the significance of odds ratios using the Benjamini-Hochberg method[30] to adjust for the false discovery rate. These *P* values are higher than those implied by the 95% CIs, as the latter are based on models for separate outcomes.

[c] Mean number of respondents in the group with the outcome averaged across the 20 multiply imputed pseudosamples.

External validity was reduced by the fact that only 23% of eligible families volunteered for the Moving to Opportunity study. However, the public housing population is large and therefore even this small fraction represents more than 300 000 low-income US children,[37] making the volunteer families significant from a policy perspective even though they were only a minority of all public housing families. A question might be raised about whether the added costs of developing a special housing intervention for such a small proportion of public housing recipients could be justified by the small proportion accepting the offer, but this concern is mitigated by the fact that many housing economists believe the true costs of housing vouchers are actually lower than those of conventional public housing because of the increased efficiency of the open housing market.[18]

It is nonetheless difficult to draw policy implications from these results, because the findings suggest that the interventions might have had harmful effects on boys but protective effects on girls. Future governmental decisions regarding widespread implementation of changes in public housing policy will have to grapple with this complexity based on the realization that no policy decision will have benign effects on both boys

and girls. One way to do so might be to develop more nuanced assignment rules than currently exist or additional intervention elements to mitigate the adverse effects of the intervention on boys while maintaining the protective effects on girls.

Development of such refinements will require a better understanding of the interactions of influences among individual, family, and neighborhood characteristics leading to child and adolescent mental disorders. Although the Moving to Opportunity study was not designed to produce this kind of understanding, these results should create an impetus to do so by documenting that neighborhoods do matter. The challenge for future research is to increase understanding enough to guide allocation of the substantial amount of money spent on public housing in the United States each year (more than $36 billion in fiscal year 2012)[38] to maximize the health and well-being of all family members rather than to maximize value for some family members at the expense of other family members.

The Moving to Opportunity study had several strengths, including an experimental design, large sample size, and long follow-up. However, it also had several noteworthy limitations: only 23% of eligible families volunteered, and families offered vouchers had rather severe time limits on enrollment and practical constraints on finding new housing that might have artificially reduced uptake.[39] These factors may reduce the generalizability of the results.[40] Other limitations include the fact that nonrespondents might have differed systematically from respondents; that the experiment was implemented when the unemployment rate was much lower than it is today;[41] that the CIDI and other mental health measures were not administered at baseline; and that, as with all policy experiments, the study design made it impossible to trace intervening processes that might account for aggregate intervention effects. In addition, the Moving to Opportunity study was underpowered to detect effects of the 2 separate intervention groups on uncommon adolescent mental disorders.

Despite these limitations, we found significant associations of the study interventions to reduce neighborhood-level poverty with several important adolescent mental disorders, providing evidence that experimental manipulation of incentives to move is associated with adolescent emotional functioning. However, because the interventions were also associated with changes in many other aspects of neighborhoods and participant experiences, pathways accounting for the associations of the interventions with adolescent mental disorders remain unclear, creating a challenge for future research to develop nuanced decision rules for matching public housing families with neighborhoods to maximize the health and well-being of all family members.

Conclusions

Interventions to encourage moving out of high-poverty neighborhoods were associated with increased rates of major depression, PTSD, and conduct disorder among boys and reduced rates of major depression and conduct disorder among girls. Better understanding of interactions among individual, family, and neighborhood risk factors is needed to guide future public housing policy changes in light of these sex differences.

ARTICLE INFORMATION

Author Contributions: Drs Kessler and Ludwig had full access to all of the data in the study and take responsibility for the integrity of the data and accuracy of the data analysis.
Study concept and design: Kessler, Duncan, Gennetian, Katz, Kling, Sanbonmatsu, Ludwig.
Acquisition of data: Gennetian, Sanbonmatsu, Ludwig.
Analysis and interpretation of data: Kessler, Duncan, Gennetian, Katz, Kling, Sampson, Sanbonmatsu, Zaslavsky, Ludwig.
Drafting of the manuscript: Kessler.
Critical revision of the manuscript for important intellectual content: Duncan, Gennetian, Katz, Kling, Sampson, Sanbonmatsu, Zaslavsky, Ludwig.
Statistical analysis: Kessler, Duncan, Katz, Kling, Zasavsky, Ludwig.
Obtaining funding: Katz, Kling, Ludwig.
Study supervision: Kessler, Gennetian, Sampson, Sanbonmatsu, Zaslavsky, Ludwig.
Administrative, technical, or material support: Gennetian, Sanbonmatsu.

Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr Kessler reported that he has been a consultant for AstraZeneca, Analysis Group, Bristol-Myers Squibb, Cerner-Galt Associates, Eli Lilly, GlaxoSmithKline Inc, HealthCore Inc, Health Dialog, Hoffman-LaRoche Inc, Integrated Benefits Institute, J & J Wellness & Prevention Inc, John Snow Inc, Kaiser Permanente, Lake Nona Institute, Matria Inc, Mensante, Merck Inc, Ortho-McNeil Janssen Scientific Affairs, Pfizer Inc, Primary Care Network, Research Triangle Institute, sanofi-aventis, Shire US Inc, SRA International, Takeda Global Research & Development, Transcept Pharmaceuticals Inc, and Wyeth-Ayerst; has served on advisory boards for Appliance Computing II, Eli Lilly, Mindsite, Ortho-McNeil Janssen Scientific Affairs, Johnson & Johnson, Plus One Health Management, and Wyeth-Ayerst; has had research support for his epidemiological studies from Analysis Group Inc, Bristol-Myers Squibb, Eli Lilly & Company, EPI-Q, GlaxoSmithKline, Johnson & Johnson Pharmaceuticals, Ortho-McNeil Janssen Scientific Affairs, Pfizer Inc, sanofi-aventis, Shire US Inc, and Walgreens; and owns 25% share in DataStat Inc. Dr Gennetian reported that he has served on advisory boards for Family Self Sufficiency TWG, Administration for Children and Families, and National Opinion Research Center, University of Chicago. Dr Katz reported that he has served on advisory boards for Manpower Demonstration Research Corporation and the Russell Sage Foundation. Dr Ludwig reported that he serves on advisory boards (uncompensated) for Uhlich Children's Advantage Network (Chicago), and the Board on Children, Youth and Families Institute of Medicine/National Academy of Sciences; and has served as a consultant for the MacArthur Foundation Network on Children and Housing and the MDRC Early Childhood Institute. The remaining authors report no conflicts of interest.

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