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Original Contribution

Beyond the Great Recession: Was the Foreclosure Crisis Harmful to the Health of Individuals With Diabetes?

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The housing foreclosure crisis was harmful to the financial well-being of many households. In the present study, we investigated the health effects of the housing foreclosure crisis on glycemic control within a population of patients with diabetes. We hypothesized that an increase in the neighborhood foreclosure rate could worsen glycemic control by activating stressors such as higher neighborhood crime, lower housing prices, and erosion of neighborhood social cohesion. To test this, we linked public foreclosure records at the census-block level with clinical records from 2006 to 2009 of patients with diabetes. We specified individual fixed-effects models and controlled for individual time-invariant confounders and area-level time-varying confounders, including housing prices and unemployment rate, to estimate the effect of the foreclosure rate per census-block group on glycated hemoglobin. We found no statistically significant relationship between changes in the neighborhood foreclosure rate per block group in the prior year and changes in glycated hemoglobin. There is no evidence that increased foreclosure rates worsened glycemic control in this continuously insured population with diabetes. More research is needed to inform our knowledge of the role of insurance and health-care delivery systems in protecting the health of diabetic patients during times of economic stress.

diabetes; foreclosure; HbA1c; glycemic; managed care; neighborhood; recession; unemployment

Abbreviations: CI, confidence interval; HbA1c, glycated hemoglobin; KPNC, Kaiser Permanente Northern California.

Editor's note: *An invited commentary on this article appears on page 436, and the authors' response appears on page 440.*

The housing foreclosure crisis that occurred during the Great Recession was unprecedented. During the peak in 2010, 1 in 10 mortgages was delinquent (1). This large financial shock to households and communities operated in tandem with the Great Recession. The effect of recessions on health and health care has been a question of great interest (2). During the Great Recession, routine health-care utilization declined (3), private health insurance enrollment slowed, and Medicaid hospital spending accelerated (4). A similar pattern was seen during the foreclosure crisis; urgent unscheduled visits, including those for preventable conditions like diabetes and asthma, increased among persons with public health insurance (5). However, in most studies, the ubiquitous role of the health system in buffering patient populations from changes in the economy was omitted. There have been few studies in which investigators have observed the association of the foreclosure crisis with self-management of a chronic condition within the patient population of a health system (6), despite the fact organizations that deliver care are most strategically positioned to intervene.

In the present study, our goal was to understand the relationship between neighborhood-level housing foreclosure crisis data from 2006 to 2010 and individual glycemic control within a continuously insured population of patients receiving diabetes care within a large integrated delivery system. An estimated 1 in 8 US adults with diabetes exhibited poor glycemic control from 2007 to 2010 (7). One objective of

Healthy People 2020 is to reduce the proportion of persons with diabetes with poor control, indicated by glycated hemoglobin (HbA1c) values greater than 9% (8). Adverse psychosocial factors, such as unemployment, work strain, and other stressful life events, have been linked with poor glycemic control (9), diabetes chronicity, comorbid conditions, and mortality (10, 11).

There are several pathways via which foreclosures could influence health (12). Neighborhood foreclosures could influence self-management of glycemic control by activating the psychological stress response, eroding social support, and reducing self-care behaviors. First, an elevated exposure to foreclosures in one's residential neighborhood might increase the incidence and anticipation of stressful events, such as a loss of wealth and forced relocation, and increase the probability of other stressors, such as crime and marital problems (13, 14). Psychological stress can increase consumption of sugary or starchy foods (15) and activate proinflammatory transcription factors, which can both disrupt glycemic control and increase the risk of diabetic complications (16). Next, a rising neighborhood foreclosure rate might erode social support if several households in a tight-knit community lose their homes and are forced to move outside the area. Social capital, which is the collective value of all social networks and norms of reciprocity, can influence health-related behaviors and access to health services and affect psychosocial processes (17). Finally, an increase in the foreclosure rate in one's neighborhood could have a spillover effect on wealth and reduce resources available to manage care. Patients with diabetes can incur high out-of-pocket costs because management of diabetes requires regular screenings, medications, and treatment of complications (11).

We hypothesized a positive relationship of community-level foreclosure rates with HbA1c and the likelihood of poor glycemic control (HbA1c ≥ 9%) among patients with diabetes. Given prior evidence that suggested that the health of persons with public health insurance is most vulnerable to economic shocks, we stratified our results by type of health insurance to test the hypothesis that the magnitude of the effect is greater among those with Medicaid.

METHODS

Study design and subjects

The clinical data came from the Diabetes Registry of Kaiser Permanente Northern California (KPNC), an integrated health-care delivery system with more than 3 million members (18). California was chosen for the study setting because it was one of the states with the highest foreclosure rates. The clinical data was collected from KPNC clinics over a 4-year period (2007–2010) from ambulatory patient visits to KPNC clinics by adults 18 years of age or older with diabetes (n = 295,544). We excluded patients with type 1 or unknown type diabetes (n = 11,760), cancer within the study period or 1 year prior (n = 19,097), and histories of lower extremity amputation (n = 3,138) and pregnancy (n = 2,893) within the study period and 1 year prior.

Patients lived in one of 9 Bay Area counties that contained or had KPNC facilities near county borders. Patients with at least 1 valid geocoded address record in 2007–2010 were retained for analysis. Because of patient privacy concerns, researchers were only provided the coordinates of the patient's residential census-block centroid. We excluded 6.5% of the subjects from the analysis because they had only a single HbA1c measurement over all 4 years. The institutional review boards of Kaiser Permanente Northern California and University of California, Berkeley, approved this study.

Health outcomes

The outcome for the present study was the annual average of HbA1c tests results from 2007 through 2010. This test measures the average plasma glucose concentration of the patient over the past 1–3 months. The average number of HbA1c tests per patient was 8.1 (range, 4–12) over the 4-year period. As an alternative specification, we created an indicator variable for whether the patient had poorly controlled diabetes in each year (at least 1 measurement of HbA1c ≥ 9%).

Foreclosure measures

We defined foreclosure as the culminating event in the process in which the deed of a property is transferred to the new owner. Events upstream of the completed foreclosure, such as notice of default, were not included in this study. We compiled address-level data on all residential foreclosure deeds filed in the 9 Bay Area counties between 2006 and 2009 from DataQuick, a private real estate research company (now CoreLogic; http://www.corelogic.com). We used ArcGIS (ArcGIS, version 10, Environmental Systems Research Institute, Redlands, California) and the package Data Scientist Toolkit in R (R Foundation for Statistical Computing, Vienna, Austria) to assign geographic coordinates to the foreclosures. Less than 1% of the foreclosure addresses were excluded because they were not geocodable. The primary exposure of interest was the annual number of foreclosures divided by the number of housing units per block group using estimates from the 2000 US Census.

Covariates

We collected demographic data, including patient Medicaid insurance status in each year, sex (female or male), and race/ethnicity (Asian, Non-Hispanic white, black) from electronic health records. Time-varying neighborhood-level covariates were collected from 2006 to 2009. We controlled for mean zip code–specific housing sales price data from DataQuick and the county-level unemployment rate from the Local Area Unemployment Statistics (LAUS) database (19).

A time-invariant indicator for movers was created for those who reported at least 2 different, valid addresses between 2006 and 2009. A measure of the proportion of housing units occupied by owners in each individual's census-block group from 2005 to 2009 was created using the American Community Survey 5-year estimates (20).

Statistical methods

To examine the relationship between foreclosure rates and HbA1c, we specified a series of models to relate mean individual HbA1c levels in year *t* to the proportion of housing units in foreclosure in the prior 1–23 months (referred to here as year $t-1$). The general form of the model was specified as follows:

$$Y_{it} = \beta_o + \beta_1 F_{it-1} + \beta_2 \mathbf{Z}_{it-1} + \beta_3 \mathbf{X}_i + \beta_4 year\ D_t + u_i + v_{it},$$

where Y_{it} is a measure of the mean HbA1c level of individual *i* in year *t*; F_{it-1} is one of the measures of foreclosures for individual *i* in year $t-1$; $\mathbf{Z}_{it-1}$ is a vector of lagged area level controls for individual *i* in year $t-1$ (unemployment, housing prices); $\mathbf{X}_i$ is a vector of individual time-invariant covariates; *yearD* are dummies for year *t*; u_i is an individual fixed-effect; and v_{it} is the time and individual specific error term.

We used fixed- and random-effects estimators to reduce omitted variable bias that might be present in traditional ordinary least squares estimators. We did not assume that all the variables that are common to both the community foreclosure rate and individual health were observed in the above equation.

We first used an individual fixed-effects estimator by including a fixed effect for each individual (u_i in the above model) to control for time-invariant confounding by design. The variables contained in $\mathbf{X}_i$ are fully collinear with the u_i and cannot be estimated or influence the coefficients.

Next, we used a random-effect estimator in which u_i was a random effect for each individual that was assumed to be uncorrelated with the foreclosure rate. The random-effects estimator is more efficient than the fixed-effects estimator and is preferred if it is consistent; however, it will be inconsistent if F_{it-1} is correlated with unobserved components in u_i. We used a Hausman test to compare model specifications for consistency (21). We also estimated the effects of foreclosure on HbA1c levels among individuals younger than 65 years of age who used Medicaid in order to mirror the study by Currie and Tekin (5).

Sensitivity analyses

A series of alternate specifications were fit to assess the robustness of the effects to foreclosure measure, model specification, attrition, and lag length. First, we created a measure of the foreclosures rate within the patient's block to proxy the length of an average block (100 m), the distance at which a foreclosure is expected to have spillover effects on the values of neighboring properties (22). We also used the absolute number of foreclosures within a 1-km Euclidean radius from the patient's block centroid, a buffer that represented roughly a 10-minute walking distance.

Because this is an unbalanced panel and not all individuals have clinical measurements for all years, we were concerned that our models might be biased if an unobserved factor that caused an individual to skip an outpatient visit was correlated with their exposure to foreclosures. We therefore re-estimated our models with a balanced panel. Next, we used 2 tests to look at observed randomness of attrition bias in this sample (23, 24). We re-ran our models using inverse probability of attrition weighting to reduce observable attrition bias.

A second type of attrition occurred because our primary predictor was measured at the block-group level and patients moved during the study period. If an individual's reason for moving was related to health status and exposure to foreclosures, our estimates might be biased. We first ran our models on the full population with an interaction term for those who moved (movers), and then because the interaction terms were statistically significant, we re-estimated our models with those who stayed in the same address for all 4 years. In order to provide context to the extent of bias from these types of attrition, we separately estimated the probability of 1) number of all patients visits at which HbA1c was measured, 2) moving, and 3) attrition as a function of the prior year's foreclosure rate and covariates above.

Finally, in the absence of any prior knowledge about the appropriate lag period, alternative lag periods were fit. The contemporaneous model included HbA1c measurements 11 months before and 11 months after a foreclosure, and a model with a 2-year lagged foreclosure rate included HbA1c measurements from 13 to 35 months after a foreclosure. All statistical analyses were performed with Stata, version 13 (StataCorp LP, College Station, Texas) in 2015.

RESULTS

Descriptive statistics

There were 105,930 individuals in the present study who met the inclusion criteria above and had at least 2 measures of HbA1c from 2007 to 2010. A majority (57.8%) of the sample was clinically observed in all 4 years, and (17.3%) of the individuals moved at least once during the study period.

The mean HbA1c was 7.23%, and the within-person standard deviation was 0.68 (Table 1). The average probability of poor control (HbA1c $\geq$ 9%) was 15.3%, and the average within-person standard deviation was 22.3%.

The foreclosure rate began to rise in late 2006 and peaked in the summer of 2008. The mean number of foreclosures was 0.28 in the average block (20 homes per block), 6.88 in the average block group (2,200 homes per block group), and 26 in the 1-km buffer. The within-person standard deviations were 0.6 foreclosures per block, 9.0 per block group, and 35 per 1-km buffer over the period.

Housing prices began to decline steeply in the summer of 2008. The average value of homes in each zip code was \$537,699, with a within-person standard deviation of \$100,938. The unemployment rate nearly doubled from May 2008 to May 2009. The mean county unemployment rate was 6.2%, and the within-person standard deviation was 2.3%.

Of the 103,096 individuals clinically observed at baseline in 2007, 24% (n = 24,480) had no measures of HbA1c in 2009 or 2010 (Table 2). These individuals were younger and were more likely to be white and male, to move at least once during the period, and to live in a poorer neighborhood with lower housing prices. In addition, they had a higher

Table 1. Mean and Within- and Between-Individual Standard Deviation Values for Participant Characteristics, Diabetes Registry of Kaiser Permanente Northern California, 2006–2010

Variable	Mean	Standard Deviation		
		Overall	Between	Within
HbA1c	7.23	1.43	1.34	0.68
Probability of poor control, %	15.30	36.00	30.20	22.30
No. of HbA1c tests	1.40	1.23	0.67	1.05
Body mass index[a]	31.15	7.02	6.97	1.23
No. of block foreclosures per 20 homes	0.28	0.85	0.70	0.58
No. of block group foreclosures per 2,200 homes	6.88	13.28	10.05	9.02
No. of foreclosures per 1 km	26.03	43.22	26.46	34.93
Mean zip code housing prices, US$	537,699	223,544	200,504	100,938
County unemployment rate, %	6.20	2.40	0.90	2.30

Abbreviation: HbA1c, glycated hemoglobin.
[a] Weight (kg)/height (m)^2.

baseline HbA1c levels, a had higher probability of poor control, and experienced higher block group foreclosure rates.

Those who had been exposed to a foreclosure in their neighborhood had slightly higher HbA1c levels, were younger, and were less likely to be non-Hispanic white and to have lived in a neighborhood with a higher poverty rate and lower housing prices (Table 3) than were those who had not.

Block group foreclosure rate and HbA1c

Results from the main models for HbA1c are shown in Table 4. In the individual fixed-effects models, there were no statistically significant associations of changes in block group foreclosure rate with change in mean HbA1c levels (models 1–5). Although there was a statistically significant (albeit not clinically substantive) association in the unadjusted model (model 1), which showed a decline of 0.03% in HbA1c (i.e., better glycemic control) for every 1% increase in block group foreclosure rate, the addition of year fixed effects (model 2) attenuated the association, and the year fixed effects became statistically significant. The addition of covariates, the county unemployment rate, and zip code–specific housing prices, attenuated the estimate even further (model 3; $\beta = -0.00005$, 95% confidence interval (CI): −0.009, 0.008). The complete case approach (model 4) and the model with inverse probability of attrition weights (model 5) yielded similar insignificant results.

In the random-effects model (model 6), for every 1% change in the block group foreclosure rate, HbA1c increased by 0.01%, an association that was not clinically meaningful. The addition of individual time-invariant covariates $\mathbf{X}_i$ did not change our estimates. When comparing model 6 with model 3, we rejected the null hypothesis of the Hausman test, which indicated that the fixed-effects model was preferred to the

Table 2. Baseline Characteristics of Study Participants, by Attrition Status, Kaiser Permanente Northern California, 2007

Characteristic	All Participants (*n* = 103,096), mean (SD)	Participants With Missing Values[a] (*n* = 24,480), mean (SD)	Participants With No Missing Values (*n* = 78,616), mean (SD)
Block group foreclosures rate, %	18.7 (29.0)	19.1 (29.5)	18.4 (28.8)
HbA1c	7.3 (1.4)	7.5 (1.7)	7.2 (1.3)
Poor control, %	16.7 (37.3)	20.7 (40.5)	14.9 (35.6)
Age, years	62.1 (12.8)	61.0 (14.3)	62.5 (11.8)
Female, %	47.2 (49.9)	45.8 (49.8)	47.8 (49.9)
Non-Hispanic white, %	48.1 (49.9)	49.2 (49.9)	47.8 (48.2)
Poverty in block group, %	9.3 (9.3)	10.0 (9.6)	9.0 (8.9)
Unemployment rate, %	4.6 (0.4)	4.6 (0.4)	4.6 (0.4)
Median housing prices, US$	611,514 (015,189)	606,680 (188,678)	613,656 (126,189)
Ever moved, %	16.0 (36.6)	20.6 (40.4)	14.5 (35.2)

Abbreviations: HbA1c, glycated hemoglobin; SD, standard deviation.
[a] Any individual who had no HbA1c measurement in 2009 and 2010 or in 2010.

Table 3. Baseline Characteristics of Participants and Their Neighborhoods, According to Exposure to Foreclosures, Kaiser Permanente Northern California, 2007

Characteristic	Full Cohort (n = 120,857), mean (SD)	Never Exposed to Foreclosures Within Block (n = 57,039), mean (SD)	Ever Exposed to Foreclosures Within Block (n = 63,818), mean (SD)	P Value for Difference
HbA1c	7.3 (1.4)	7.2 (1.4)	7.4 (1.5)	<0.01
Body mass index[a]	31.1 (6.9)	30.8 (6.8)	31.5 (6.9)	<0.01
Age, years	61.1 (12.8)	62.4 (12.8)	59.9 (12.6)	<0.01
Female, %	46.7 (49.9)	46.4 (49.9)	47.0 (49.9)	0.34
White, %	48.1 (49.9)	52.5 (49.9)	43.9 (49.6)	<0.01
Black, %	12.5 (33.1)	9.4 (29.2)	15.4 (36.1)	<0.01
Block poverty, %	9.4 (9.3)	8.6 (8.9)	10.1 (9.5)	<0.01
Unemployment, %	4.6 (0.4)	4.5 (0.4)	4.6 (0.4)	0.07
Mean housing sales prices, US$	610,536 (188,363)	698,764 (150,215)	554,972 (143,822)	<0.01

Abbreviations: HbA1c, glycated hemoglobin; SD, standard deviation.
[a] Weight (kg)/height (m)^2.

random-effects model. There was no statistically significant association of the foreclosure rate with HbA1c level among those younger than 65 years of age who used Medicaid for at least 1 year (n = 1,470; 95% CI: −0.13, 0.05).

Sensitivity analyses

Several other specifications yielded similar null results (not shown). The individual fixed-effect logit model that we used to estimate the probability of poor control generated similar statistically insignificant results (β = 0.01, 95% CI: −0.02, 0.05). Results from the models fitted with block foreclosure rate, (β = 0.0003, 95% CI: −0.001, 0.001) and absolute foreclosures per 1 km (β = −0.00001, 95% CI: −0.0001, 0.0001) as alternative predictors were also statistically insignificant. Additionally, the models were robust to alternate lag structures. Results from the model fitted with a contemporaneous foreclosure rate (β = 0.005, 95% CI: −0.009, 0.020) and the model fitted with a 2-year lagged foreclosure rate (β = 0.004, 95% CI: −0.004, 0.013) were statistically insignificant. Additionally, the estimates for those who did not move during the time period were identical to those for the full sample that contained those who moved.

There was no association between the prior year's foreclosure rate and attrition in the next year (β = 0.001, 95% CI: −0.002, 0.004) or moving in the next year (β = 0.001, 95% CI: −0.001, 0.004). However, for each 1% increase in the block group foreclosure rate in the prior year, there was a 0.011% decline in number of visits (95% CI: −0.020, −0.002).

Table 4. Linear Regression of Block Group Foreclosure Rate on Glycated Hemoglobin, Diabetes Registry of Kaiser Permanente Northern California, 2006–2010

Model	Lagged[a] Block Group Foreclosures per 100 Homes, β (SE)	Lagged[a] Unemployment Rate, β (SE)	Lagged[a] Mean Housing Price in Thousands, β (SE)	Intercept, β (SE)	No. of Individuals	No. of Observations
1[b]	−0.03 (0.004)[c]			7.2 (0.002)[c]	107,242	342,672
2[b,d]	−0.0005 (0.004)			7.3 (0.003)[c]	107,242	342,672
3[b,d]	−0.00005 (0.0004)	−0.006 (0.006)	0.00008 (0.00003)	7.3 (0.030)[c]	107,242	342,672
4[b,d,e]	−0.007 (0.004)	0.002 (0.006)	−0.00001 (0.00003)	7.3 (0.041)[c]	61,748	240,585
5[b,d,f]	−0.006 (0.005)	−0.005 (0.006)	−0.00001 (0.00003)	7.3 (0.041)[c]	91,305	397,599
6[b]	0.01 (0.000)[c]	−0.01 (0.000)[g]	−0.00 (0.000)[c]	7.6 (0.032)[c]	107,242	342,672

Abbreviations: SE, standard error.
[a] One-year lag.
[b] Model includes individual fixed-effects.
[c] $P < 0.01$.
[d] Model includes year dummy variables.
[e] Model uses complete cases only.
[f] Model is P weighted.
[g] $P < 0.05$.

DISCUSSION

We undertook the present study because of previous reports of a relationship between foreclosure rates and health status. In the first investigation of glycemic control, we found no evidence of an association with foreclosure rates. Our estimates were robust across varying spatial constructs of foreclosures and within strata of populations, which we hypothesized would vary in their sensitivities to this type of economic shock.

Our results differ from prior studies in which investigators found a positive relationship between increasing neighborhood foreclosure rates and poor health (25). We believe that the individual fixed-effects approach attenuated estimates by reducing bias away from the null if, for example, an unobserved time-invariant factor such as individual debt simultaneously increased the community foreclosure rate and individual HbA1c levels (26). Individual wealth or debt is related to poor health and has a direct effect on the probability of foreclosure of one's home.

As in the prior study by Currie and Tekin (5), we found that the foreclosure crisis had little or no effect on those who were privately insured. However, in contrast to their findings, we did not observe an effect among those with public health insurance either. This suggests that the nature of KPNC's integrated delivery system might have buffered these individuals from externalities of the foreclosure crisis, that our outcome measure (HbA1c) was less sensitive to economic shocks, or that our study was underpowered or varied because of geographic context.

There are important limitations to our study. First, we were not able to observe those who stopped seeking health care during the study period. It is possible that patients with diabetes who were most impacted by the foreclosure crisis dropped out of our sample. To address this concern, we included inverse probability of attrition weights in our regression models to reduce nonrandom attrition caused by observable factors. If we believe that those who stopped seeking health care were worse off than those who remained in our sample, our main results should be interpreted as a conservative estimate of the association between foreclosure rates and HbA1c levels, and therefore the true magnitude might be larger. Our results suggest that the degree of bias is likely small; individuals who lived in block groups in which there was an increase in the foreclosure rate of 1% had an average 0.002–0.2 fewer HbA1c visits in the next year. The rare individuals who experienced a large increase—on the order of 50%—had an average of 0.1–1 fewer visits in the next year.

Next, the period of observation of 2006–2010 might not have been long enough to reject the null or there may have been too much noise in the timing of the lag period. The lag period from foreclosure to health was 1–23 months in our data, meaning that some individuals may have had insufficient time for their HbA1c to respond to the shock, whereas others were exposed to foreclosure too far in the past. In addition, there might still have been unmeasured residual confounding; if available, inclusion of individual-level measures of income and employment status would have strengthened our results. Our results may not be generalizable outside of our population. Although the external validity of the study is improved by of the relatively large market share (≈30%) of KPNC, this region has a high penetration of managed health-care delivery systems, and this limits the generalizability of the results to other states with different financing and delivery models. Finally, the validity of our spatial construct is unknown. Even though we used several spatial specifications of foreclosures, we have little evidence that individuals across various communities interact with their environment in the same way. Prior studies have shown that visibility of foreclosures varies based on whether the property is real estate owned (i.e., owned by a lender after an unsuccessful attempt to sell at a foreclosure auction) and at different stages of the foreclosure process (27).

There are several ways to interpret the null results of the present study. Our outcome of interest, HbA1c level, may be insensitive to economic stressors. Alternatively, we might have been able to observe an association in an uninsured population that was undetectable in this insured managed care population because the care delivery model has effectively buffered this chronically ill population from environmental stressors. The former intimates that patients with diabetes need not worry about neighborhood foreclosures, whereas the latter suggests a possible intervention for diabetes management in communities hit hard by foreclosures. More research is needed to determine whether these findings are robust across clinical populations with different models of health-care delivery and financing and using individual-level exposure to foreclosure rather than the contextual measure we used in this study.

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