J Urban Health (2018) 95:423–430
https://doi.org/10.1007/s11524-018-0236-8

Transitions between Housing States among Urban Homeless Adults: a Bayesian Markov Model

Ben Alexander-Eitzman · Carol S. North · David E. Pollio

Published online: 5 April 2018

Abstract The purpose of this study is to explore how marginalization, substance abuse, and service utilization influence the transitions between streets, shelters, and housed states over the course of 2 years in a population of urban homeless adults. Survey responses from three yearly interviews of 400 homeless adults were matched with administrative services data collected from regional health, mental health, and housing service providers. To estimate the rates of transition between housed, street, and shelter status, a multi-state Markov model was developed within a Bayesian framework. These transition rates were then regressed on a set of independent variables measuring demographics, marginalization, substance abuse, and service utilization. Transitions from housing to shelters or streets were associated with not being from the local area, not having friends or family to count on, and unemployment. Pending charges and a recent history of being robbed were associated with the shelters-to-streets transition. Remaining on the streets was uniquely associated with engagement in "shadow work" and, surprisingly, a high use of routine services. These findings paint a picture of unique and separate processes for different types of housing transitions. These results reinforce the importance of focusing interventions on the needs of these unique housing transitions, paying particular attention to prior housing patterns, substance abuse, and the different ways that homeless adults are marginalized in our society.

Keywords Homeless · Adult · Housing · Bayesian · Substance abuse

B. Alexander-Eitzman (✉) · C. S. North · D. E. Pollio
Appalachian State University, Boone, NC, USA
e-mail: alexandereitzmanbe@appstate.edu

Introduction

Housing instability and periods of homelessness are associated with a plethora of negative consequences including increased mortality, higher rates of physical and mental health problems, and legal problems [1–6]. The recent economic decline has precipitated a new crisis in emergency rooms and other service settings that work with a rising tide of adults and families who are either homeless or near homeless, often with few resources to address the underlying problems associated with homelessness [7, 8]. At the same time, our efforts to serve this population often result in narrowly focused and static responses to what is in reality a dynamic and complex series of interrelated problems for both health practitioners and other service providers. Effective responses will need to build on a more complete understanding and dynamic model of homelessness, marginalization, and service use. Marginalized individuals are often subject to multiple exclusions from social, spatial, financial, and legal resources [9]. The purpose of this study is to explore how marginalization, substance

abuse, and service utilization influence the transitions between streets, shelters, and housed states over the course of 2 years in a population of urban homeless adults.

Methods

This study used longitudinal secondary data collected from the SUNCODA project (Service Use, Needs, Costs and Consequences among Drug Abusing homeless). It was funded by a grant to Dr. North by the National Institute on Drug Abuse (DA 10713). Researchers systematically recruited homeless adults at 11 city night shelters, one daytime shelter, and along 16 different street routes between 1999 and 2001. At shelter sites, potential participants were randomly selected from current rosters weighted for current census and briefly screened regarding housing status. Participants were considered homeless if they (a) reported no current stable residence and (b) had spent the 14 previous nights in a public shelter, or in a park, an abandoned building, car, on the streets, or some other unsheltered location without a personal mailing address. Nights staying with relatives or friends ("doubled up") counted only if the individual had remained in such a situation for no more than six of the previous 14 nights. Also, nights staying in an inexpensive hotel or motel counted only if the individual had spent fewer than 30 consecutive days at that location. Of all eligible persons, 92% agreed to participate in the study. Participants were contacted for a second and third full follow-up interview at 12 and 24 months after the initial baseline contact. The entire timeframe from the beginning of recruitment to the last interview was 1999–2003. All procedures used in this study were approved by the appropriate institutional review boards at participating universities.

Survey Information

All interviews (baseline, year 1, and year 2) included the sociodemographic sections from the National Comorbidity Study [10], psychiatric diagnostic sections from sections from the Diagnostic Interview Schedule (DIS-IV) for the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; DSM-IV) [11, 12], the alcohol and drug abuse sections of the Composite International Diagnostic Interview-Substance Abuse Module [13], and the residence sections of the DIS Homeless Supplement [14].

Housing Status Changes over Time

For the purposes of this study, housing status was considered as a transient state and was operationalized as one of three qualitatively different housing situations: (1) "living on the street," (2) "living in shelters," or (3) "housed". At each of the three interview time points participants were asked "In the past 12 months, which one of these places was your usual sleeping place?" Living in one's own apartment or house and living with someone else was categorized as "housed". Staying in cheap motels, shelters, boarding houses, hospitals, or jails was considered as "shelters or other institutions". Lastly, "streets" status included sleeping in parks, cars, abandoned buildings, and similar locations not designated for sleeping in.

Substance Abuse and Mental Illness

Meeting the criteria for abuse or dependence as defined by the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; DSM-IV) [12] was coded for both cocaine and alcohol. Also, the definition of "serious mental illness" (SMI) used in the article captures the influence of any lifetime history of a diagnosis of any of the following: schizophrenia, major depressive disorder, bipolar disorder, panic disorder, generalized anxiety disorder, and post-traumatic stress disorder.

Marginalization Variables

Indicators of marginalization were divided into the three primary domains of social, legal, and financial marginalization. Social marginalization was measured by connections to family and friends, number of serious interpersonal conflicts, and connections to a geographic area. Current connections to family and friends are captured by the questions, "Can you count on any of your relatives for help?" and "Do you have any friends you can count on for help?" Also included was a measure of serious interpersonal conflicts experienced over the past year. As an indicator of how connected an individual is with the surrounding area (and, by proxy, the local service system), a variable was created from the question, "How long have you lived continuously in [this city]?"

Legal marginalization was measured by questions about recent legal problems including current or pending charges and any detention (by law enforcement) reported over the previous month. Both of these questions were

asked at every annual assessment. Victimization refers to instances where the individual has been robbed over the past year. Financial marginalization was measured by the presence of illegal or non-standard sources of income such as selling drugs, prostitution, stealing, or panhandling were coded as "shadow work".

Services Data

In addition to answering survey questions, study participants also consented to release any information collected from regional service providers for 2 years after the initial baseline contact. Administrative data was collected from three different sources: (1) the city sponsored shelter and transitional housing Management Information System (MIS), (2) manual review of intakes for shelter services not participating in the city MIS, and (3) the state Purchase of Service (POS) databases. The POS database included contacts with regional hospitals, emergency rooms, outpatient mental health and substance abuse treatment facilities, and case management services. Service counts were divided into two types: "Routine" (substance abuse and mental health outpatient visits and case management) and "Emergency" (inpatient hospitalization, detoxification, and emergency room visits). Because there was a relatively high number of zero values in this data series, the service counts per year were categorized into "none," "low," (1–20 contacts) and "high" (more than 20 contacts).

Analysis

In this study, a Bayesian analytical strategy was used. This approach has a number of advantages in working with complex, longitudinal, and multilevel models as we describe here. The utility of these methods has been demonstrated in a wide range of research applications and the methods have been outlined in a number of texts on the subject [15–18]. The multi-state Markov estimates the probability of making transitions between different states over some time period and the impact of covariates on these transition probabilities [19]. In this study, transitions between different housing states (housed, streets, shelters) are assumed to follow a simple first-order Markov process with no constraints on transitions between the states in the model, meaning that individuals may move from any state to any other state in the two intervening time periods. Individual transition probabilities between housing states were modeled contingent on the demographic, mental health, and marginalization covariates. Because of the high likelihood of correlation between parameters for all the different combinations of transition probabilities, a multivariate normal prior was used with a fairly non-informative covariance term which was, in turn, drawn from a Wishart prior [20].

Missing Data

The R package MICE (Multivariate Imputation by Chained Equations) was used to generate eight imputed datasets from the original data [21]. Regression models were independently run on each imputed data set and then the imputation results were pooled into a single set of point estimates and standard errors which were corrected to reflect what the variance of all of the imputations together. Recoding, descriptive analysis, and other data manipulation was completed using the R statistical language, version 3.0.0 [22] and Bayesian analysis used the WinBUGS, version 1.4.3 software [23].

Results

Sample Description

The sample used in the SUNCODA study is similar to samples in several other previous studies of street and shelter populations in large urban areas, enhancing the generalizability of results of the proposed study. Table 1 shows a selection of variables from the baseline interview grouped by usual housing status over the previous year. Of the 394 participants with full baseline information, 282 (72%) were interviewed 1 year later, 279 (71%) 2 years later, and 251 (64%) were interviewed at every time point. Previous analysis of missing compared to non-missing participants on baseline demographic variables showed little significant difference between the two groups [24]. The numbers of participants in each housing state at each time point as well as the proportion that make transitions between housing states can be seen in Fig. 1.

Base Model of Transition Probabilities

A base model of transition probabilities is produced from aggregating the two transition periods (baseline to year 1 and year 1 to year 2). Probabilities for each transition state change for the reported usual housing

Table 1 Participant profiles by baseline housing status

Characteristic	Total sample ($n = 394$), % or mean ± SD	Housed ($n = 156$), % or mean ± SD	Shelters ($n = 171$), % or mean ± SD	Streets ($n = 67$), % or mean ± SD
Age	41.0 ± 10.4	38.4 ± 11.0	43.4 ± 9.7	41.0 ± 9.3
Male	75	60	84	88
White	18	11	19	34
Married	6	9	2	7
Employed	29	35	29	18
Lifetime diagnosis				
Alcohol	61	52	65	75
Cocaine	44	38	47	48
SMI	49	51	42	64

Lifetime diagnosis of alcohol and cocaine refers to a diagnosis of either dependence or abuse

SMI serious mental illness

statuses over for the prior year are shown in Fig. 2. Over time, there was a general movement toward housing as is observed in higher probabilities of going from shelters to housing (0.47) and streets to housing (0.30) when compared to movements away from housing. Also, there was a relatively high probability of staying housed (0.70). There was a relatively small probability of moving to the streets from a housing situation (0.06) or to the streets from a shelter (0.09). Individuals who were already on the streets had a 0.40 probability of staying on

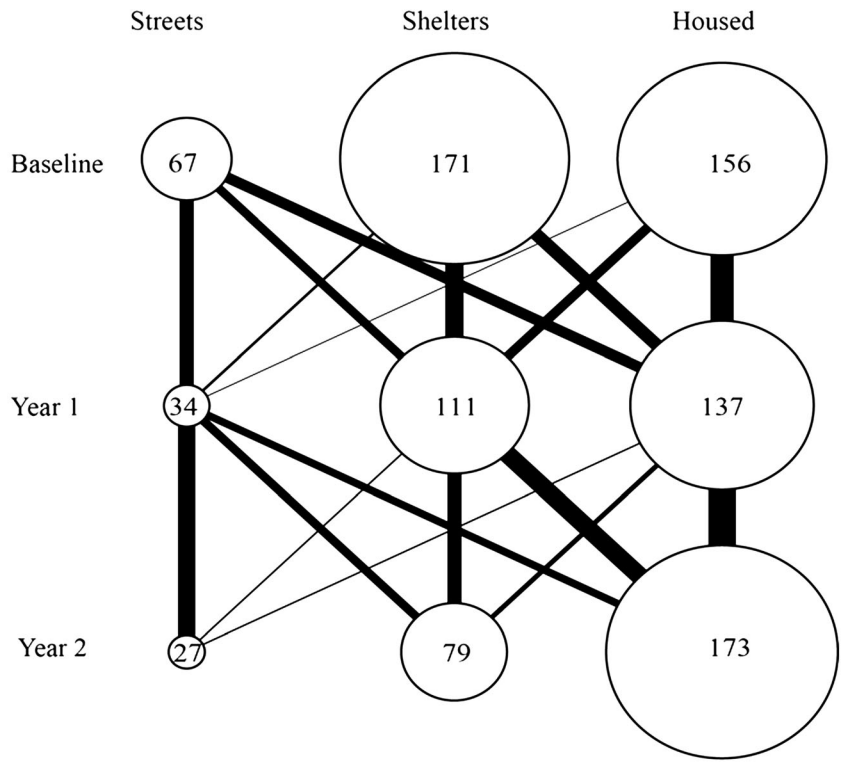

Fig. 1 Number of participants that report their usual living situation as streets, shelters, or housed at each time point and transitions between housing states

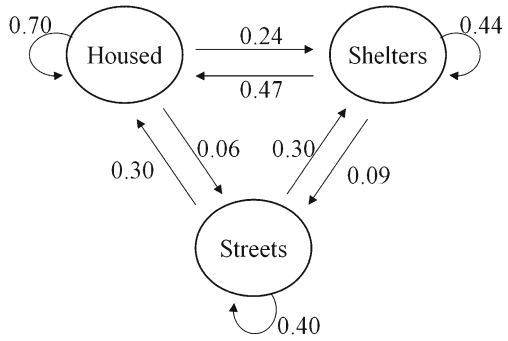

Fig. 2 Base model of housing state transition probabilities

the streets and in a similar manner, people in shelters had a 0.44 probability of staying in shelters from year to year.

Inference from Pooled Imputations for Housing Transitions

Covariates related to substance abuse, marginalization, and demographics were then added in as predictors for each of these transition probabilities on each of the imputed data sets independently using the WinBUGS Bayesian simulation program. All models showed stability after a 30,000 initial burn-in period. After this, 5000 additional samples were collected and pooled for inference. The Gelman-Rubin shrink factor, calculated as the proportion of between-chain and within-chain variance, was used to determine when convergence had been reached for each set of simulations [25]. In this study, all chains had Gelman-Rubin factor ratios of below 1.10 (1.00 is ideal). For the figures below, the reported estimates and credible intervals are standardized (non-exponentiated) estimates of odds ratios allowing direct comparison across parameters. Credible intervals that cross the zero indicate a high (95%) likelihood that a parameter has no influence on the probability for that particular transition between housing states.

Figure 3 shows the estimated influence of each parameter on transition probabilities of either moving from shelter locations to housing or remaining housed. Being able to count on family for support and a high use of routine services along with moderate use of emergency services (as opposed to no use) were all associated with higher probabilities of moving from shelters to housing. Unique to this transition was the influence of being robbed over the previous 12 months, which was associated with lower probabilities of moving out of shelters. Higher probabilities of staying housed were associated with having a diploma, being from the local area, and being able to count on friends and family. Participants who had a history of lifetime convictions or who had pending charges were less likely to remain housed over the course of the study. Also, meeting criteria for a diagnosis of alcohol or cocaine abuse or dependence over the previous year was associated with lower probabilities of remaining in housing.

The variables that influence transitions in the opposite direction (towards the streets or staying on the streets) have very different profiles and are shown in Fig. 4. Unemployment was associated with all types of transitions to street locations. Moving from housing to street locations was associated with not being from the local area, not being able to count on friends or family, and past year alcohol abuse or dependence as well as cocaine abuse or dependence. A high utilization rate for emergency service types such as inpatient hospitalizations, detoxification centers, and emergency rooms was associated with lower probabilities of moving from housing to streets.

But not being from the local area and not being able to count on family for help increased the base probability of making a transition from shelters to street locations. This transition probability was also predicted by having pending charges and being robbed in the past year. This particular transition was uniquely associated with any lifetime serious mental illness reduced the probability of moving from shelters to streets. Both low and high levels of routine service use were associated with a lower probability of moving from shelters to streets. Low levels (1–20 contacts over the course of a year) of emergency services use was associated with a lower probability of moving from shelters to street locations.

The last transition of interest was the probability of staying in street locations. Demographically, the groups that had higher probabilities of staying in street locations were white, male, older, and more educated. Engaging in shadow work and having pending legal charges both predicted a higher probability of remaining on the streets. No substance abuse/dependence variable was associated with higher or lower probabilities of remaining on the streets. Lastly, remaining on the streets was associated with a high use of routine types of services (20 or more routine visits) and, in contrast, a low use (1–20 routine visits) was associated with a lower probability of remaining on the streets over time.

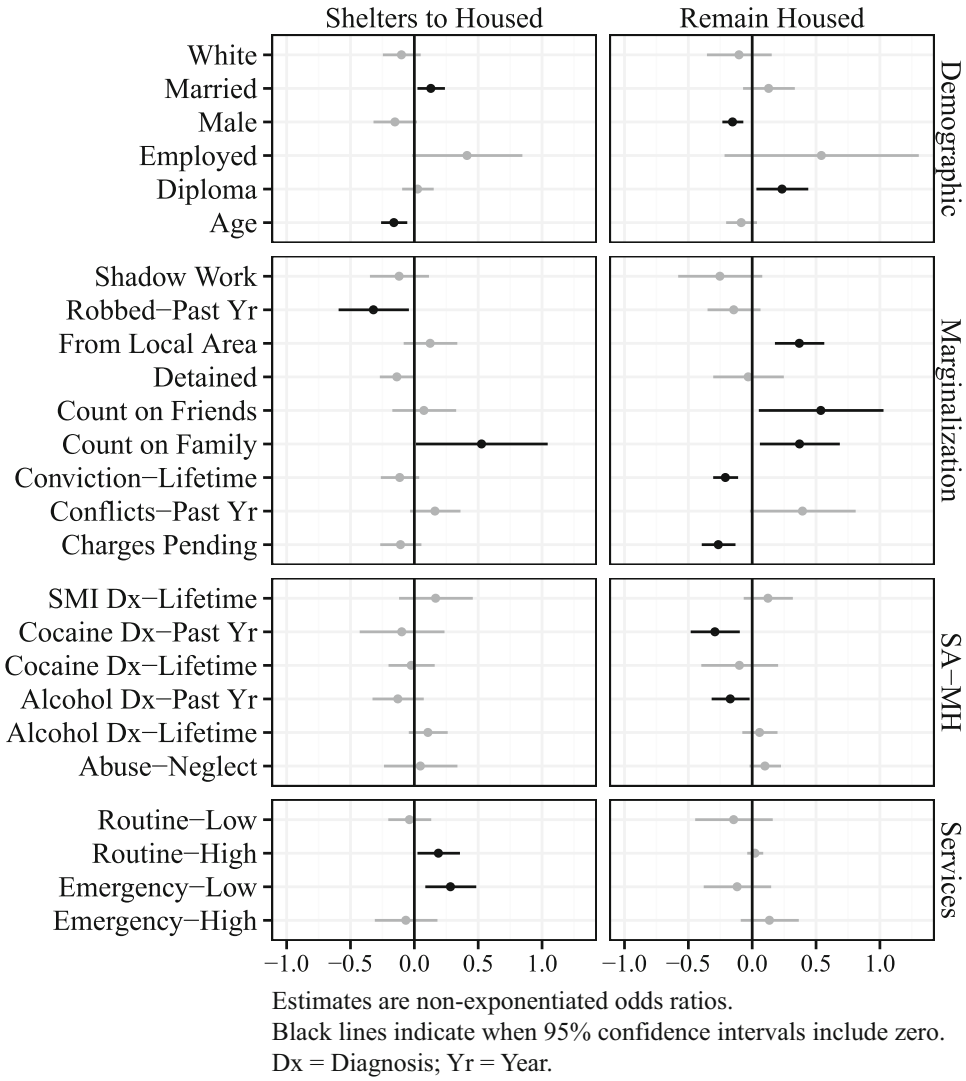

Fig. 3 Multivariate model estimates of the influence of parameters on transitions to housing

Discussion

This study used a Markov multi-state transition model to estimate the influence of marginalization, substance abuse, and service utilization on the transitions between housing states in an adult urban population. As might be expected, current year diagnosis of substance abuse or dependence and multiple indicators of marginalization were associated with a higher probability of moving from a housed situations to street or shelters. Conversely, staying housed was associated with being able to count on friends and family and coming from the local area. Legal problems of any sort were associated with a lower chance of remaining housed over time. This reinforces the common theory of alienation and marginalization as an important influence on either keeping or losing housing. This dynamic is further supported by the unique position of the street stable group which was the only transition influenced by engagement in shadow work such as selling drugs, prostitution, or panhandling.

The patterns of service utilization were not as predictable and were unique to each transition type. Both high utilization of routine services (more than 20 visits in a year) and low utilization (1–20 emergency type visits in a year) were associated with transitions from shelters to housing. This may be encouraging for service planners, as these connections to service settings are generally associated with moving towards housed

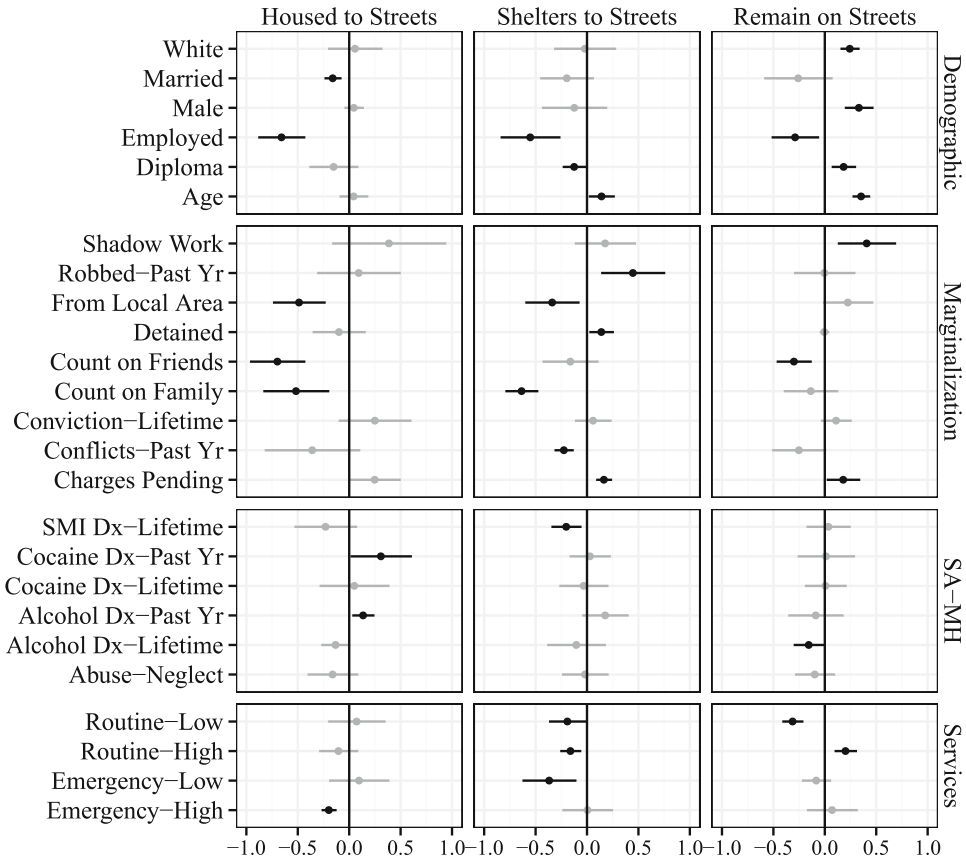

Fig. 4 Multivariate model estimates of the influence of parameters on transitions to streets or remaining on streets

status. These findings, however, do not support the notion that the street homeless are entirely service disconnected, as indeed they may be receiving a fair amount of support and case management.

The original SUNCODA study was designed to capture a probability sample of homeless individuals in an urban setting, but of course the sample in this study does not necessarily represent other regions or homeless populations such as those in dispersed rural settings. Also, when treated as a time series, there is an implicit assumption that the processes being examined (i.e., changes in housing status or marginalization) actually have real meaning when surveyed at one-year intervals. For example, housing status may change multiple times over the course of a year, revealing a very unstable pattern, but the overall usual housing status may still be marked as housed. More frequent assessments would address this issue but was beyond the scope of this study.

The findings of this study have important implications for working with people who become homeless, particularly in a large urban environment. First, we should be aware of distinct patterns of social, spatial, and economic isolation related to living on the streets in particular. Service providers and planners need to look beyond the one-size-fits-all combination of homeless services typical to most urban areas. For some adults, shelters and case management may provide just the combination of services needed to return to housed states, but for other groups who live in social, economic, and legal deserts, new pathways are needed that can provide some movement away from these harsh environments. Particular attention should be paid to the legal consequences or necessities of time spent on the streets such as legal charges, shadow work, and victimization. Interventions should also take into consideration the importance of social support and employment as both

of these factors had a consistent positive influence on transitions to housing.

In rethinking service systems to unique subpopulations of homeless adults, we must try to better understand the unique policy structures driving the legal, economic, and social problems associated with becoming and remaining homeless in urban settings. The necessities of surviving on the streets most likely reinforce a cycle of unstable housing, unemployment, victimization, and social isolation. Service system planners and administrators should continue to think about how system policies and processes such as anti-homeless laws and spatial placement of services can produce unintended consequences or enhance barriers to gaining housing.

Acknowledgements This research was supported by grants from the National Institute on Drug Abuse (DA10713 [North, Pollio], DA025782-01 [Alexander-Eitzman]).

References

1. Nickasch B, Marnocha SK. Healthcare experiences of the homeless. *J Am Acad Nurse Pract*. 2009;21:39–46. https://doi.org/10.1111/j.1745-7599.2008.00371.x.
2. Morrison DS. Homelessness as an independent risk factor for mortality: results from a retrospective cohort study. *Int J Epidemiol*. 2009;38:877–83. https://doi.org/10.1093/ije/dyp160.
3. Greenberg GA, Rosenheck RA. Jail incarceration, homelessness, and mental health: a national study. *Psychiatr Serv*. 2008;59(2):170–7. https://doi.org/10.1176/appi.ps.59.2.170.
4. Fischer SN, Shinn M, Shrout P, Tsemberis S. Homelessness, mental illness, and criminal activity: examining patterns over time. *Am J Community Psychol*. 2008;42:251–65. https://doi.org/10.1007/s10464-008-9210-z.
5. Oppenheimer SC, Nurius PS, Green S. Homelessness history impacts on health outcomes and economic and risk behavior intermediaries: new insights from population data. *Fam Soc*. 2016;97(3):230–42. https://doi.org/10.1606/1044-3894.2016.97.21.
6. Baggett TP, Hwang SW, O'Connell JJ, Porneala BC, Stringfellow EJ, Orav EJ, et al. Mortality among homeless adults in Boston. *JAMA Intern Med*. 2013;173(3):189–95. https://doi.org/10.1001/jamainternmed.2013.1604.
7. Pearson DA, Bruggman AR, Haukoos JS. Out-of-hospital and emergency department utilization by adult homeless patients. *Ann Emerg Med*. 2007;50:646–52. https://doi.org/10.1016/j.annemergmed.2007.07.015.
8. Rodriguez RM, Fortman J, Chee C, Ng V, Poon D. Food, shelter and safety needs motivating homeless persons' visits to an urban emergency department. *Ann Emerg Med*. 2009;53:598–602.e1. https://doi.org/10.1016/j.annemergmed.2008.07.046.
9. Fitzpatrick S, Johnsen S, White M. Multiple exclusion homelessness in the UK: key patterns and intersections. *Soc Policy Soc*. 2011;10(4):501–512. http://0-journals.cambridge.org.wncln.wncln.org/abstract_S147474641100025X. Accessed June 25, 2014.
10. Kessler RC, McGonagle KA, Zhao SY, Nelson CB, Hughes M, Eshleman S, et al. Lifetime and 12-month prevalence of Dsm-iii-R psychiatric-disorders in the United-States—results from the National-Comorbidity-Survey. *Arch Gen Psychiatry*. 1994;51(1):8–19.
11. Robins LN, Cottler LB, Compton W, Bucholz K, North CS, Rourke KM. *Diagnostic Interview Schedule for the DSM-IV (DIS-IV)*. St. Louis, MO: Washington University in St. Louis; 2000.
12. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. 4th ed. Washington, DC: Author; 1994.
13. Cottler L, Robins LN, Helzer JE. The reliability of the CIDI-SAM: a comprehensive substance abuse interview. *Br J Addict*. 1989;84(7):801–14.
14. North CS, Eyrich KM, Pollio DE, Foster DA, Cottler LB, Spitznagel EL. The homeless supplement to the diagnostic interview schedule: test-retest analyses. *Int J Methods Psychiatr Res*. 2004;13:184–91. https://doi.org/10.1002/mpr.174.
15. Congdon P. *Applied Bayesian Modelling*. Chichester, UK: Wiley; 2003.
16. Congdon P. *Bayesian Models for Categorical Data*. New York: Wiley; 2005.
17. Gelman A. *Bayesian Data Analysis*. Boca Raton, FL: CRC press; 2004.
18. Gill J. *Bayesian Methods: a Social and Behavioral Sciences Approach*. Chapman & Hall/CRC: Boca Raton, FL; 2002.
19. Frees EW. *Longitudinal and Panel Data: Analysis and Applications in the Social Sciences*. Cambridge, UK: Cambridge University Press; 2004.
20. Sung M, Soyer R, Nhan N. Bayesian analysis of non-homogeneous Markov chains: application to mental health data. *Stat Med*. 2007;26(15):3000–17.
21. Van Buuren S, Oudshoorn C. *Multivariate Imputation by Chained Equations: MICE V1.0 User's Manual*. TNO Prevention Center: Leiden, The Netherlands; 2000.
22. Ihaka R, Gentleman R. R: a language for data analysis and graphics. *J Comput Graph Stat*. 1996;5(3):299–314.
23. Lunn DJ, Thomas A, Best N, Spiegelhalter D. WinBUGS—a Bayesian modelling framework: concepts, structure, and extensibility. *Stat Comput*. 2000;10(4):325–37.
24. North CS, Pollio DE, Perron B, Eyrich KM, Spitznagel EL. The role of organizational characteristics in determining patterns of utilization of services for substance abuse, mental health, and shelter by homeless people. *J Drug Issues*. 2005;35(3):575–91.
25. Gelman A, Rubin DB. Inference from iterative simulation using multiple sequences. *Stat Sci*. 1992;7:457–72.