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Curr HIV/AIDS Rep. Author manuscript; available in PMC 2019 April 01.

Published in final edited form as:

Curr HIV/AIDS Rep. 2018 April ; 15(2): 113–119. doi:10.1007/s11904-018-0391-2.

Network-based Research on Rural Opioid Use: An Overview of Methods and Lessons Learned

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Abstract

Purpose—The purpose of this paper is to provide a thorough overview of methods used for recruitment, network data collection, and network data management in a network-based study of rural people who use drugs (PWUD), and to offer methodological recommendations for future research on rural drug use.

Recent Findings—The Social Networks among Appalachian People (SNAP) Study recruited a cohort of 503 rural PWUD via respondent-driven sampling (RDS) and has retained more than 80% of eligible participants over 7–9 years. SNAP has yielded important methodological insights, including that (1) RDS referral was non-random and disproportionately involved kin, and (2) interviewer-administered questionnaires were successful in eliciting accurate name and age information about network members.

Summary—The SNAP experience suggests that RDS was a successful recruitment strategy for rural PWUD and questionnaires administered by community-based interviewers in the context of a Certificate of Confidentiality could elicit detailed data on PWUD risk networks.

Keywords

Social networks; rural; substance use; HIV; hepatitis C; Appalachia; opioid

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Compliance with Ethics Guidelines

Conflict of Interest

April M. Young reports grants from National Institute on Drug Abuse and from National Institute of Mental Health.

Abby E. Rudolph reports a grant from National Institute on Drug Abuse (K01 DA033879).

Jennifer R. Havens declares that she has no conflict of interest.

Human and Animal Rights and Informed Consent

This article does not contain any studies with human or animal subjects performed by any of the authors.

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Introduction

Central Appalachia, a predominantly rural and mountainous region which encompasses Eastern Kentucky and portions of West Virginia, Virginia, and Tennessee [1], has long been an epicenter for the intertwined national crises of non-medical prescription opioid use, opioid-related overdoses, and hepatitis C (HCV) [2–4]. HIV prevalence in the region has historically been low [5], although a recent ranking of US counties' vulnerability to HIV/HCV outbreaks among people who inject drugs (PWID) revealed that 69 of the 82, or 84%, of counties in Central Appalachia rank in the top 5% [6]. These challenges are exacerbated by the region's severe economic distress and under-resourced public health infrastructure [7, 8].

Since 2008, researchers have been examining opioid use and opioid-related harms through the longitudinal Social Networks among Appalachian People (SNAP) study involving people who use drugs (PWUD) in Central Appalachia, specifically in Eastern Kentucky. The study has yielded valuable insights into the epidemiology of opioid use, injection drug use, HCV, overdose, and HIV risk among rural PWUD [9–17]. The study is unique in that it focuses on a community-based sample of PWUD and employs network methods to understand risks for HIV, HCV, and other opioid-related sequelae.

Network data from the SNAP study have shown that PWUD in Appalachian Kentucky are connected in a dense network of sexual and drug co-usage ties, highlighting the potential for rapid and widespread HIV transmission if seeding occurred. Of the 503 people in the study, 418 (83.1%) were connected to each other in one large component through drug co-usage or sexual relationships and 89 (17.7%) were connected through injection equipment-sharing and/or condomless sex [9]. Similar analyses examining biologic data on HCV viremia and genotype in the context of the injection network highlighted potential for network-factors to play a role in HCV transmission [10]. Network analyses have also been used to better understand nonmedical use of prescription opioids among rural PWUD; one analyses of drug co-usage network data revealed that OxyContin was associated with network-based measures of social capital, indicating that prescription opioids may serve as a form of social currency in Appalachia [11]. The SNAP drug, sex, and social support network data have also been used to explore a range of other outcomes, including HCV antibody status, overdose, herpes-simplex virus, anti-social personality disorder, geographic and social factors driving homophily by recent injection drug use, as well as the feasibility of using network-based methods to promote HIV vaccination and HCV vaccine clinical trial participation in social, sexual, and drug networks in Appalachia [12, 13, 15, 18–23].

The SNAP study has also yielded important information about methods used in network-based research among rural PWUD, including recruitment patterns, accuracy of information reported about network members, and participants' perceptions of privacy and confidentiality [24–26]. The project has successfully recruited over 500 rural PWUD and has achieved follow-up rates over 8 years that exceed 82% of the original sample and 90% of those eligible for follow-up (i.e., those who were neither deceased nor incarcerated outside of Kentucky, and who were willing to continue to participate in the study) [17]. The ongoing SNAP study may serve as a powerful methodological template for other studies of rural

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PWUD. Therefore, the purpose of this paper is to provide a thorough overview of methods used for recruitment, network data collection, and network data management in the SNAP study, and to offer methodological recommendations for future research on rural PWUD.

Study Design

The overall goal of the SNAP study was to examine risk factors for HIV and other infections such as HCV in the Central Appalachian region of Kentucky using a social network approach. The SNAP study is conducted out of a storefront field office that is staffed by full-time interviewers who are residents of the county in which data collection is occurring. The field office is located in the center of the largest town (population size of approximately 5500) in the county which has a total population of approximately 29,000 [27]. In total, 93.8% (n=472) of the sample came from the county in which the field office is located and 58.8% (n=296) came from the town in which field office is located. Geocoding of participant address data revealed that the study office was centrally located, only 0.4 miles (straight-line distance) from the median center of the spatial distribution of participants. The median road network distance between the office and participants was 3.7 miles [26]. The central location of the field office was important given that only 36% of the sample had access to transportation (i.e., had a valid license and access to a vehicle) [11].

Eligibility criteria for the study included being at least 18 years of age, residing in an Appalachian Kentucky county, and having used at least one of the following to get high in the past 30 days: prescription opioids, heroin, crack/cocaine or methamphetamine. From November 2008 to August 2010, participants were recruited using respondent-driven sampling (RDS; described in more detail below) [26]. Prior to enrollment, participants completed an interviewer-administered screening questionnaire assessing their age and recent substance use followed by a urine drug screen for opiates, benzodiazepines, barbiturates, cocaine, marijuana, and methamphetamine. Participants who completed the survey and biologic testing were compensated $50 for their time. The Institutional Review Board at the University of Kentucky approved the protocol and a Certificate of Confidentiality was obtained. All reported studies/experiments with humans performed by the authors have been previously published and complied with all applicable ethical standards (including the Helsinki declaration and its amendments, institutional/national research committee standards, and international/national/institutional guidelines).

Among individuals screened for eligibility (n=939), 79% (n=742) were eligible and 506 completed the baseline interview. Those who were eligible provided written informed consent to participate in the study. Of those who were eligible but did not participate, the majority were not scheduled before the study’s baseline recruitment goal of 500 was reached. Three additional individuals reported discrepant substance use information on their eligibility screening assessment and baseline interview (described below) and were excluded from analysis, leaving a final sample size of 503 [26]. The demographic and behavioral profile of participants is described in detail elsewhere [11]. Briefly, the majority of the baseline sample was white (94%), male (57%), not currently married (74%), had graduated from high school (57%) and were employed (58%). The median age was 31 years (range: 18–65) [9, 11].

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Recruitment of rural PWUD

RDS is a common tool for recruiting hard-to-reach populations for HIV surveillance and research [28–30] and has been used in other studies of rural PWUD [31]. RDS is a network-based sampling technique whereby purposively sampled initial participants, or "seeds", are identified and provided with a limited number of referral coupons to recruit their peers. The recruited peers are in turn asked to recruit their peers, and so on until the desired sample size is reached. Incentives are provided for both peer recruitment and study participation [32, 33].

In the SNAP study, seeds were identified through outreach workers and community informants, as well as flyers posted in the community and outside the study field office. Those seeds completing the baseline interview were given three paper coupons to refer additional network members. Notably, the paper coupons did not indicate that the study was focused on substance use; the coupons contained only the study office address, phone number, as well as a code that indicated to staff who had referred whom. Participants were reimbursed US$10 per redeemed coupon (i.e., peer was eligible for and completed the baseline interview) for up to three peer referrals.

The SNAP study involved a total of 108 seeds (including one participant who was later excluded from the study due to discrepancies between self-reported substance use and the urine drug test). Over 50% (n=57) of the seeds were nongenerative (i.e., recruited no one). Of the RDS chains initiated by the 50 seeds who recruited at least one peer, 40% initiated a chain length of two (i.e., the seed recruited a peer or peers, but those peers recruited no one), 18% initiated a chain length of three (i.e., a seed recruited peer(s) and those peer(s) recruited someone), and 32% initiated chains of length 4 to 6. In addition, there were three chain lengths of 7, one chain length of 11, and one chain length of 14. Among the 234 participants who recruited someone, 49% only recruited one person, 35% recruited two people, and 17% recruited the maximum number that they were allowed to recruit (including four people who were accidentally allowed to recruit four peers due to administrative error). On average, 7.4 participants enrolled in the study per week throughout the study period (range: 1 – 15). Figures displaying the RDS referral chains and pace of recruitment over time are published elsewhere [26].

Overlap between rural PWUD social networks and RDS referral networks

In the SNAP survey, participants are asked to provide information about the people with whom they have used drugs, had sex, and/or from whom they have received social support in the past 6 months (described in more detail below). Participants were allowed to name up to 24 people total (8 per category), but no one reported the maximum. On average, participants named 5.2 network members (standard deviation: 2.7, range: 1 to 18). Participants were not directly encouraged to recruit the individuals they named in their networks, but if the list of network members was exhaustive, it could be assumed that participants' RDS referral network would overlap with the networks they reported in the questionnaire. Consistent with previous research [34], analyses of SNAP study data revealed that a relatively small proportion of RDS referral ties were listed as social network members; 209 of the 397 total RDS ties (52.6%) could be confirmed as drug, sex, and/or social support network ties,

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indicating that 47% of RDS referral ties involved peers whom participants had not named during the name-generating portion of the questionnaire [25].

Relationship-level patterns in RDS referral

Analyses of relationship-based characteristics associated with RDS recruitment of rural PWUD in the SNAP study have revealed that RDS peer-referral was a non-random process [26]. Compared with relationships reported by participants that did not involve RDS peer referral, relationships involving peer referral were more likely to be kin and those characterized by more frequent communication, increased trust, longer relationship duration, exchange of financial support, and drug sharing. In a model containing gender similarity, financial support, frequency of communication, duration of relationship, trust, drug sharing, and kinship, only kinship and frequency of communication remained significantly associated with RDS peer referral in the sample. Participants were significantly more likely to recruit kin and those with whom they more frequently communicated. Although only 26% of relationships reported in the network inventory were to kin, 42% of those referred through RDS recruitment were kin. These patterns are different from those identified in RDS studies in other settings where a majority of RDS recruitment ties were between friends or acquaintances [31, 35–37].

Spatial patterns in recruitment and RDS referral

Due to the mountainous terrain, difficulty traveling roads in the winter, and lack of public transportation, SNAP study staff hypothesized that people who were enrolled in the winter were more likely to live closer to the study office in the town center; however, the analyses revealed no statistically significant differences in distance to the office by season of study entry. Similarly, there were no seasonal differences in distance between recruiters and recruits overall and among those in which one or both people had transportation compared to pairs in which both lacked transportation. Participants with transportation access lived significantly further from the field office than those without transportation access and, among those who referred participants, those with transportation access recruited participants residing significantly further from them than those without. On average, participants with transportation lived approximately 8 miles away in road network distance from those whom they recruited while those without transportation lived approximately 5.7 miles from those they recruited. The furthest a person lived from one of the people they recruited was 10.8 miles [26].

In a comparison of relationships listed in the network inventory that involved peer-referral versus those that did not involve peer-referral, there were no significant differences in terms of geographic proximity; this finding is contrary to previous research in other settings [38–40]. Although distance between peers was not significantly different for pairs of participants where one or both members had transportation vs. pairs in which neither had transportation, the effect size for distance was stronger for those dyads in which neither had transportation. This suggests that distance may play a stronger role in peer-recruitment in contexts where fewer study participants have access to transportation [26].

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Data collection

The SNAP study employs full-time community-based research staff who collect data from participants using interviewer-administered questionnaires. The staff use the Computer-Assisted Personal Interviewing (CAPI) program developed by Questionnaire Development Systems [41] downloaded on touchscreen laptops. The SNAP study questionnaire is based largely on the Risk Behavior Assessment [42], ASI-lite [43], and DSM-MINI [44] and takes approximately 60 to 90 minutes to administer. Although evidence suggests that self-administered methods may be best for eliciting information on sensitive behaviors [45], the SNAP study elected to use an interviewer-administered approach to overcome barriers posed by literacy, to assist with navigating the complex network questions, to reduce the likelihood of missing data, and to establish rapport between field staff and participants. Follow-up qualitative research with SNAP participants revealed that the rapport with study interviewers as well as the Federal Certificate of Confidentiality, which was described to participants during the informed consent process, is critical to their willingness to participate in the research and to provide truthful responses when asked about sensitive topics [24]. Most participants in the qualitative interviews also indicated that they preferred face-to-face interviews as compared with entering information on their own, though this finding could have been influenced by participation bias (i.e., they were purposively sampled from the SNAP cohort to participate in a face-to-face qualitative interview) or could have emerged as a preference simply because face-to-face interviewing is the method of data collection with which they were most familiar.

Network data collection

The SNAP study network data collection methods are described in greater detail elsewhere [9, 25]. In the SNAP study interviewer-administered questionnaire, participants are asked to provide the name (first name and first initial of the last name), age, and gender of people (i.e. ‘Alters’) with whom they had sex, used drugs (excluding alcohol and marijuana), and/or whom they relied on for social support during the past 6 months. Participants can name up to eight Alters for each relationship type (24 people maximum). For each network member named listed, participants are asked a series of questions eliciting additional information about each person (i.e., age, gender) and his/her relationship with each Alter, including information on duration of their relationship, frequency of communication, kinship, trust, drug co-usage (including questions on drug sharing, injection equipment sharing, etc), and sexual behavior (including questions on frequency of condomless sex).

Constructing rural PWUD networks

One of the goals of the SNAP study is to understand the network connectivity among rural PWUD and how those networks influence risk and/or health seeking behaviors. To identify connections among participants, study staff must identify instances in which participants name other study participants as network Alters. To do so, staff cross-reference the names and characteristics of Alters with the data that participants provide about themselves in a process referred to as entity resolution. In the SNAP study, participants provide their own first name, middle name, nickname, and last name, as well as gender and age. Therefore, in the SNAP study, the first name and first initial of the last name of each network member can

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be cross-referenced against several variations of participants' names (i.e., first vs. first, first vs. nickname, etc.) [25].

The entity resolution process proceeds through multiple steps. First, name cross-referencing algorithms such as Microsoft's "Fuzzy Look-up Add-in" [46] were used to cross-reference the names of reported Alters with those of participants to produce possible matches based on name similarity. The Microsoft Fuzzy Look-up Add-in produces a name similarity score (range 0 to 1), based on Jaccard similarity coefficients with built-in transformations (i.e., recognizing that 'Bob' may match with 'Robert'). Microsoft's Fuzzy Look-up Add-in was used for entity resolution on the SNAP baseline data and 6-, 12-, 18-, and 24-month follow-up data. In 2017, SNAP study staff phased out use of the Microsoft Fuzzy Look-up Add-in and began using a new software program developed for entity resolution on network data by the author (AY) and colleagues. The new software program, SPIDER, is a semi-automated tool that combines text and variable cross-referencing tools [47]. SPIDER includes an assortment of text cross-referencing tools (i.e., Fuzzy Soundex, Phonex, and Q-gram) and customizable ER criteria for matching on continuous and categorical variables using arithmetic functions and equality operators.

After name and attribute comparison algorithms are used to generate a list of possible matches, SNAP study analysts partnered with community-based staff (i.e., interviewers) to review results. At baseline, the community-based staff reviewed ALL possible matches and confirmed/disconfirmed (through consensus) each possible match, as well as the names without a match. At subsequent follow-ups, community-based staff were only asked to review questionable ties (i.e., those that appeared to be a match but had some discrepant characteristics that warranted review). Of note, the interviewers were not asked to confirm the type of relationship (i.e., drug use, sexual, or social support) between each pair of individuals; only whether the two knew one another (yes vs. no). Similar to previous research [48, 49], interviewers based this decision on whether they (1) had ever observed the pair of participants interacting in the office or in public, (2) knew of a familial relationship or mutual friends connecting the pair, or (3) knew the pair lived in close geographic proximity to one another. Interviewers did NOT re-contact study participants to assist with this process. The entity resolution process for SNAP has been described in more detail elsewhere [25].

At baseline, the interviewers confirmed a total of 897 relationships between participants; representing 34% of all reported relationships; other relationships involved Alters for whom no match to a study participant was identified. Ties among participants involved 463 of the 503 participants, 40 participants did not report a relationship with another participant that could be identified using the methods described above. Overall, 41% of ties were reciprocal (i.e., ties in which ego named Alter and Alter-named ego) [25]. A combined analysis examining the relationship between social network distance and road network distance between geocoded residences suggests that degrees of separation in the social network were positively correlated with geographic distance ($p<0.001$) [13].

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Accuracy of identifying information used in generation of rural PWUD networks

Successful entity resolution relies heavily on the accuracy of reported identifying characteristics, such as age and name. Analyses of the SNAP study data have revealed that most participants reported the identifying characteristics of their Alters accurately; in 75% of confirmed relationships, participants gave the exact name and last initial of their Alter, and in 79% of relationships, participants reported the Alter age within two years of their actual age. Of note, more participants over-estimated than under-estimated their Alter's age, a trend which could be due to participants appearing older because of their history of drug use. Having information on participants' middle names and nicknames was critical to the matching process, especially among men for whom middle name and nickname matches accounted for 11% and 12% of the exact name matches, respectively [25]. Notably, the accuracy of name and age reported for pairs of individuals engaging in illicit behaviors (i.e., drug co-usage, drug sharing, injecting drugs together, injection equipment sharing) was not statistically significantly different from the accuracy of name and age information reported about Alters with whom they did not engage in illicit behaviors. Further, the accuracy of name and age information about Alters was greater for pairs engaged in sexual relationships [25].

Conclusion

In summary, the SNAP Study used RDS to recruit a cohort of 503 PWUD in rural Appalachian Kentucky from 2008 to 2010 and, as of 2017, has retained more than 80% of eligible participants and 90% of those eligible for follow-up (i.e., those who were neither deceased nor incarcerated outside of Kentucky, and who were willing to continue to participate in the study). Throughout the study, there have been a number of lessons learned that may be helpful in informing future research among rural PWUD. For example, recruitment data revealed that a high number (n=108) of RDS seeds were needed to recruit the cohort and that over 50% were non-generative. RDS referral often involved people who were not named in the network name-generator and referral was non-random, with individuals preferentially recruiting kin and people with whom they had frequent contact [26].

Despite limited access to transportation in the sample, geospatial proximity was not associated with likelihood of RDS referral among network members. However, among reported network relationships in which both peers lacked transportation, the effect size for spatial proximity was greater, suggesting that distance could be a barrier in peer referral where transportation is more inaccessible [26]. To overcome these barriers, future studies of rural PWUD may consider allowing participants to text message a picture of the RDS coupon to their peers rather than requiring them to physically hand them a copy. Also, future studies examining spatially dispersed populations and epidemiological outcomes that have geographic variation may benefit from purposively selecting a geographically diverse sample of seeds [26]. Of note, when using geographic data on residences or activity spaces in rural research, researchers should be careful not to display the point data in any publication or presentation, in order to protect the confidentiality of individual participants. Unlike in urban settings where population density is greater and where several urban

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housing units may share the same location, addresses and intersections reported in rural settings provide less anonymity and may reveal the identity of a person and/or family. Research among rural PWUD requires extra precautions to protect the confidentiality of spatial data and protect participants' privacy.

The SNAP study also revealed that questionnaires administered by community-based interviewers in the context of having a Certificate of Confidentiality can elicit accurate information from participants on the names and ages of their drug co-usage, sex, and social support network members. In 75% of confirmed relationships, participants gave the exact name and last initial of their Alter, and in 79% of relationships, participants reported the Alter age within two years of their actual age. The accuracy of these data were critical to enabling entity resolution, as was having data about variations of participants' names (i.e., first name, middle name, nickname, maiden name, last name) [25]. Qualitative research with SNAP participants has revealed that their rapport with the community-based SNAP study interviewers is critical to their willingness to provide sensitive information [24]. Future studies of rural PWUD may benefit from employing community-based staff and using interviewer-administered questionnaires to collect sensitive data.

In conclusion, the SNAP study team demonstrated that it is possible to conduct longitudinal studies of rural PWUD in a remote area. Community-based staff and investigators were able to recruit, retain, and collect, manage, and analyze complex network data from a cohort of rural PWUD. This research has yielded data that have been valuable in informing both policy, practice, and subsequent research.

Acknowledgments

The Social Networks among Appalachian People (SNAP) study described in this review was supported by the National Institute on Drug Abuse (grant R01 DA024598 and R01 DA033862).

The qualitative ethics research was funded in part by the Fordham University HIV and Drug Abuse Prevention Research Ethics Training Institute and National Institutes of Drug Abuse (Grant R25 DA031608). We would like to acknowledge the community-based study staff for the critical role they have played in the success of the project.

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