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Respondent-Driven Sampling to Recruit Young Adult Non-Medical Users of Pharmaceutical Opioids: Problems and Solutions

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Abstract

Respondent-driven sampling (RDS) has been promoted as a superior method in recruiting hard-to-reach and hidden populations. Although its application has expanded enormously, there remains a need for empirical data evaluating the performance of RDS in different settings. This study describes the application of RDS to recruit a community sample (N=396) of young adults (18–23 years old) into a natural history study of non-medical pharmaceutical opioid use. Since recruitment targeted non-dependent pharmaceutical opioid users, and applied other eligibility restrictions, several modifications had to be made to make RDS work with this narrowly-defined target population. RDS recruitment was less efficient than expected, and produced greater numbers of African American recruits than anticipated. Although the sampling quota was met, sample analysis revealed a lack of equilibrium in terms of ethnic composition and very strong in-group recruitment tendencies among White and African American respondents. This study contributes potentially helpful insights into the strengths and limitations of using RDS which may benefit future studies.

Keywords

sampling; respondent driven sampling; hidden populations; illicit use of pharmaceutical opioids; young adults

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1. Introduction

The non-medical use of pharmaceutical opioids is one of the fastest growing forms of drug abuse in the United States (Johnston et al., 2010; SAMHSA, 2010a), with young adults showing rates higher than other age groups. In 2009, 24.3% of 18–25 year olds reported lifetime non-medical pharmaceutical opioid use (SAMHSA, 2010a). Increases in illicit pharmaceutical opioid use have resulted in escalating accidental overdose death rates (Paulozzi et al., 2006), increasing prevalence of prescription opioid abuse and dependence disorders (McCabe et al., 2008), and expanded pathways to heroin addiction (Siegal et al., 2003). However, little is known about the factors associated with transition to DSM-IV abuse and/or dependence among non-medical pharmaceutical opioid users, and virtually all of what is known emanates from cross-sectional studies (Anthony et al., 1994; Ridenour et al., 2005; McCabe et al., 2007; Becker et al., 2008; McCabe et al., 2008).

This paper describes the first step of a study designed to fill this research gap with the application of respondent-driven sampling (RDS) to recruit young adult (18–23 years old) non-medical pharmaceutical opioid users into a natural history study designed to describe use trajectories and potential transitions to abuse and/or dependence. Because recruitment targeted non-dependent pharmaceutical opioid users, and required other restrictions that significantly narrowed the potentially eligible population, the implementation of RDS was challenging. This paper has two aims: 1) to describe recruitment challenges and the modifications implemented, and 2) to assess RDS performance.

RDS combines a network-based referral methodology and mathematical modeling to produce a representative sample (Heckathorn, 1997; Heckathorn, 2002; Salganik and Heckathorn, 2004; Magnani et al., 2005; Abdul-Quader et al., 2006a; Malekinejad et al., 2008). Recruitment begins with a small number of “seeds” who are non-randomly selected from the target population. Participants are provided financial rewards for participation in the study and for the referral of other potentially-eligible peers (dual incentives). RDS uses recruitment coupon quotas, thereby helping to prevent the emergence of semi-professional recruiters and reduce the effects of volunteerism. It is suggested that if the peer recruitment unfolds through a sufficiently large number of recruitment waves (usually 4–5), sample compositions converge and reach equilibrium. Based on the reciprocity model and using social network information, RDS is able to estimate asymptotically unbiased population compositions that can be used to make inferences about the target population (Heckathorn, 1997; Heckathorn, 2002; Semaan et al., 2002; Salganik and Heckathorn, 2004; Magnani et al., 2005).

RDS has been proposed as a superior method to sample hard-to-reach populations because of its potential to generate a representative sample, and other advantages, including efficiency, cost effectiveness, increased safety for research staff, and a potential to reach the most hidden segments of target populations (Semaan et al., 2002; Abdul-Quader et al., 2006a; McKnight et al., 2006; Robinson et al., 2006; Yeka et al., 2006; Johnston et al., 2008a). As a result, the use of RDS has expanded enormously in the United Stated and in international settings (Gallagher et al., 2007; Lansky et al., 2007; Johnston et al., 2008b; Malekinejad et al., 2008). Still, several studies have reported mixed experiences with RDS-based recruitment, including poor efficiency (Draus et al., 2005; Simic et al., 2006; Wang et al., 2007) and an inability to access certain segments of a target population (Burt et al., 2010). Further, some research has suggested that RDS-based estimates may be substantially less accurate than generally acknowledged (Frost et al., 2006; Goel and Salganik, 2010). Consequently, there remains a need for empirical data evaluating the performance of RDS in different settings (Abdul-Quader et al., 2006b; Malekinejad et al., 2008).

2. Methods

2.1. Formative research

Formative research, conducted between November 2008 and March 2009, had two objectives: 1) to gain preliminary knowledge of non-medical pharmaceutical opioid use and explore key issues in the implementation of the recruitment plan, including assessment of social network properties, acceptability of RDS to participants, and logistical issues, such as convenience of the research site, hours of operation, contact procedures for follow-up interviews, etc.; and 2) to begin to develop rapport with the population, and identify and recruit potential "seeds."

Formative research consisted of 8 focus groups and 10 individual qualitative interviews with a total of 30 "key informants." Two additional focus groups were conducted one month after the start of the main study to assess the process of RDS-based recruitment (see below). As posited by other RDS researchers, "key informants" are defined as "cultural experts" and can come from different populations and groups in the community, as long as they display significant familiarity and knowledge about the target population and the topic of interest (Allen et al., 2009).

Key informants included: 1) members of the target population (n=19) who were 18–23-years old, used pharmaceutical opioids illicitly on at least 5 occasions in the past 3 months and resided in Franklin, Fairfield or Delaware counties; and 2) other active users of pharmaceutical opioids (n=11) who may have been too old to qualify for the study, but were knowledgeable about illicit pharmaceutical opioid use in the area and familiar with the target population (Allen et al., 2009; Johnston et al., 2010). Eligibility criteria were purposefully broad to gain familiarity with the phenomenon of illicit use of pharmaceutical opioids in the research location. Participants completed an IRB-approved informed consent, and were compensated $30 for their time and transportation costs. Two consultants who were familiar with the illicit drug use scene in Columbus helped identify key informants. Focus groups and individual qualitative interviews, conducted by the authors, were audio-recorded, transcribed, and analyzed using NVivo (QSR International, 2002) to identify major themes.

2.2. RDS-based recruitment

The RDS-based recruitment for the main study was initiated in April 2009 and was completed in May 2010. A total of 396 eligible individuals (including "seeds") were recruited. All participated in a structured baseline assessment administered by trained interviewers.

2.2.1. Eligibility—To be eligible for the natural history study, participants had to: 1) be 18–23 years old; 2) reside in the Columbus, Ohio, area (Franklin, Fairfield, and Delaware counties); 3) self-report non-medical use of pharmaceutical opioids on at least 5 occasions in the past 90 days; 4) have no history of heroin use or drug injection; 5) not be engaged in a formal drug abuse treatment program in the last 30 days; 6) intend to use non-prescribed pharmaceutical opioids again; 7) not currently be awaiting trial or have pending criminal charges; and 8) show no lifetime dependence on opioids based on DSM-IV criteria. Participants who met three criteria for dependence within any 12-month period were ineligible; participants who met a criterion for abuse and/or 1–2 criteria for dependence were eligible. In addition, participants who met 3 or more dependence criteria that were not clustered in a 12-month period were also eligible.

To increase the veracity of self-reported use, participants were asked to identify the opioids they reported having used recently from pictures of non-labeled pain pills (SAMHSA,

2009). In addition, participants' hands and arms were observed for injection track marks. Urinalysis was not conducted because it would not produce meaningful data for eligibility determinations given the three-month use window.

2.2.2. Referral process and eligibility determination—After the baseline interview, seeds and subsequent study participants were offered three recruitment coupons and were asked to recruit people "like themselves," that is, people about the same age who they knew had recently used non-prescribed pharmaceutical opioids. Coupons had serial numbers to track recruitment information. Complete eligibility criteria were never disclosed to the study participants to avoid people gaining entry to the study who were ineligible.

Eligibility determination proceeded in two stages: 1) Upon telephoning the site (walk-ins were not accepted), individuals were screened on all aforementioned eligibility criteria, except lifetime opioid dependence. Individuals who passed the screen were invited to a site office for additional screening. 2) At the office, the purpose of the study was described, IRB-approved informed consent was administered, and final eligibility determination was made. This included screening for lifetime opioid abuse and dependence using the DSM-IV Checklist (Forman et al., 2004). Participants were required to show a picture ID to assure that they were of appropriate age. This procedure was initiated after about 3 months of recruitment after it was learned some participants had lied about their ages and/or identity. Identity verification at baseline also helped with the follow-up process by assuring the accuracy of names and contact information. Information necessary for RDS analysis was collected from referrals, including basic information about social networks and preexisting social relationships between a referral and recruiter (Heckathorn, 2002). Participants were asked to estimate how many people they knew personally who had recently used pharmaceutical opioids non-medically, resided in the Columbus area, and were between 18 and 23.

2.2.3. Compensation—A dual incentive system was employed. The primary incentive was $50 for completing a baseline interview (and $10 for transportation); the secondary incentive was $15 for each referral who passed the telephone-based eligibility screen and came to the office for final eligibility determination. Referrals who came to the office but did not pass the eligibility screen were compensated $10 for participation in the screening and $10 for transportation.

2.3. RDS sample analysis

Sample analysis was conducted using RDSAT (Volz et al., 2007). Trait groups selected for analysis were gender, ethnicity, and age. Age was broken into two categories based on being at least age 21 ("legal" age) or younger (18–20). Income level was not included in RDS analysis, because some individuals, due to their age, were still financially dependent on their parents and/or other family members. As a result, their reported personal income was not a reliable measure of their socio-economic status and/or of the financial resources available to them.

A measure of tolerance, defined here as the weighted mean absolute discrepancy between the actual sample and the equilibrium sample compositions, was used to determine sample convergence (Wang et al., 2005). A tolerance of about 2% or smaller is considered to indicate a close approximation between the actual sample and computed equilibrium sample compositions. Oversampling or undersampling of certain segments of the target population was assessed by comparing the final RDS sample compositions with the asymptotically unbiased estimates of population compositions. Homophily (in-group recruitment) is also described.

3. Results

3.1. Formative research: preparing for RDS recruitment

During the formative research stage, members of the target population expressed willingness to recruit peers. They reported extensive networks of non-medical pharmaceutical opioid users and described them as being integrated in terms of ethnicity, gender, and age. This suggested that social network characteristics of the target population were appropriate for RDS (Johnston et al., 2010). For example, a white man described his network of pain pill using peers as “everything, no discrimination.” An African-American male also commented on the ethnic integration of the social networks of pain pill users as “Half [white] and half [African American]; I think this is the most racial diverse city I’ve ever been in, so it’s, like, half and half.”

Further, several modifications to the research protocol and logistics were made to reduce potential recruitment barriers. For example, the age limit was increased from 21 to 23, since many participants felt the proposed age limits of 18–21 was too narrow and would impede recruitment.

Formative research also alerted us to issues which were very difficult to address. First, some key informants noted that travel time for those residing in suburban areas might be considerable, which could present a barrier for some. Prior research has pointed out that in such situations multiple or mobile interview sites could help increase the representativeness of the sample (Stormer et al., 2006), but would be prohibitively expensive for a longitudinal study. Second, discussions surrounding monetary incentives and motivations to participate in the study unveiled potential barriers to recruit more affluent members of the target population. Although some individuals expressed altruistic motives such as a desire to help others engaged in similar behaviors, commitment to the altruistic reasons was dependent on a person’s belief in the problematic nature of his/her drug use. For example, one focus group participant explained why he most likely would not be interested in the study:

> Well, it depends on the problem … my personal problem. If my personal problem gets to a level that I’ve experienced pain or any discomfort that I would not want anybody else to experience or walk through my footsteps, then I would definitely contribute to any studies or any efforts that’s out there to prevent the repeat of my experience….

Since the study targeted users who were not opioid dependent, many participants did not view their illicit use of pain pills as a problem. Consequently, their interest and commitment to research goals for the purpose of helping others “like themselves” were relatively low. Monetary compensation, instead, was a more significant motivator for many participants. However, it became apparent that monetary compensation offered by the study was viewed as insufficient by some individuals of higher socioeconomic standing. For example, participants in a focus group said:

Participant 1: $60 [for baseline compensation], that’s an iffy for me, personally.

Participant 2: I’ve been to other case studies [market research]. The money there is usually a lot better than what you’re offering.

Participant 3: Oh, absolutely, yeah. For two hours you’re probably going to make $200 to $250….

Prior studies have suggested that stratified incentives could be used to assure a representation of individuals from a broad range of socioeconomic backgrounds (Johnston, 2008). However, this approach would have substantially increased the cost of the study.

3.2 Recruitment process: challenges and modifications

Only 17% of a total number of 47 seeds were recruited during the formative research stage (Table 1). Out of 30 people who participated in the focus groups and/or individual interviews as key informants, 19 met preliminary eligibility criteria (residency, age, and frequency of use) that qualified them for an office-based assessment. Twelve of them expressed interest in the study and were invited for eligibility screening. However, only 4 of them met all eligibility requirements and were enrolled in the study. The remaining 7 did not qualify because they met DSM-IV criteria for lifetime opioid dependence and 1 lied about his age. Four additional seeds were recruited during the formative research stage via the personal networks and contacts of the research staff, although they did not participate in the key informant focus groups and/or individual interviews.

The first baseline interview was conducted on April 2, 2009; however, recruitment was very slow, and by the end of April, only 7 participants were recruited. To explore recruitment barriers, 2 focus groups were conducted in late April 2009 with individuals who had completed baseline interviews and a few people who they brought in as potential recruits. Some participants indicated others feared coming to the research site alone. Therefore, we modified the protocol to provide additional compensation ($10) to the recruiter for accompanying/transporting a potential subject to the site for eligibility determination. This strategy was not successful. After two months, only 15 participants had enrolled in the study, well below the recruitment target of about 34 people per month.

In June 2009, additional modifications to the recruitment process were implemented. Individuals who did not pass the office eligibility screen were encouraged to refer others to the study, and qualifying referrals from these individuals were considered “seeds,” since they did not link to any eligible participants. As seen from Table 1, 51% of the seeds were referred by individuals who did not meet eligibility criteria. Further, advertisements were placed in alternative newspapers, and flyers were posted in geographically diverse areas such as coffee shops, bars, laundromats, pizza parlors, and bus stops, which brought in an additional 15 seeds (Table 1). This approach is sometimes referred to as “targeted canvassing” (Sifaneck and Neaigus, 2001), and has been successfully applied to recruit non-dependent heroin and/or opium users (Korf et al., 2010). These changes jumpstarted the recruitment process, and the number of eligible recruits increased from 8 in May, to 24 in June, to 34 in July, eventually reaching a sample size of 396 individuals in 13 months. This approximates the planned sample size of 400.

In the middle of the recruitment process (November 2009–February 2010), a significantly greater number of African American than White participants began entering the study: out of 119 participants recruited during that time period, 83 (70%) were African American, and 30 (25%) were White. This contrasted starkly with the trends reflected in large scale epidemiological studies. For example, in 2009, out of a total 8.16 million young adults (18–25 years old) in the U.S. who reported lifetime illicit use of pharmaceutical opioids, more than 6 million (about 74%) were White while 647,000 (about 8%) were African American (SAMHSA, 2010a). Consequently, participants were provided extra coupons to recruit Whites.

3.3 Ineligibles and "no shows"

Because of the stringent eligibility criteria, and the fact that complete eligibility requirements were never disclosed to participants, many ineligible referrals were made. Out of 100 people who did not pass the telephone eligibility screen, about 26% were too old, 30% reported using pharmaceutical opioids on too few occasions to qualify, 15% had no intentions of future use, 10% reported injection drug use, and 19% had used heroin. Forty-three persons passed the phone eligibility screen, but were determined ineligible during the office-based screen mostly (90%) because they met criteria for lifetime opioid dependence. None of them had to be excluded for not bringing a valid ID. In addition, 96 individuals passed the telephone screen but did not keep their scheduled appointments. Ten individuals who completed a baseline interview were eliminated from the study after it was learned at a follow-up interview that they misrepresented their age, identity, or history of heroin use. As ineligibles, these 10 individuals were excluded from the RDS sample analysis. Eligible participants, who were recruited by these ineligibles, if any, were treated as seeds.

All individuals had to first pass a telephone-eligibility screen before engaging in the office-based eligibility assessment (except for the 4 "seeds" who were initially recruited as key informants for the formative research stage and were assessed in the office for eligibility). A total of 641 individuals participated in the telephone eligibility screen. Of these, 61% (392) passed the telephone screen and office-based eligibility determination, and enrolled in the study. The remaining 39% (n=249) of those who contacted the project were found ineligible either during the telephone assessment (n=100, 16%), the office-based assessment (n=43, 7%), at a follow-up interview (n=10, 1.6%), or did not complete the eligibility determination (n=96, 15%).

3.4 Sample assessment

Out of 47 seeds, 13 (28%) did not produce any recruits, and 14 had a referral chain length of 5 or more waves (Table 1). These 14 chains produced 302 recruits, accounting for 86.5% of the total recruits (n=349). Of 349 participants (excluding the 47 seeds), 71.3% were recruited by friends, 24.4% by family members, 3.4% by acquaintances, and ≤ 1% by strangers. This indicates that use of the reciprocity model was appropriate (Heckathorn, 2002). The sample composition for age and gender gradually stabilized at waves 5 and 6, respectively (Table 2). However, the sample's ethnic composition continued to change. The actual sample compositions and the theoretically-computed equilibrium compositions are compared in Table 3. Equilibrium is reached when variation in the sample's characteristics is ≤ 2% regardless of how many additional waves are recruited (Heckathorn, 2002; Salganik and Heckathorn, 2004). When sample composition approximates equilibrium, the bias introduced from the non-random selection of seeds is eliminated and the sampling is successful. The weighted mean absolute discrepancies between the actual and equilibrium sample compositions were small for age (0.6%) and gender (0.5%), but large (7%) for ethnicity, indicating that the ethnic composition of the sample did not reach equilibrium. In addition, the sample composition was compared with the estimated population composition for age and gender, but not for ethnicity as the latter did not reach equilibrium. Differences for gender composition were statistically significant (t=2.04, p=0.042), indicating that male respondents were slightly oversampled (Table 3). However, no statistically significant differences were observed between sample composition and the estimated population composition for the two age groups (t=0.405, p=0.69) (Table 3).

The homophily index was 0.79 among Whites and 0.80 among African Americans, indicating a very high tendency among these groups for in-group recruitment (Table 3). Respondents of "Other" ethnicity showed a lower tendency for in-group recruitment as indicated by the homophily index of 0.21. Negative heterophily indices, which measure out-

group recruitment tendencies, between White and African American respondents indicate social distance between the two ethnic groups. The affiliation of Whites towards African Americans was −0.89, while the affiliation of African Americans towards whites was −0.84. The affiliation of African Americans towards "Others" was also negative (−0.44), while the affiliation of Whites toward "Others" was close to neutral (0.006). The preference for in-group recruiting was also observed across gender and age group lines, but homophily indices were not as large as for the ethnic groups (Table 3).

4 Discussion

This is one of the first studies to apply RDS to recruit young adult, non-dependent, illicit users of pharmaceutical opioids for longitudinal research. RDS was used successfully in reaching recruitment quotas within the planned time frame (about 12 months). The small differences between the actual and equilibrium sample compositions indicate that the sample converged in terms of age and gender compositions. However, despite lengthy recruitment chains, the sample did not reach equilibrium for ethnicity.

Usually, 4–5 recruitment waves should be sufficient for the sample to reach equilibrium (Heckathorn, 1997). Our sample contained 17 chains that had 4 or more waves, and 7 chains that had 7 or more waves. The absence of equilibrium in terms of ethnic composition is most likely due to high homophily levels observed among Whites and African Americans. Generally, RDS is considered to have greater efficiency when sampling populations that have equal and low to moderate homophily (Heckathorn, 2002). Although African Americans and Whites had similar homophily levels, the rate of in-group recruitment was very high (close to complete homophily), indicating that the two groups recruited almost exclusively from their own group, producing a "bottleneck" in the network and impacting the quality of RDS estimates (Goel and Salganik, 2009). Further, there were large differences in average network sizes reported by White and African American participants (Table 3). Although RDS controls for biases related to the differences in average network size among groups by giving less weight to proportions with large average network sizes and more weight to proportions with small network sizes, large differences in network size can introduce bias (Johnston, 2008) and potentially contribute to a lack of equilibrium in terms of ethnic composition.

The social distance observed in recruitment tendencies between African American and White participants is one of the most interesting aspects of the current study. The level of in-group ethnic recruitment in our study contrasts markedly with other studies involving illicit drug users. For example, in a study of MDMA/Ecstasy users in Columbus, Ohio, homophily among Whites was 0.54, and among African Americans, 0.49 (Wang et al., 2005). In a study with illicit stimulant users recruited in rural Ohio, where ethnic integration is expected to be much lower than that in a city like Columbus, the homophily index was 0.58 among Whites and 0.39 among Non-Whites (Wang et al., 2007). The high level of social distance observed between Whites and African Americans in the current study might be because illicit pain pill use more commonly occurs in private settings rather than public venues, and has a less-well defined "subculture" of use, compared to drugs like MDMA/Ecstasy or crack cocaine. Consequently, there are fewer opportunities for social interaction, as compared, for example, to mixing in dance clubs or crack houses. Notably, formative research failed to alert us of potential issues related to social distance between Whites and African Americans, as key informants reported ethnically mixed social networks of users.

The recruitment process generated a sample with a much larger proportion of African Americans than initially expected; the sample was 50% White and 44% African American. The expectation was that the sample would contain a larger proportion of Whites because: 1)

the Columbus, OH, population is about 66% White and 26% African American (the corresponding numbers for Franklin County are 73% and 19%) (U.S. Census Bureau, 2009); and 2) prior studies and epidemiological reports have consistently shown higher rates of illicit use of pharmaceutical opioids among Whites than African Americans (Simoni-Wastila et al., 2004; McCabe et al., 2005; OSAM Network, 2008, June; Daniulaityte et al., 2009; SAMHSA, 2010b). The high proportion of African American recruits in our study might indicate local and/or emerging drug use trends that have not been reflected in national studies. Alternatively, it may indicate larger than expected over-sampling of certain segments of drug user populations. Others have challenged the claim that RDS increases sample representativeness, compared to traditional sampling methods (Heimer, 2005).

The growth of the RDS recruitment process was much slower than the theoretically expected geometric growth proposed by Heckathorn (1997, 2002), and reported in other studies. For example, in a study with illicit drug users in New York City, 618 participants were enrolled from 8 seeds over a period of 13 weeks (Abdul-Quader et al., 2006a). As noted, after the first 8 weeks, our study had only 15 participants. There are a number of potential factors responsible for the slower than expected recruitment rate.

First, unlike many other studies using RDS, ours had very narrow eligibility criteria, which created very unique demands for referral and recruitment. This resulted in many referrals not qualifying for the study. In comparison, a study that used RDS to recruit illicit users of pharmaceutical opioids in Maine needed 23 seeds and only three months to recruit a total sample of 237 participants. However, eligibility criteria for that study were less stringent (Grau et al., 2007). Second, since our sample was limited to individuals who were not opioid dependent and, consequently, may have experienced fewer adverse consequences from their drug use, perhaps they were less motivated by the financial incentive and/or by altruistic motives to participate. Notably, prior research indicated significant difficulties recruiting non-dependent opioid users. A study conducted in Amsterdam that used ethnographic fieldwork, snowball sampling, newspaper advertisements and website announcements to recruit non-dependent opiate users (including heroin and opium) was only able to recruit 127 individuals over 2 years. Further, monetary compensation had to be increased from €40 to €100 to assure participation (Korf et al., 2010). Third, because of the financial constraints, multiple interview sites, which might have facilitated the RDS process, were not feasible. Fourth, participants were required to show valid IDs to verify age and identity, which might have presented a barrier for some individuals. Fifth, in our previous studies using RDS, we employed a full-time ethnographer who had the ability to expand formative research and help identify seeds (Draus et al., 2005; Wang et al., 2005; Wang et al., 2007). We did not employ a full-time ethnographer in this study due to financial constraints and because the phenomenon of non-medical use of pharmaceutical opioids is less public with a less well defined “sub-culture” of beliefs, attitudes, behaviors, and identifiable locations of use. Finally, the lack of social connectedness in the target population and the “bottleneck” in the network of target population (Goel and Salganik, 2009), which were not detected during formative work, may also have contributed to the slower than expected recruitment.

Prior research indicates that financial pressures may introduce significant biases in sample recruitment. It has been suggested that RDS’s dual incentive system has a potential to minimize such biases, since those who are too affluent to care about material rewards might give in to the social pressure from recruiting peers (Heckathorn, 1997). However, it is very likely these biases, although somewhat offset by social pressures of peer recruitment and the secondary incentive system, are not completely eliminated. Most RDS-based studies that displayed efficiency and productivity in recruitment targeted economically marginalized groups such as injection drug users or sex workers (Heckathorn, 1997; Heckathorn, 2002; Johnston et al., 2006), and/or were conducted with communities that were very active in

their social welfare, such as MSM in sub-Saharan Africa where no economic incentive was used to recruit the sample (Johnston, 2008). However, RDS recruitment failed with "mainstream" marijuana users since it targeted individuals who represented wealthier and better socially adjusted segments of drug using populations (Hathaway et al., 2010). Other studies have also shown that individuals of higher socioeconomic status and/or those who were not sufficiently motivated by the amount of the monetary initiatives, were less likely to recruit others (de Mello et al., 2008; Reisner et al., 2010; Uuskula et al., 2010; Rudolph et al., 2011). Although RDS sample analysis based on the economic status of our participants was not performed, formative research suggested that economically challenged individuals with ample disposable time might have been more likely to participate and recruit others for the study. Reaching wealthier substance users presents a challenge not only for RDS-based recruitment (Ramirez-Valles et al., 2005; Rudolph et al., 2011).

Sample analysis was limited because questions about network size did not include the definition of the population with all the eligibility restrictions, as required by RDS standards (Johnston, 2008). This omission was made so as not to reveal all eligibility criteria to potential participants and to minimize misrepresentations among referred individuals. However, precision in the estimation of social network size is important since it determines the probability of someone being selected into the study. Omission of eligibility criteria may result in the possible over-estimation of participants' network sizes. In addition, inaccuracies in estimates of network sizes, which may have resulted in part because all eligibility criteria were not divulged to participants, may have also contributed to the discrepancies in network size by ethnicity. Issues related to the artificial nature of how the study population and social/drug user networks are defined have been noted in prior research (e.g., Platt et al., 2006) and perhaps are inherent with many applications of RDS.

In summary, this study details our experiences using RDS as a recruitment method with a narrowly-defined target population. Although the sample did not converge in terms of ethnic composition, the sampling quota was eventually met within the specified time frame. Recruitment of non-dependent illicit drug users with stringent eligibility criteria presents significant challenges to the drug abuse field (Korf et al., 2010). Strict eligibility criteria were necessary to determine the characteristics of those who transition to opioid dependence and/or heroin use. Use of alternative recruitment methods, such as time-space or ethnographic targeted sampling, was hardly feasible, since illicit pain pill use more commonly occurs in private settings rather than public venues, and non-dependent users are little involved in "street culture" of illicit drug use (Sifaneck and Neaigus, 2001). As a result, we felt that RDS was the best available recruitment strategy. Nevertheless, our experience also suggests that integrating elements of other recruitment strategies, including recruitment via newspapers and flyers ("targeted canvassing") (Sifaneck and Neaigus, 2001; Korf et al., 2010) improved the efficiency of RDS in recruiting our narrowly defined sample. Further, although we followed a common practice of including a broad range of "cultural experts" in the formative research stage (Allen et al., 2009), our experience suggests that RDS planning and implementation would have benefited if we included a greater number of key informants who also met all eligibility criteria for the main study, although this might have increased the time frame and resources. Finally, our study suggests caution in the use of RDS and stresses the importance of formative work to determine whether the target population is socially connected enough (given eligibility criteria) to generate a "representative" sample using RDS. RDS may be a practical recruitment approach to reach hidden populations, but claims regarding representativeness and subsequent generalizability cannot always be made.

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Table 1

Seed characteristics (n=47).

Seeds Characteristics	Number (%)	
Method of recruitment		
Formative	8	(17%)
Flyer	9	(19%)
Newspaper ads	6	(13%)
Ineligibles	24	(51%)
Number of recruits		
0	13	(28%)
1	17	(36%)
2	7	(15%)
3	9	(19%)
4	1	(2%)
Number of waves linked		
1 (no referrals)	13	(28%)
2–3	17	(36%)
4 or more	17	(36%)

Table 2

Changes in RDS sample size and compositions over recruitment wave.

			Gender		Ethnicity			Age Group	
Wave	**N**	**Change in *n***	**Male *n* (%)**	**Female *n* (%)**	**African American *n* (%)**	**White *n* (%)**	**Other *n* (%)**	**18–20 *n* (%)**	**21–23 *n* (%)**
0 **seeds**	47	-	27 (57.5)	20 (42.5)	22 (46.8)	22 (46.8)	3 (6.4)	19 (40.4)	28 (59.6)
1–1	62	62	34 (54.8)	28 (45.2)	25 (40.3)	31 (50.0)	6 (9.7)	31 (50.0)	31 (50.0)
1–2	112	50	59 (52.7)	53 (47.3)	46 (41.1)	58 (51.8)	8 (7.1)	54 (48.2)	58 (51.8)
1–3	161	49	85 (52.8)	76 (47.2)	68 (42.2)	82 (50.9)	11 (6.8)	72 (44.7)	89 (55.3)
1–4	209	48	108 (51.7)	97 (48.3)	82 (39.2)	113 (54.1)	14 (6.7)	89 (42.6)	120 (57.4)
1–5	248	39	131 (52.8)	117 (47.2)	92 (37.1)	140 (56.5)	16 (6.5)	104 (41.9)	144 (58.1)
1–6	273	25	149 (54.6)	124 (45.4)	101 (37.0)	154 (56.4)	18 (6.6)	114 (41.8)	159 (58.2)
1–7	288	15	157 (54.5)	131 (45.5)	106 (36.8)	162 (56.3)	20 (6.9)	119 (41.3)	169 (58.7)
1–8	299	11	161 (53.8)	138 (46.2)	111 (37.1)	168 (56.2)	20 (6.7)	122 (40.8)	177 (59.2)
1–9	309	10	167 (54.0)	142 (46.0)	119 (38.5)	170 (55.0)	20 (6.5)	125 (40.5)	184 (59.5)
1–10	316	7	173 (54.7)	143 (45.3)	124 (39.2)	172 (54.4)	20 (6.3)	128 (40.5)	188 (59.5)
1–11	322	6	177 (55.0)	145 (45.0)	129 (40.0)	172 (53.4)	21 (6.5)	129 (40.1)	193 (59.9)
1–12	328	6	179 (54.6)	149 (45.4)	135 (41.2)	172 (52.4)	21 (6.4)	132 (40.2)	196 (59.8)
1–13	335	7	184 (54.9)	151 (45.1)	142 (42.4)	172 (51.3)	21 (6.3)	135 (40.3)	200 (59.7)
1–14	344	9	186 (54.1)	158 (45.9)	150 (43.6)	173 (50.3)	21 (6.1)	139 (40.4)	205 (59.6)
1–15	348	4	188 (54.0)	160 (46.0)	153 (44.0)	174 (50.0)	21 (6.0)	142 (40.8)	206 (59.2)
1–16	349	1	189 (54.2)	160 (45.8)	153 (43.8)	175 (50.1)	21 (6.0)	143 (41.0)	206 (59.0)

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Table 3

RDS analysis: Sample characteristics.

Variables	Gender		Ethnicity			Age	
	Male	**Female**	**White**	**African Amer.**	**Other**	**18–20 years old**	**21–23 years old**
Recruits	189	160	175	153	21	143	206
Total sample, with seeds (p_s), %	54.5	45.5	49.7	44.2	6.1	40.9	59.1
Equilibrium sample (p_e), %	54.0	46.0	57.0	36.7	6.3	41.5	58.5
Population estimates (P), % C.I., 95%)	49.4 (41.1, 57.8)	50.6 (42.2, 59.0)	48.4 (33.4, 64.7)	45.9 (29.1, 61.6)	5.7 (2.9, 8.6)	39.9 (32.7, 47.2)	60.1 (52.8, 67.3)
Mean network size (unadjusted)	30.1	19.5	30.6	18.7	27.3	25.6	25.0
Homophily	0.39	0.26	0.79	0.80	0.21	0.26	0.21
Populations weights	0.906	1.113					