A Systematic Review of Published Respondent-Driven Sampling Surveys

Collecting Behavioral and Biologic Data

Authors here based on contribution

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ABSTRACT

Reporting key details of respondent-driven sampling (RDS) survey implementation and analysis is essential for assessing the quality of RDS surveys. RDS is both a recruitment and analytic method and, as such, it is important to adequately describe both aspects in publications. We extracted data from peer-reviewed literature published through September, 2013 that reported collected biological specimens using RDS. We identified 151 eligible peer-reviewed articles describing 222 surveys conducted in seven regions throughout the world. Most published surveys reported basic implementation information such as survey city, country, year, population sampled, interview method, and final sample size. However, many surveys did not report essential methodological and analytical information for assessing RDS survey quality, including number of recruitment sites, seeds at start and end, maximum number of waves, and whether data were adjusted for network size. Understanding the quality of data collection and analysis in RDS is useful to effectively plan for public health service delivery and funding priorities.

INTRODUCTION

The first respondent-driven sampling (RDS) surveys to assess HIV prevalence in addition to risk behaviors were conducted in 2004 (1–3). Since then hundreds of surveys have been conducted worldwide to capture data from populations considered at higher risk for HIV exposure, including people who inject drugs (PWID), men who have sex with men (MSM), female sex workers (FSW), and other populations without a readily available sampling frame (4–6). Over the past decade, many organizations, including the U.S. Centers for Disease Control and Prevention, UNAIDS, WHO, Global Fund and others have endorsed the use of RDS to establish baseline and trend measurements of HIV and other infections (Syphilis, Hepatitis, etc.) prevalence, risk behaviors, and program impact through biological and behavioral surveys (6–9).

RDS is an important recruitment and analysis tools for sampling populations with no sampling frame that are linked through social networks, including those considered “hard-to-reach” due to stigma and the practice of illegal behaviors (4–6). RDS, a chain-referral sampling technique, uses statistical adjustments for network sizes and recruitment effort to produce estimates representative of a population’s network. Beginning with a set number of participants, “seeds”, selected purposefully by the research team from the target population, RDS builds a sample based on the recruitment of individuals with pre-existing relationships. Using a limited number of coupons for each participant limits the possibility of overrepresentation of those with more ties to others in the population. Providing ‘incentives’ for those participating in and for recruiting peers into the survey helps ensure ongoing participation and recruitment. Ideally, this process results in long recruitment chains made up of numerous “waves” of

recruits (10,14). As recruitment chains lengthen, the structure of the sample becomes less dependent on the purposefully selected seeds and more increasingly similar to the population being sampled.

In addition to these implementation steps, RDS is premised upon several assumptions, most importantly, random walk models (10). Briefly, these assumptions include 1) reciprocal ties between respondents (i.e., know one another as members of the sampled population); 2) respondents are connected by a single network component; 3) sampling occurs with replacement; 4) respondents provide accurate personal network sizes (i.e., number of relatives, friends, and acquaintances they know from the sampled population); 5) peers are recruited randomly from the recruiter's network; and, 6) each respondent can recruit at least one peer (11). RDS also involves a complex analytical component crucial for generating population estimates and confidence intervals using data collected about each participant's social network size (10–14). Estimates generated through RDS should allow for inferences about the network of the population being sampled.

Findings from surveys purporting to use RDS are vital for developing national and international policies, guiding service delivery, informing budgets and dictating funding priorities. Quality reporting of data collected and analyzed using RDS methods allows users to assess their usefulness in decision making. However, there is ample potential for bias when using this method, many of which are related to implementation and analytical failures (15–20). The allure of RDS as a more robust alternative to convenience snowball sampling methods has resulted in partial incorporation of RDS techniques (i.e., the use of coupons) while ignoring some of the more complex aspects

which ensure the mitigation of chain referral related biases (13). Indeed, numerous published surveys report having used RDS, but present insufficient methodological and analytical information to support this assertion (21).

Building upon the STROBE RDS guidelines (22) to recommend improvements in the reporting of survey data, we extracted peer-reviewed literature that reported using RDS for collecting HIV and other infections biological and behavioral data through September, 2013. Specifically, we evaluate a set of general and RDS-specific survey indicators based on the STROBE RDS guidelines (21,22) to describe the extent, consistency, and changes over time for planning, implementation, and analysis as reported in peer reviewed journals. In addition, we provide reasons why some published surveys were not included in the extraction and examples of surveys that reported using RDS when, in fact, evidence suggests they did not. We hope to build upon other efforts to increase accuracy in conducting RDS and to encourage more thorough and standardized reporting of RDS methods and analysis (4,22).

Location of study, citation	Year of study	Population	Pre-survey assess-ment	Sites, #	Interview method†	Seeds at start, #	Final seeds, #	Primary incentive of value‡	Secondary incentive of value‡	Target sample size	
Africa											
Kenya, Kisumu(23)	2008	FSW	Yes	1	ACASI	15	NR	4.00	1.25	480	4
Nigeria, Abuja(24)	2010	MSM	NR	NR	ACASI/SA	NR	NR	NR	NR	NR	1
Nigeria, Cross River(25)	2007	MSM	NR	1	IA	10	10	4.00	NR	293	2
Nigeria, Cross River(26)	2010	PWID	NR	>1	IA	10	10	4.00	4.00	266	2
Nigeria, Federal Capital Territory(26)	2010	PWID	NR	>1	IA	10	10	4.00	4.00	266	2
Nigeria, Ibadan(27)	2006	MSM	NR	NR	IA	38	38	4.00	NR	NR	1
Nigeria, Ibadan(24)	2010	MSM	NR	NR	SA ACASI/SA	NR	NR	NR	NR	NR	2
Nigeria, Kaduna(26)	2010	PWID	NR	>1	IA	10	10	4.00	4.00	266	1
Nigeria, Kano(26)	2010	PWID	NR	>1	IA	10	10	4.00	4.00	266	2
Nigeria, Kano(25)	2007	MSM	NR	1	IA	10	10	4.00	NR	293	3
Nigeria, Lagos(25)	2007	MSM	NR	1	IA	10	14	4.00	NR	293	2
Nigeria, Lagos(26)	2010	PWID	NR	>1	IA	10	10	4.00	4.00	266	1
Nigeria, Lagos(27)	2006	MSM	NR	NR	IA	38	38	4.00	NR	NR	1
Nigeria, Lagos(24)	2010	MSM	NR	NR	SA ACASI/SA	NR	NR	NR	NR	NR	3
Nigeria, Oyo(26)	2010	PWID	NR	>1	IA	10	10	4.00	4.00	266	2
Mauritius(28)	2009	PWID	Yes	2	IA	6	6	7.00	3.50	500	5
Mauritius(29)	2010	FSW	NR	2	IA	5	5	17.50	7.00	NR	2

Somalia, Hargeisa, Somaliland(30)	2008	FSW	Yes	1	IA w/ HAPI	6	NR	4.00	3.00	146	2
South Africa, Durban(31)	2011	MSM	Yes	1	SA	4	15	5.00 & 5.00 voucher	5.00 & 5.00 voucher	200	8
South Africa, Johannesburg(31)	2011	MSM	Yes	1	IA or SA	5	14	5.00 & 5.00 voucher	5.00 & 5.00 voucher	200	2
South Africa, Soweto(32)	2008	MSM	NR	1	IA	15	15	NR	NR	NR	3
South Africa, W. Cape Province(33–35)	2006	Heterosexual men	Yes	1	IA	8	20	8.00 phone voucher	2.70 phone voucher	430	4
South Africa, W. Cape Province(36)	2008	Heterosexual men	Yes	1	IA	19	19	8.50 phone voucher	2.85 phone voucher	430	4
South Africa, W. Cape Province(37)	2007	Young women	Yes	1	SA	5	5	8.00 make-up voucher	2.50	270	2
South Africa, W. Cape Province(38)	2011	Heterosexual women	Yes	1	ACASI	15	15	7.50 grocery voucher	7.50 grocery voucher	756	8
Sudan, Khartoum(39)	2008	FSW	NR	1	IA	NR	NR	10.00	10.00	NR	3
Tanzania, Zanzibar(40,41)	2007	MSM	Yes	1	IA	10	10	3.00	1.50	500	5
Uganda, Kampala(42)	2008-09	MSM	Yes	1	ACASI	8	14	3.00	1.00	600	3
Eastern Mediterranean											
Egypt, Cairo(43)	2006	IDU	Yes	1	IA	28	NR	7.00	5.30	406	4
Iran, Kerman(44)	2010	FSW	NR	1	IA	8	12	4.00	2.00	NR	1
Lebanon, Beirut(45,46)	2007-08	FSW	NR	NR	NR	NR	NR	6.60	2.00	NR	1
Lebanon, Beirut(45)	2007-08	MSM	NR	NR	NR	NR	NR	6.60	2.00	NR	1
Lebanon, Beirut(45,47)	2007-08	PWID	NR	NR	NR	NR	NR	6.60	2.00	NR	8
Libya, Tripoli(48)	2010	PWID	Yes	1	IA	7	7	20.00	9.00	NR	3
Libya, Tripoli(49)	2010	MSM	Yes	1	IA	NR	14	NR	NR	NR	2
Libya, Tripoli(49)	2010	FSW	Yes	1	IA	NR	13	NR	NR	314	6
Morocco, Agadir(50)	2010-11	MSM	NR	NR	IA	NR	10	7.00	3.50	NR	3
Morocco, Marrakesh(50)	2010-11	MSM	NR	NR	SA	NR	8	7.00	3.50	NR	3
Palestine, East Jerusalem(51)	2010	PWID	Yes	1	IA	NR	7	NR	NR	NR	1
Europe											
Albania, Tirana(52)	2005	PWID	Yes	3	IA	15	15	12.00	7.00	NR	2
Albania, Tirana(53)	2008	MSM	NR	1	IA	12	NR	10.00	5.00	NR	1
Croatia, Zagreb(54–56)	2006	MSM	NR	1	SA	8	10	18.00	9.00	400	3
Croatia, Zagreb(54)	2012	MSM	Yes	1	SA	10	15	None	9.60	370	4
England, Bristol(57,58)	2006	PWID	NR	NR	CASI	7	7	15.00	10.00	NR	2
England, Bristol(57)	2009	PWID	NR	NR	NR	6	6	NR	NR	NR	2
Estonia, Kohtla Jarve(59,60)	2005	PWID	NR	NR	SA	NR	NR	NR	NR	NR	1
Estonia, Tallinn(61–63)	2007	PWID	Yes	1	SA	5	5	10.00 food voucher	5.00 food voucher	NR	3
Estonia, Tallinn(63,64)	2005-06	FSW	Yes	1; other	SA	6	43	10.00 shop voucher	11.00 shop voucher	NR	2
Estonia, Tallinn(60,65)	2005	PWID	NR	NR	SA	6	NR	NR	NR	NR	3
Estonia, Tallinn(62)	2009	PWID	NR	NR	SA	6	6	10.00 food voucher	5.00 food voucher	NR	3
Kazakhstan, Almaty(66)	2010	MSM	Yes	NR	IA	4	4	10.00	2.50	400	4
Moldova, Balti(67)	2009-10	FSW	NR	NR	IA	5	5	7.00	5.00	350	3
Moldova, Balti(68)	2007-08	PWID	Yes	NR	IA	NR	NR	Items, cash (value NR)	NR	NR	3
Moldova, Balti(69)	2010	MSM	Yes	NR	IA	5	5	8.30	5.80	250	2
Moldova, Chisinau(68)	2007-08	PWID	Yes	NR	IA	NR	NR	Items, cash (value NR)	NR	NR	3
Moldova, Chisinau(67)	2009-10	FSW	NR	NR	IA	5	5	16.00	12.00	350	2
Moldova, Chisinau(69)	2010	MSM	Yes	NR	IA	8	8	8.30	5.80	250	1
Moldova, Tiraspol(68)	2007-08	PWID	Yes	NR	IA	NR	NR	Items, cash (value NR)	NR	NR	3
Montenegro, Podgorica(70)	2008	PWID	NR	1	SA	5	NR	20.80	7.00	NR	3

Montenegro, Podgorica(71)	2005	PWID	NR	1	ACASI	NR	NR	13.00	6.00	NR	3
Russia, Ivanovo(72)	2010	PWID	NR	NR	IA	11	11	Items, food (value NR)	Items, food (value NR)	NR	3
Russia, Novosibirsk(72)	2010	PWID	NR	NR	IA	10	10	Items, food (value NR)	Item, food (value NR)	NR	2
Russia, St. Petersburg(73–75)	2005-08	PWUD/PWID	NR	NR	CASI	48; 108	156	10.00 (items)	items (value NR)	NR	6
Russia, St. Petersburg(74,75)	2005-06	PWID	NR	NR	CASI	35	NR	10.00 (items)	NR	NR	3
Serbia, Belgrade(76)	2010	Youth	Yes	NR	IA	8	8	13.00	6.00	371 ¶	2
Serbia, Belgrade(71)	2005	PWID	NR	1	ACASI	NR	NR	13.00	6.00	NR	4
Serbia, Kragujevac(76)	2010	Youth	Yes	NR	IA	4	4	13.00	6.00	370 ¶	1
Ukraine, Poltava(77)	2011	PWID	NR	NR	SA	4	4	3.00	2.00	NR	2
Ukraine, Khmelnitsky(77)	2011	PWID	NR	NR	SA	7	7	3.00	2.00	NR	2
Ukraine, Dnipropetrovsk(77)	2011	PWID	NR	NR	SA	6	6	3.00	2.00	NR	1
Ukraine, Cherkasy(77)	2011	PWID	NR	NR	SA	3	3	3.00	2.00	NR	1
Ukraine, Donetsk(77)	2011	PWID	NR	NR	SA	6	6	3.00	2.00	NR	4
Ukraine, Kharkov(77)	2011	PWID	NR	NR	SA	5	5	3.00	2.00	NR	1
Ukraine, Kherson(77)	2011	PWID	NR	NR	SA	4	4	3.00	2.00	NR	2
Ukraine, Kirovograd(77)	2011	PWID	NR	NR	SA	4	4	3.00	2.00	NR	1
Ukraine, Kyiv(77)	2011	PWID	NR	NR	SA	8	8	3.00	2.00	NR	4
Ukraine, Lugansk(77)	2011	PWID	NR	NR	SA	6	6	3.00	2.00	NR	2
Ukraine, Lutsk(77)	2011	PWID	NR	NR	SA	4	4	3.00	2.00	NR	1
Ukraine, Lviv(77)	2011	PWID	NR	NR	SA	7	7	3.00	2.00	NR	1
Ukraine, Mykolaiv(77)	2011	PWID	NR	NR	SA	6	6	3.00	2.00	NR	2
Ukraine, Odesa(77)	2011	PWID	NR	NR	SA	6	6	3.00	2.00	NR	4
Ukraine, Simferopol(77)	2011	PWID	NR	NR	SA	5	5	3.00	2.00	NR	2
Ukraine, Sumy(77)	2011	PWID	NR	NR	SA	5	5	3.00	2.00	NR	1
Latin America and Caribbean											
Argentina, Buenos Aires(78,79)	2009	MSM	NR	NR	SA web-based	16	16	NR	NR	NR	5
Brazil, Belo Horizonte(80–82)	2009	MSM	Yes	NR	IA	6	NR	10.00	6.67	350	N
Brazil, Belo Horizonte(17,83)	2008-09	FSW	NR	NR	ACASI	5 to 10	NR	Misc. (value NR)	4.00	300	2
Brazil, Brasilia(80–82)	2009	MSM	Yes	NR	IA	6	NR	10.00	6.67	350	N
Brazil, Brasilia(17,83)	2008-09	FSW	NR	NR	ACASI	5 to 10	NR	Misc. (value NR)	4.00	300	3
Brazil, Campinas(84)	2005-06	MSM	NR	NR	ACASI	10	30	NR	NR	NR	6
Brazil, Campo Grande(80–82)	2009	MSM	Yes	NR	IA	6	NR	10.00	6.67	350	N
Brazil, Campo Grande(17,83)	2008-09	FSW	NR	NR	ACASI	5 to 10	NR	Misc. (value NR)	4.00	150	1
Brazil, Curitiba(80–82)	2009	MSM	Yes	NR	IA	6	NR	10.00	6.67	350	N
Brazil, Curitiba(17,83)	2008-09	FSW	NR	NR	ACASI	5 to 10	NR	Misc. (value NR)	4.00	200	2
Brazil, Fortaleza(85)	2008	Transvestite	Yes	NR	IA	6	NR	6.00 food voucher	3.00	NR	3
Brazil, Fortaleza(86)	2005	MSM	Yes	2	IA	10	10	5.00	5.00	400	4
Brazil, Itajaí(80–82)	2009	MSM	Yes	NR	IA	6	NR	10.00	6.67	350	N
Brazil, Itajaí(17,83)	2008-09	FSW	NR	NR	ACASI	5 to 10	NR	Misc. (value NR)	4.00	100	9
Brazil, Manaus(80–82)	2009	MSM	Yes	NR	IA	6	NR	10.00	6.67	350	N
Brazil, Manaus(17,83)	2008-09	FSW	NR	NR	ACASI	5 to 10	NR	Misc. (value NR)	4.00	200	1
Brazil, Recife(80–82)	2009	MSM	Yes	NR	IA	6	NR	10.00	6.67	350	N
Brazil, Recife(17,83)	2008-09	FSW	NR	NR	ACASI	5 to 10	NR	Misc. (value NR)	4.00	200	2
Brazil, Rio de Janeiro(80–82)	2009	MSM	Yes	NR	IA	6	NR	10.00	6.67	350	N
Brazil, Rio de Janeiro(17,83)	2008-09	FSW	NR	NR	ACASI	5 to 10	NR	Misc. (value NR)	4.00	600	6
Brazil, Salvador(80–82)	2009	MSM	Yes	NR	IA	6	NR	10.00	6.67	350	N
Brazil, Salvador(17,83)	2008-09	FSW	NR	NR	ACASI	5 to 10	NR	Misc. (value NR)	4.00	300	2
Brazil, Santos(80–82)	2009	MSM	Yes	NR	IA	6	NR	10.00	6.67	350	N
Brazil, Santos(17,83)	2008-09	FSW	NR	NR	ACASI	5 to 10	NR	Misc. (value NR)	4.00	150	1
Dominican Rep., Barahona(87)	2008	MSM	Yes	NR	IA	8	NR	9.00	3.00	300	2

Dominican Rep., La Altagracia(87)	2008	MSM	Yes	NR	IA	7	NR	9.00	3.00	300	2
Dominican Rep., Santiago(87)	2008	MSM	Yes	NR	IA	6	NR	9.00	3.00	300	3
Dominican Rep., Santo Domingo(87)	2008	MSM	Yes	NR	IA	7	NR	9.00	3.00	500	5
El Salvador, San Miguel(88,89)	2008	MSM	Yes	NR	CASI w/ interviewer	5	5	4.00 as items	2.70 (items)	200	1
El Salvador, San Salvador(89)	2008	FSW	NR	1	CASI w/ interviewer	10	10	Items (value NR)	Items (value NR)	NR	7
El Salvador, San Salvador(88,89)	2008	MSM	Yes	NR	CASI w/ interviewer	11	11	4.00 as items	2.70 (items)	600	5
El Salvador, Sonsonate(89)	2008	FSW	NR	1	CASI w/ interviewer	5	5	Items (value NR)	Items (value NR)	NR	7
Honduras, Comayagua(90)	2006	FSW	Yes	1	ACASI	5	5	Purse (value <2.00)	Items (value 3.50)	200	1
Honduras, La Ceiba(90)	2006	FSW	Yes	1	ACASI	7	7	"	"	200	2
Honduras, San Pedro Sula(90)	2006	FSW	Yes	1	ACASI	7	7	"	"	200	1
Honduras, Tegucigalpa(90)	2006	FSW	Yes	1	ACASI	5	5	"	"	200	2
Peru, Lima(91)	2012	Transwoman	Yes	6	SA	8	11	7.00	NR	420	4
North America											
Mexico, Juarez(92–96)	2005	PWID	NR	1	SA	NR	NR	NR	NR	NR	2
Mexico, Juarez(97)	2005	PWID	NR	1	SA	9	17	20.00	5.00	200	1
Mexico, Tijuana(92–96)	2005	PWID	NR	3	SA	15	15	10.00	5.00	200	2
Mexico, Tijuana(98–102)	2006-07	PWID	NR	NR	SA	32	NR	20.00	NR	NR	1
USA, Appalachia(103)	NR	DU	NR	NR	NR	NR	NR	50.00	10.00	NR	5
USA, Atlanta(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, Baltimore(104)	2002-04	Youth IDU	NR	NR	ACASI, w/ w/out interviewer	NR	NR	NR	NR	NR	7
USA, Baltimore(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	7
USA, Baltimore(105)	2006	PWID	NR	NR	CAPI	20	20	20.00	10.00	NR	6
USA, Boston(106,107)	2008	MSM	NR	2	SA	8	21	50.00	10.00	NR	1
USA, Boston(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	4
USA, Chicago(104)	2002-04	Youth IDU	NR	NR	ACASI, w/ w/out interviewer	NR	NR	NR	NR	NR	5
USA, Chicago(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, Dallas(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, Denver(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, Detroit(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, Ft. Lauderdale(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	3
USA, Houston(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, Houston(108)	2006-07	High risk heterosexuals	Yes	1	CAPI	NR	NR	40.00	10.00	750	9
USA, Las Vegas(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	3
USA, Los Angeles(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	6
USA, Los Angeles(75,109–111)	2005-06	DU/PWID/ MSM	NR	1	ACASI	25	25	50.00	20.00	NR	4
USA, Miami(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	6
USA, Nassau(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, New Haven(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, Las Cruces(97)	2005	PWID	NR	1	SA	NR	NR	NR	NR	NR	1
USA, New York City(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, New York City(112)	2009	PWID	Yes	NR	SA	NR	3	NR	NR	NR	4
USA, New York City(113–118)	2006-07	High risk heterosexuals	Yes	NR	SA	8	NR	30.00	11.00	NR	8

USA, New York City(1,119,120)	2004	DU	NR	NR	NR	NR	NR	20.00	10.00	NR	4
USA, Newark(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	4
USA, Norfolk(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	4
USA, Oakland(121)	2011-12	High risk/HIV pos. African American	Yes	4	SA	48	NR	10.00 gift card	Varied	NR	2
USA, Philadelphia(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, San Diego(122)	2009-10	PWID	NR	NR	ACASI	NR	NR	NR	10.00	NR	5
USA, San Diego(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, San Francisco(123)	2007-08	MSM	Yes	1	CAPI	10	10	40.00	10.00	NR	2
USA, San Francisco(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, San Juan(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, Seattle(124)	2009	PWID	NR	1	IA	6	6	40.00	10.00	NR	4
USA, Seattle(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	4
USA, St. Louis(6)	2005-06	PWID	NR	NR	SA	8 to 10	NR	25.00	10.00	NR	5
USA, Wash. DC(125)	2006-07	High risk heterosexuals	Yes	1	SA	NR	NR	35.00	10.00	NR	7
USA, Wash. DC(126)	2009	PWID	NR	1	SA	NR	NR	30.00	10.00	NR	5
USA, Texas, El Paso(97)	2006	PWID	NR	1	SA	NR	NR	NR	NR	NR	1
South East Asia											
Bangladesh, Dhaka(127)	2006	MSM	Yes	1	SA	5	8	2.14	1.43	530	5
India, Bishenpur District, Manipur(128)	2006	PWID	NR	NR	SA	NR	NR	NR	NR	400	4
India, Chennai(129)	2008	MSM	Yes	2	SA	NR	19	6.00	None	NR	7
India, Churachandpur District, Manipur(128)	2006	PWID	NR	NR	SA	NR	NR	NR	NR	400	4
India, Coimbatore(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Dimapur District, Nagaland(130)	2006	FSW	NR	NR	SA	10	10	NR	NR	400	4
India, Dindigul(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Erode(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Goa(131,132)	2005	FSW	Yes	NR	SA	59	59	2.50	1.50	318	3
India, Kanyakumari(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Madurai(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Mumbai & Thane Districts(128)	2006	PWID	NR	NR	SA	NR	NR	NR	NR	400	3
India, Nagapattinam(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Nilgiris(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Perambalur(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Phek District, Nagaland(128)	2006	PWID	NR	NR	SA	NR	NR	NR	NR	400	4
India, Pudukottai(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Ramanathapuram(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Salem(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Sivagangai(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Thanjavur(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Tiruchy(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Tirunelveli(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Tiruvarur(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Tuticorin(129)	2008	MSM	Yes	1	SA	NR	19	6.00	None	NR	7
India, Wokha District, Nagaland(128)	2006	PWID	NR	NR	SA	NR	NR	NR	NR	400	4
Pakistan, Abbottabad(133)	2007	MTSW	Yes	2	IA	NR	NR	NR	NR	NR	1
Pakistan, Abbottabad(133)	2007	FSW	Yes	2	IA	NR	NR	NR	NR	NR	1
Pakistan, Lahore(133)	2007	FSW	Yes	3	SA	3	NR	NR	NR	726	7
Pakistan, Rawalpindi(133)	2007	MTSW	Yes	2	IA	NR	NR	NR	NR	NR	8

Pakistan, Rawalpindi(133)	2007	FSW	Yes	2	IA	NR	NR	NR	NR	NR	4
Thailand, Bangkok(134)	2007	FSW	NR	3	ACASI, with/ w/out interviewer	15	15	11.80	1.50	NR	7
Western Pacific											
China, Beijing(135)	2009	MSM	NR	1	ACASI	7	7	4.50	3.00	NR	5
China, Beijing(3)	2004	MSM	NR	1	SA	1	1	None	2.10	NR	3
China, Beijing(3,136)	2005	MSM	NR	1	SA	10	10	None	2.10	NR	4
China, Beijing(3)	2006	MSM	NR	1	SA	8	8	None	2.10	NR	5
China, Beijing(137)	2009	MSM	NR	1	CAPI	7	8	5.00	3.20	NR	5
China, Chongqing(138)	2009	MSM	NR	NR	CASI	7	7	4.50	3.00	NR	5
China, Guangdong(139)	2008	PWID	Yes	1	SA	6	7	7.50	3.00	238	2
China, Guangdong(140)	NR	FSW	NR	1	IA or CASI	4	4	NR	NR	NR	3
China, Guangzhou(141)	2008	MSM	NR	1	SA	13	13	5.00, gift/cash	1.50	NR	3
China, Jinan(142,143)	2007	MSM	Yes	1	SA	9	9	None	NR	428	4
China, Jinan(142,143)	2008	MSM	Yes	1	SA	5	5	None	NR	500	5
China, Jinan(144)	2008	FSW	Yes	1	SA	7	7	7.30	2.90	NR	3
China, Jinan(144)	2009	FSW	Yes	1	SA	4	4	7.30	2.90	NR	4
China, Liuzhou(145,146)	2009-10	FSW	Yes	1	SA	7	8	14.00	7.00	380	5
China, Nanjing(147)	NR	MSM	NR	1	NR	9	9	4.00 phone card	NA	NR	4
China, Shandong(148)	2007-08	Money boys	NR	NR	SA	16	NR	NR	NR	120	1
Indonesia, Bandung(149)	2007	IDU	NR	NR	SA	8	NR	NR	4.00	250	2
Indonesia, Surabaya(149)	2007	IDU	NR	NR	SA	8	NR	NR	4.00	250	2
Vietnam, Cam Ranh(150)	2005	MSM	NR	1	NR	2	NR	1.90	0.95	300	2
Vietnam, Dien Khanh(150)	2005	MSM	NR	1	NR	2	NR	1.90	0.95	300	2
Vietnam, Hai Phong(150)	2004	FSW	NR	NR	SA	20	25	3.00	1.00	200	2
Vietnam, Ho Chi Minh City(150)	2004	FSW	NR	NR	SA	20	24	4.00	1.50	400	4
Vietnam, Nha Trang(150)	2005	MSM	NR	1	NR	2	NR	1.90	0.95	300	2
Vietnam, Ninh Hoa(150)	2005	MSM	NR	1	NR	2	NR	1.90	0.95	300	2
Vietnam, Van Ninh(150)	2005	MSM	NR	1	NR	2	NR	1.90	0.95	300	2

METHODS

Literature search

We examined peer-reviewed literature published in physical or on-line journals that reported using RDS and were either accessible through September, 2013, or were identified from a previously conducted search (22). Searches were conducted using MEDLINE (1997-2013), EMBASE (1997 -2013), and Global Health (1997-2013). Search terms included “respondent driven”, “respondent-driven” or “RDS”. The original extraction included surveys in any country, in any language, and among any study population that reported using RDS (n=4562). Articles excluded in the initial extraction were those that were duplicates (n=2360), irrelevant (e.g., protocols, presentations,

flyers, etc.; n=1716) and either reviews, opinion pieces, editorials, commentaries and papers strictly addressing RDS methodology (n=44, i.e., those not intending to report population based estimates). This resulted in a total of 442 articles and abstracts. We further refined our search by eliminating abstracts (n=58) and publications that were either duplicated (n=3), non-English (n=40), without biological data (n=167), or claimed to, but did not, use RDS (n=23). When there were a number of publications for a single study, all related publications were reviewed to update the extraction sheet. This resulted in 151 articles representing 222 surveys (Figure 1).

Categorizing documents and extraction

We selected and extracted key data from 151 journal articles and entered them into a master table in Excel® into rows specific to the survey(s) described. Journal data entered into the table were organized into seven sub-tables based on WHO categorization of regions: Africa, Eastern Mediterranean (EM), Europe, Latin America and the Caribbean (LAC), North America, South-East Asia (SEA), and Western Pacific. We extracted information considered essential for assessing RDS-specific survey quality as reported in Malekinejad et al (4), Montalegre et al (5) and White et al (21,22) in each publication. The indicators reviewed included those informing survey design and implementation and analysis. Indicators informing survey design and implementation are the survey year, eligibility criteria, specimen type collected for biological testing, whether pre-survey research was conducted, number of recruitment sites, interview method, number of seeds at the start and end (and whether seeds were added or failed during data collection) of the survey, amount or type of primary and secondary incentives (USD), calculated target and final sample size, design effect used for sample

size calculation, maximum number of waves, duration of data collection (in weeks), and maximum number of coupons distributed to each recruiter. Indicators informing analysis are whether equilibrium or convergence was assessed, whether data were adjusted for network size, software used, and the citation and estimator used for adjustment. The rationale for selecting these indicators, including their usefulness in any survey versus specifically for RDS surveys, are provided in Table II.

	Percent of publications reporting information		**Values of reported information**	**Rational for reporting**
Indicators	**N (222)**	**%**	**Median (range)**	
Year of survey	219	99	--	Useful for any survey in order to know how current data are, to plan future surveys and to compare data from other surveys.
Eligibility criteria (minimum of behavior description) §	222	97	--	Useful for any survey to determine the denominator being measured, to know measurement for the construction of the social network question needed for

				RDS analysis. Provides readers with possible criteria to use in different populations and settings; allows for comparison of data across countries.
Type of specimen collected for biological testing §	193	87	--	Useful for any survey. Informs readers about the types of testing being conducted in different populations and settings.
Pre-survey research conducted	88	40	--	Useful for any survey. Informs readers about the survey planning process, especially whether attempts were possibly made to assess the underlying network structure of the population.
Number of recruitment sites per survey area	95	43	1 (1-6)	Especially useful in RDS as it alerts readers to the possible violation of the network being one complete component if participants at each site are not connected; informs readers

				about the possible clustering (or diffusion) of sample.
Interview method	210	94	--	Useful for any survey. Provides information about level of confidentiality in the survey (i.e., ACASI may provide more confidentiality) and informs readers about the different types of methods used for interviewing hidden populations in RDS surveys.
Number of seeds at the start of the survey	62	28	7.5 (1-48)	Specifically useful for RDS surveys. Informs readers about whether many seeds were added during data collection and the number of seeds in relation to the sample size and number of waves (too many seeds may result in too few waves needed to reduce seed dependence, adding too many seeds may be an indication that the population is not well
Whether seeds were added during data collection	17	8	5 (1-37)	
Whether seeds failed during data collection	14	6	4 (1-24)	
Number of seeds by the end of the survey	121	54	10 (1-156)	

				networked); provides parameters for readers about seeds needed in different populations and settings.
Amount or type of primary incentive (USD)	186	84	3 (1.9-5) ∗	Specifically useful for RDS surveys. Provides readers with parameters about amounts used in different populations and settings, provides an indication of potential bias during recruitment (if incentives are too high, more people may enroll who are not eligible).
Having no primary incentive	6	3	--	
Amount or type of secondary incentive (USD)	177	80	10 (0.95-20) †	
Having no secondary incentive	18	8	--	
Calculated target sample size	89	40	300 (100-756)	Useful for any survey. Indicates if an original sample size was calculated and if that sample size was reached in order to ensure sufficient power and confidence for data analysis. Provides readers with parameters about sample sizes used in different populations and settings. Specific for RDS
Final sample size	212	95	325 (100-1056)‡	
Final sample size for multiple cities combined	28	12	--	

				surveys: combining multiple survey sites is often a violation of the network being one network component.
Design effect used for sample size calculation §	50	22	2 (1.3-3)	design effects, currently recommended to be at least 2 (151,152,16), are important for calculating a sufficient sample size to account for RDS not being a traditional random sample
Maximum number of waves	95	43	9 (3-21)	
Duration of data collection (in weeks)	139	63	12 (2-124)	Informs readers of the time needed to gather samples of different sizes from different populations and settings; alerts readers of unusual recruitment lengths that may impact representativeness of the sample.

Maximum number of coupons distributed to each recruiter §	163	73	3 (2-7)	Specifically useful for RDS surveys. The number of coupons used are normally three (7), but some surveys have used more. Analysis does not account for branching induced by the number of coupons provided to each participant so fewer coupons, when possible, is suggested to mimic a random walk process.
Whether equilibrium or convergence was assessed§	44	20		Specifically useful for RDS surveys. Informs readers of seed dependence and is a diagnostic to assess bias.
Whether data were adjusted for network size	157	70	--	Specifically useful for RDS surveys. Informs readers of the extent to which RDS was fully utilized, resulting in the ability to assess whether the survey may represent the network of the population from which the sample was gathered

Software used to adjust data §	162	73	--	Specifically useful for RDS surveys. There are limited software packages available for analyzing RDS data. Analyzing RDS data in more popular, preexisting software (i.e., STATA, SPSS) may not eliminate RDS specific biases.
Citation for adjustment §	59	26	--	Specifically useful for RDS surveys. Given the evolvement of the estimators for the analysis of RDS data, this is useful for providing information about the assumptions supporting the adjustments.
Heckathorn (10,153) §	19	32	--	
Salganik & Heckathorn (12) §	28	47	--	
Heckathorn (11) §	10	17	--	
Volz & Heckathorn (13) §	7	12	--	
Gile (154) §	4	7	--	
Estimator used for adjustment §	10	4	--	
Whether seeds were discarded during analysis	31	14	--	Some studies either did not collect data from seeds or did not include their data their analysis, which could likely

				result in the sample having addition seeds (analysis would assume wave 1 participants are seeds) thereby potentially impacting seed dependence and biasing the final estimate.

Analysis

Frequencies were used to characterize the surveys and their contents. We conducted robust and logistic regressions of survey start year and pre-survey research, eligibility age, number of seeds at the start and end of survey, survey duration, final sample size, estimated design effect, length of longest recruitment chain, and adjustment of RDS to assess linear trends in the value of these indicators over time (155). Design effects were calculated for surveys that presented a point estimate for HIV prevalence, 95% confidence intervals and the final sample size. The calculation for design effects consisted of dividing the widths of the confidence interval by two, dividing again by 1.96 (the standard normal value corresponding to a central area of 95%), and squaring the final number.

RESULTS

The identified published articles of RDS surveys were conducted in the following WHO regions: 21 from Africa (28 surveys), 12 from EM (11 surveys), 30 from Europe (44 surveys), 17 from LAC (37 surveys), 41 from North America (45 surveys), 12 from SEA (32 surveys), and 18 from the Western Pacific (25 surveys). Extracted surveys included

85 among PWID, 78 among MSM and 38 among FSW. Surveys of other groups included people who use and/or inject drugs (n=2), male sex workers (n=3), high-risk heterosexuals (n=7), transgender (n=2), and youth (n=3). The remaining surveys were of mixed groups such as youth PWID (n=2), people who use and/or inject drugs together (n=1) and MSM who use and/or inject drugs (n=1).

Assessing reports of survey quality

Survey data extracted from published articles included in this review were used to assess whether RDS recruitment and analysis were conducted, but the details provided for these surveys varied across articles. For instance, all published surveys reported basic implementation information such as the city, country and the population sampled, and 99% reported the survey year (Table II). Over 90% of surveys reported the interview technique (e.g., face-to-face questionnaire, computer-assisted self-interviews, etc.) (94%), final sample size (95%) and at least the behavioral component of the eligibility criteria (97%). Eighty four percent reported the primary and 80% reported the secondary incentive amounts or types, and 73% reported the maximum number of coupons given to each recruiter. Sixty-three percent reported the data collection duration, 40% reported whether pre-survey research was conducted, 43% reported the number of recruitment sites used and the maximum number of waves, 40% reported the target sample size, 22% reported the design effect used for calculating the sample size. For those surveys that presented both calculated and final sample sizes (n=77, 35%), the median percentage difference was 1.0 (range 0.2-1.6). There was no significant difference in this measure over time among all populations combined or by population.

Seventy percent reported whether data were adjusted for network size, 73% reported the type of software used to adjust data (74% of which used RDS Analysis Tool [RDSAT]) and 26% cited the statistical adjustment, among which 47% cited Salganik & Heckathorn (12), 32% cited Heckathorn (10) and/or 2002, 17% Heckathorn (11), 12% Volz & Heckathorn (13) and 7% Gile (14,154). Only 20% of surveys reported whether equilibrium or convergence was assessed and 4% reported which estimator was used for their statistical adjustment. Thirty-one surveys (14%) specifically reported discarding seeds from their analysis.

Design effects for HIV

Of the 222 surveys reviewed, 185 reported HIV prevalence point estimates above 0, 136 included 95% confidence bounds, and 210 reported final sample sizes. Ninety-five surveys (42.7%) included all three elements to enable calculation of the estimated design effect for HIV prevalence. Four (4.2%) had a design effect less than 1.0, 28 (29.5%) had a design effect of 1.0, 46 (48.4%) had a design effect of 2. The remaining design effects were as high as 5.9, indicating that a larger sample size was needed to estimate HIV prevalence.

Assessing changes over time

In assessing changes over time (Table III), we found significant decreases in eligibility age, final number of seeds, and final sample size ($p<0.01$, for all) and significant increases in pre-survey research and using a design effect to calculate the target sample size ($p<0.01$). There were no significant changes for survey duration even when adjusting for target population and final sample size. Nor were there significant changes by year for survey duration or length of longest recruitment chain.

DISCUSSION

Reporting on details of survey design, implementation, and analysis is essential for assessing the quality of RDS surveys and findings. It is important to adequately describe both the methodological and analytical aspects of RDS in any publication. The preponderance of publications from surveys reported the most essential information such as survey city, country, year, population sampled, interview method, and final sample size. Given that all publications from surveys reported collecting biological specimens, it is surprising that 13% did not provide information about specimen collection and testing methods. Gaps in reporting RDS methodological and analytical information made it difficult to assess survey quality and the strength of results. RDS does not work in all situations and failure to meet assumptions should be noted. For instance, only 43% of surveys reported the maximum number of waves and 20% reported assessment of equilibrium or convergence, information needed to assess potential biases. Among those surveys reporting their maximum number of waves, some reported having only a maximum of three waves, indicating that the survey results were likely biased by the non-randomly selected seeds.

Although pre-survey research should be part of any survey, it is increasingly recognized as an important part of any RDS survey (7,15,22,156), as evidenced by the increase in surveys reporting having conducted formative research. Because RDS samples a social network, formative research is imperative to understand the underlying network structure of the sampled population. If the sampled network is fragmented or has isolated sub-groups, the chances of sampling more than one network are higher, possibly resulting in unstable estimates (15). Furthermore, pre-survey research data

can help investigators plan survey operations and encourage participation by learning about which survey procedures would be most acceptable to the target population. It is possible that the increased use of pre-survey research helped improve recruitment and led to the decrease in the final number of seeds reported over time. Fewer seeds generally occur concomitantly with longer chains, which in turn means decreased bias stemming from seed dependence. We recommend that all surveys using RDS conduct pre-survey research to evaluate social networks, as well as to assess the feasibility of using RDS in a particular population.

Although 70% of surveys reported whether data were adjusted for network size and 73% reported the software used to adjust those data, few cited the adjustment procedure and even fewer reported the estimator used. There are currently at least five different estimators for adjusting RDS data (157). Given that many of the reviewed articles were written before the existence of some estimators, it is understandable that earlier publications did not cite the estimator used for analysis. Forthcoming publications should cite the estimator since knowing this information will allow readers to know how adjustments were made, if they were made properly, and the assumptions supporting those adjustments.

Several publications reported discarding seeds from analysis. While it has been written that “seeds are eliminated from analysis” (13,153), this is not to say that seeds should be manually eliminated from a dataset. The RDS-I and RDS-II estimators (11–13,153) use a matrix of recruits and recruiters whereby data from the recruits are necessary for calculating inclusion probabilities used to derive final estimates. Even though the seeds do not technically show up in the probability matrix since they were

never recruited by their peers, their data are nonetheless necessary for establishing the placement of the seeds' recruits in the matrix.

We found an increase over time in surveys reporting design effects, an element in the sample size calculations to account for RDS not being a simple random sample. Although recent publications have found that design effects of 3 or 4 would be optimal, in most situations, a design effect of 2 is sufficient and recommended (16,151,152). Because operational constraints, such as limited financial resources, often preclude large sample sizes for some RDS surveys, using a design effect greater than 2 may result in unfeasibly large sample sizes. Post-hoc design effects on key variables can help determine if sample sizes were large enough for the analysis and inform sample size calculations for follow-up surveys of the same population. As such it is useful for publications to include point estimates, 95% confidence intervals and final sample size to allow for the post-hoc estimation of design effects.

Equilibrium or convergence was reported in only 20% of the articles reviewed. Equilibrium, the term most often used when referring to RDS surveys, measures the progression of waves to determine when the proportion for a characteristic approaches and remains stable in relation to the final sample statistic (10). Convergence, a more sensitive measurement, measures the progression of enrolling subjects to determine when the proportion for a characteristic approaches and remains stable in relation to the adjusted estimate (15). Nevertheless, the assessment of either equilibrium or convergence is useful for determining seed dependence, a typical bias found in chain referral sampling methods, and should be reported for publications reporting population estimates from RDS surveys (22).

While most surveys reported a minimum eligibility age of 18 years (n=150), we found the minimum age decreased over time. Collecting HIV and other biological and behavioral data from younger key populations is important given they are disproportionately affected by HIV worldwide and are comprising a high percentage of new HIV infections (9,158).

Our review has limitations. As in any systematic review, we are restricted by the completeness of our publication search and whether investigators published their surveys in peer-reviewed journals. Furthermore, we only included surveys that collected biological data leaving room for further evaluation of those surveys that reported using RDS and did not collect biological data. The number of peer-reviewed articles found reporting RDS surveys is far fewer than the actual number of surveys conducted. Although key data were missing from articles, this is in itself an important finding which supports the need to uniformly report results from RDS surveys. It also limited the scope of our analyses and introduced uncertainty into some of our other findings (22). We excluded articles clearly stating they either used RDS 'recruitment' only or did not fulfill necessary features of the method; however, we may have included some surveys that did not incorporate all RDS methodological and analytical features, given their incomplete reporting. In those instances, we classified the surveys as using RDS and included them in the extraction. Several of the 23 articles claiming to use RDS, but did not, reported using a 'modified' or 'mixed methods' RDS. However, they did not provide conclusive evidence such as the collection and use of personal network size data, recruitment ties (who recruited whom) and coupon quotas, and multiple recruitment waves. In several extracted publications, significant limitations were reported, including

unprepared staff, numerous ineligible persons trying to participate, closing or moving survey sites during data collection, overly high incentives (possible indication of enrollment of ineligible participants) or too low, overcrowding at the interview site, failure to recruit important population sub-groups (i.e., females in PWID surveys, older MSM), incorrect or no social network question, and early survey termination due to finances or community disturbances (3,34,41,55,86,127,159). Presenting key limitations is useful for interpreting findings and should be included in all publications presenting data from RDS surveys.

The majority of published surveys were from North American and Europe; it would be useful to see more publications of RDS survey results from other regions. Not only could experiences from these different settings help researchers improve survey methods and analysis, but the results themselves could help policy makers, donors, and service providers to improve responses to HIV and other infection risk. Future publications of biological and behavioral surveys using RDS should provide a minimum set of parameters in order for readers to assess specific methodological and analytical procedures and to make determinations of the overall quality of these surveys.

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