Identifying Heterogeneity Among Injection Drug Users: A Cluster Analysis Approach

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Objectives. We used cluster analysis to subdivide a population of injection drug users and identify previously unknown behavioral heterogeneity within that population.

Methods. We applied cluster analysis techniques to data collected in a cross-sectional survey of injection drug users in Winnipeg, Manitoba. The clustering variables we used were based on receptive syringe sharing, ethnicity, and types of drugs injected.

Results. Seven clusters were identified for both male and female injection drug users. Some relationships previously revealed in our study setting, such as the known relationship between Talwin (pentazocine) and Ritalin (methylphenidate) use, injection in hotels, and hepatitis C virus prevalence, were confirmed through our cluster analysis approach. Also, relationships between drug use and infection risk not previously observed in our study setting were identified, an example being a cluster of female crystal methamphetamine users who exhibited high-risk behaviors but an absence or low prevalence of blood-borne pathogens.

Conclusions. Cluster analysis was useful in both confirming relationships previously identified and identifying new ones relevant to public health research and interventions. (*Am J Public Health.* 2008;98:1430–1437. doi:10.2105/AJPH.2007.120741)

Syringe sharing is a well-established mechanism for the spread of HIV and HCV.[1–3] The introduction of syringe exchange programs (SEPs) has had a substantial impact with respect to decreasing the attributable risk of infectious blood-borne pathogens such as HIV and HCV among injection drug users.[4–11] However, studies have shown variations in the effectiveness of SEPs,[11–18] in that syringe sharing behavior persists among some injection drug users.[12,18–21]

Epidemiological studies in which contextual factors are used to explain syringe sharing (i.e., social network analyses[22]) have demonstrated that sharing behavior is not based exclusively on individual choice[7,23–26]; that is, factors other than syringe access may drive sharing among certain injection drug users.[20,26–28] For example, syringe sharing has been demonstrated to be associated with dyadic relationships involving close friends or sexual partners[12,26,29,30] and partnerships in which injection drug users pool resources to obtain drugs or injection equipment.[21,24,26,31,32] Thus, variation in sharing behaviors is explained by differences between high-risk groups.

Some researchers suggest that designing interventions around variances seen between groups, and the context in which these variances reside, may be both efficient and efficacious,[33–38] especially in terms of public health practice. Understanding the heterogeneity in high-risk groups may be particularly relevant for those behaviors that persist despite the establishment of structural interventions such as SEPs.[15,18–20,28,39–44] Consequently, the use of nontraditional statistical methodologies (such as social network analysis) has been encouraged to capture this variance.[33,35] Cluster analysis,[45,46] "an exploratory technique that can be used to reveal unknown heterogeneity,"[35(p196)] focuses on the inherent differences between cases rather than variables. It has been used in the HIV literature to develop typologies of behavior[33,37]; however, its use is more widespread in the psychiatric and psychological literatures.[38,47–50]

We used cluster analysis as an exploratory tool to investigate whether empirically derived clusters could help to explain heterogeneity in a sample of injection drug users. The broader applicability of this technique to public health investigations in general was also addressed.

METHODS

Study Setting and Survey Instrument

The study setting and survey instrument have been described previously.[51,52] Briefly, a cross-sectional survey of injection drug users in Winnipeg, Manitoba (population: 675 000) was conducted from December 2003 to September 2004. Potential participants were recruited through advertisements placed at local community health centers and meeting places (the latter as identified by key informants) and via word of mouth. To be eligible, individuals had to report use of illicit injection drugs in the 6-month period preceding the interview and had to be 15 years or older.

Participants self-initiated telephone contact with the study nurse, who administered all surveys in person. Interviews took place in a private setting of the participant's choosing. A total of 435 people were interviewed, and an honorarium of Can$40 (approximately US$52 at the time of the study) was provided to all participants. The questionnaire was divided into 3 sections. The first section consisted of questions based on the respondent's own characteristics, the second elicited information on the respondent's egocentric network, and the third included questions on the respondent's injection drug use risk network. The first section was of primary interest in this study.

Cluster Analysis

Agglomerative hierarchical cluster analysis was used to cluster respondents.[45,46,53] Ward's linkage[54] was used, with the matching coefficient[55,56] specified as the similarity measure. Numerous proximity or similarity measures and algorithms are available for use in cluster analysis, although none can be considered as the gold standard.[45,57] We chose Ward's linkage because it has been shown to be a useful clustering algorithm for binary data[58–60] and is more likely than other techniques to produce approximately equal group sizes, thus

facilitating statistical comparisons. We used the matching coefficient as a similarity measure as it has been shown to be effective when used with Ward's algorithm.[61]

Other similarity measures are also suitable for use with Ward's algorithm as well[62]; therefore, following Finch,[62] we also used the Dice[63] and Jaccard[64,65] similarity measures to analyze our data. Because cluster solutions were similar (i.e., there were only slight differences in the optimal number of clusters and the number of individuals within each cluster), we describe only the results derived from use of the matching coefficient. Following the recommendation of Finch to use stopping rules that are readily available and have been proven to be effective in past research,[62] we used Duda's pseudo T^2 statistic[66] and Calinski's pseudo F statistic[67] to determine ideal cluster sizes.

Clustering variables. We took a public health investigative approach in selecting clustering variables; thus, we balanced the choice of variables between those important for transmission of blood-borne pathogens among injection drug users and those that can be ascertained rapidly, validly, and reliably. Syringe sharing is one of the key behaviors associated with transmission of blood-borne pathogens among injection drug users.[1,6,15,68] Type of drug injected has been shown to be an important predictor of infection risk among injection drug users.[2,69–71] Risk has also been differentiated along ethnic boundaries[18]; specifically, in our setting, Aboriginal status was a significant factor in considering transmission risk.[34,72–79]

We constructed binary variables according to drugs injected in the preceding 6 months, receptive syringe sharing in the preceding 6 months, and ethnicity. All analyses were stratified by gender.[7,79] Participants could respond affirmatively or negatively with respect to use of the following list of drugs: cocaine, Talwin (pentazocine) and Ritalin (methylphenidate), morphine, heroin, amphetamines, methadone, crack cocaine, crystal methamphetamine, Dilaudid (hydromorphone), and oxycodone.

Respondents who identified themselves as "Aboriginal" or "Metis" were classified as Aboriginal. Individuals reporting non-Aboriginal, non-White ethnicity accounted for less than 3% of the sample; therefore, they were grouped with those reporting White ethnicity to form a "non-Aboriginal" group. The dichotomized item, "In the last 6 months, have you injected with a needle after someone else used it first?" was used to determine receptive syringe sharing.

Postclustering comparison. We selected postclustering variables with the objective of facilitating understanding of the sociobehavioral contexts within which injection drug users reside.[35] The postclustering variables chosen were age; education; time elapsed since first injection; age at first injection[2]; presence of HIV, hepatitis B virus (HBV), and HCV; bingeing; sharing of injection equipment[31]; injecting others as a favor or as a service[43]; syringe access[14,18,80,81]; and injection locality.[51,82]

Age, time elapsed since first injection, and age at first injection were treated as continuous variables in the postclustering comparison; all other variables were dichotomous. Education was coded as those completing grade 12 or higher versus those who did not reach this level of education. Respondents' blood samples were used to assess HIV, HBV, and HCV infection. Syringe access was determined with the question, "In the last 6 months, how difficult was it for you to obtain a new, unused syringe?" Bingeing was ascertained with the question, "Over the last 6 months, did you go on runs or binges of injection drugs?" As a means of assessing injection locality, respondents indicated whether (in the preceding 6 months) they had injected in their own residence, a family member's residence, a friend's residence, a hotel room, a shooting gallery, on the street, or in a vehicle.

With the clusters as predictors, we used linear regression to detect cluster differences for continuous outcomes; we conducted logistic regression analyses to examine dichotomous outcomes, with the level of significance set at less than .05 (2 tailed). Stata version 9 was used in performing all analyses.[83]

RESULTS

Clusters Identified

The original data set was based on interviews with 435 participants. Complete data on each of the clustering variables were available for 414 participants (235 male and 179 female participants), and we used these data in our analyses. Stopping rules suggested that 7 clusters were ideal for both male and female participants. Table 1 shows the characteristics of each cluster based on the clustering variables used. For brevity and clarity, only the top 2 drugs of choice are listed for each cluster (or in some cases only 1). These drugs were those reported by almost all members of a cluster; reported use of other drugs was relatively sporadic.

With type of drug(s) injected as a nominal cluster descriptor, the following clusters were identified (for both genders with the exception of cluster 5): cluster 1, exclusively cocaine; cluster 2, cocaine and crack; cluster 3, cocaine and crystal methamphetamine; cluster 4, morphine and cocaine; cluster 5, a second morphine and cocaine cluster among male participants and a Dilaudid and morphine cluster among female participants; cluster 6, Talwin and Ritalin in combination with cocaine; and cluster 7, exclusively Talwin and Ritalin.

Clusters were further differentiated by the remaining 2 clustering variables: syringe sharing and ethnicity. Among male clusters, the percentage of those who had shared a syringe in the preceding 6 months ranged from 0% to 35%, with an average of 14%; the percentage of Aboriginals ranged from 0% to 100%, with an average of 53%. Among female clusters, syringe sharing ranged from 0% to 69%, with an average of 21%; the percentage of Aboriginals ranged from 8% to 100%, with an average of 79%.

Postclustering Comparisons

Tables 2 and 3 summarize the postclustering comparisons for each cluster. Only variables for which there were significant differences between the clusters are shown (for Tables 2 and 3, and for all summations that follow, the significant differences noted between clusters use cluster 1 as the reference). Table 2 includes variables (continuous) analyzed using linear regression, whereas Table 3 includes dichotomous variables assessed in logistic regression analyses (hence, unstandardized linear regression parameter estimates are presented in Table 2 and odds ratios are presented in Table 3). We summarize these results for the male and female clusters.

Male participants. There were significant associations between cluster membership and

TABLE 1—Characteristics of Male and Female Injection Drug Users, by Clustering Variables: Winnipeg, Manitoba, 2003–2004

	Cluster							
	1	2	3	4	5	6	7	Total
Men								
Total, no.	29	18	36	43	46	28	35	235
Drugs used, %	Cocaine, 100.0	Cocaine, 83.3; crack, 100.0	Cocaine, 63.9; CM, 41.7	Morphine, 95.4; cocaine, 90.7	Morphine, 91.3; cocaine, 41.3	T&R, 100.0; cocaine, 96.4	T&R, 94.3	
Engaged in drug sharing, %	3.5	0.0	2.8	34.9	4.4	3.6	31.4	13.7
Aboriginal ethnicity, %	100.0	61.1	0.0	23.3	45.7	96.4	74.3	52.8
Women								
Total, no.	32	23	16	37	13	19	39	179
Drugs, % used	Cocaine, 100.0	Crack, 100; cocaine, 73.9	CM, 62.5; cocaine, 50.0	Morphine, 86.5; cocaine, 67.6	Dilaudid, 100.0; morphine, 76.9	Cocaine, 100.0; T&R, 100.0	T&R, 100.0	
Engaged in drug sharing, %	0.0	0.0	68.8	27.0	15.4	31.6	23.1	21.1
Aboriginal ethnicity, %	100.0	82.7	25.0	75.7	7.7	100.0	97.4	78.8

Note. CM = crystal methamphetamine; T&R = Talwin and Ritalin. Values are percentages of individuals within a cluster showing a given characteristic.

TABLE 2—Continuous Variables in Postclustering Comparisons of Male and Female Injection Drug Users: Winnipeg, Manitoba, 2003–2004

	Male Participants			Female Participants		
Variable and Cluster	Mean (SD)	b (95% CI)	*P*	Mean (SD)	b (95% CI)	*P*
Age, y			.723			<.001
1 (Ref)	34.7 (9.0)	. . .		32.9 (9.0)	. . .	
2	36.6 (8.9)	1.89 (−4.10, 7.87)		34.9 (8.2)	1.98 (−2.82, 6.77)	
3	35.4 (13.1)	0.69 (−4.28, 5.67)		21.9 (5.9)	−11.00*** (−5.63, −16.37)	
4	35.1 (9.7)	0.35 (−4.45, 5.14)		38.3 (8.9)	5.36* (1.12, 9.60)	
5	35.6 (10.9)	0.91 (−3.82, 5.64)		32.0 (9.7)	−0.94 (−6.71, 4.84)	
6	39.0 (8.4)	4.28 (−1.01, 9.56)		34.6 (9.9)	1.64 (−3.44, 6.72)	
7	35.2 (8.7)	0.48 (−4.53, 5.48)		34.9 (9.3)	1.93 (−2.25, 6.12)	
Total	35.8 (10.1)			33.8 (9.7)		
Length of time since first injection, y			.877			<.001
1 (Ref)	14.3 (9.2)	. . .		11.9 (8.0)	. . .	
2	15.3 (8.8)	0.99 (−5.25, 7.23)		14 (8.7)	2.13 (−2.48, 6.73)	
3	14.5 (13.1)	0.16 (−5.03, 5.34)		3.0 (2.9)	−8.88*** (−3.72 , −14.03)	
4	16.7 (10.1)	2.33 (−2.67, 7.32)		13.9 (10.3)	2.04 (−2.02, 6.11)	
5	15.3 (11.3)	0.96 (−3.97, 5.89)		13.3 (11.6)	1.43 (−4.11, 6.97)	
6	16.2 (9.1)	1.83 (−3.67, 7.34)		13.5 (7.8)	1.60 (−3.28, 6.48)	
7	13.4 (9.8)	−0.92 (−6.14, 4.30)		15.1 (7.7)	3.20 (−0.82, 7.22)	
Total	15.1 (10.5)			12.7 (9.0)		

Note. CI = confidence interval. Age at first injection was not significant at the $P < .05$ level and is not included here.
*$P < .05$; ***$P < .001$.

(1) injecting in a user's residence, (2) injecting in a hotel room, (3) HCV prevalence, and (4) the likelihood of sharing injection equipment. Members of cluster 4 (the predominantly morphine and cocaine cluster) were more likely to have injected in their own home and were more likely to be HCV positive. Members of cluster 6 (the cluster marked by Talwin and Ritalin use in combination with cocaine use) were more likely to have injected in a hotel room, to have injected in a family member's residence, and to be HCV positive. Injection drug users in cluster 7 (Talwin and Ritalin only) were more likely to have shared injection equipment.

Female participants. There were significant associations between cluster membership and (1) age, (2) length of injection, (3) injection in a family member's residence, (4) injection in a hotel room, (5) injection on the street, (6) HCV prevalence, and (7) HBV prevalence. Members of cluster 3 (marked by crystal methamphetamine and cocaine use) were significantly younger and (not surprising given their young age) had injected for fewer years. They also were more likely to have injected on the street. They were less likely to be HCV positive, and this cluster was notable for the absence of any members infected with HIV or HBV. Injection drug users in cluster 6 (Talwin and Ritalin in combination with cocaine) were more likely to have injected in a family member's residence, in a hotel room, and on the street; also, this cluster was more likely to include members who were HCV and HBV positive. Similar to cluster 6, cluster 7 was also more likely (than the reference cluster) to include members who were HCV and HBV positive.

DISCUSSION

We used agglomerative hierarchical cluster analysis to develop empirical, gender-specific

TABLE 3—Dichotomous Variables in Postclustering Comparisons of Male and Female Injection Drug Users: Winnipeg, Manitoba, 2003–2004

	Male Participants			Female Participants		
Variable and Cluster	No. (%)	OR (95% CI)	*P*	No. (%)	OR (95% CI)	*P*
HCV infection			<.001			<.001
1 (Ref)	11 (37.9)	1.00		12 (37.5)	1.00	
2	8 (44.4)	1.31 (0.40, 4.32)		8 (34.8)	0.89 (0.29, 2.72)	
3	10 (27.8)	0.63 (0.22, 1.79)		1 (6.3)	0.11* (0.01, 0.95)	
4	29 (67.4)	3.39* (1.27, 9.07)		19 (51.4)	1.76 (0.67, 4.61)	
5	20 (43.5)	1.26 (0.49, 3.25)		4 (30.8)	0.74 (0.19, 2.94)	
6	22 (78.6)	6.00* (1.86, 19.40)		14 (73.7)	4.67* (1.34, 16.24)	
7	15 (42.9)	1.23 (0.45, 3.35)		26 (66.7)	3.33* (1.25, 8.86)	
Total	115 (48.9)			84 (46.9)		
HBV infection			.069			<.001
1 (Ref)	6 (20.7)	1.00		5 (15.6)	1.00	
2	4 (22.2)	1.10 (0.26, 4.57)		2 (8.7)	0.51 (0.09, 2.92)	
3	7 (19.4)	0.93 (0.27, 3.13)		0 (0.0)	. . .	
4	11 (25.6)	1.32 (0.43, 4.08)		12 (32.4)	2.59 (0.80, 8.41)	
5	12 (26.1)	1.35 (0.44, 4.12)		2 (15.4)	0.98 (0.17, 5.84)	
6	15 (53.6)	4.42 (1.38, 14.19)		10 (52.6)	6.00* (1.62, 22.28)	
7	7 (20.0)	0.96 (0.28, 3.25)		20 (51.3)	5.68* (1.81, 17.81)	
Total	62 (26.4)			51 (28.5)		
Sharing of injection equipment			.004			.077
1 (Ref)	8 (27.6)	1.00		11 (34.4)	1.00	
2	4 (22.2)	0.75 (0.19, 2.97)		8 (34.8)	1.02 (0.33, 3.14)	
3	12 (33.3)	1.31 (0.45, 3.82)		5 (31.3)	0.87 (0.24, 3.13)	
4	18 (41.9)	1.89 (0.68, 5.22)		6 (16.2)	0.37 (0.12, 1.15)	
5	11 (23.9)	0.83 (0.29, 2.38)		8 (61.5)	3.05 (0.80, 11.60)	
6	3 (10.7)	0.32 (0.07, 1.34)		8 (42.1)	1.39 (0.43, 4.46)	
7	19 (54.3)	3.12* (1.09, 8.92)		16 (41.0)	1.33 (0.50, 3.50)	
Total	75 (31.9)			62 (34.6)		
Injection in own residence			.014			.088
1 (Ref)	12 (41.4)	1.00		11 (34.4)	1.00	
2	11 (61.1)	2.23 (0.67, 7.40)		15 (65.2)	3.58 (1.16, 11.04)	
3	16 (44.4)	1.13 (0.42, 3.05)		8 (50.0)	1.91 (0.56, 6.78)	
4	34 (79.1)	5.35*** (1.89, 15.17)		24 (64.9)	3.52 (1.30, 9.52)	
5	29 (63.0)	2.42 (0.93, 6.26)		9 (69.2)	4.30 (1.07, 17.17)	
6	18 (64.3)	2.55 (0.88, 7.42)		10 (52.6)	2.12 (0.67, 6.76)	
7	18 (51.4)	1.50 (0.56, 4.05)		26 (66.7)	3.82 (1.42, 10.25)	
Total	138 (58.7)			103 (57.5)		
Injection in family residence			.044			.004
1	0 (0.0)			5 (15.6)	1.00	
2	0 (0.0)			2 (8.7)	0.51 (0.09, 2.82)	
3	2 (5.6)	1.00		3 (18.8)	1.25 (0.26, 6.03)	
4	9 (20.9)	4.50 (0.91, 22.38)		0 (0.0)		
5	4 (8.7)	1.62 (0.28, 9.38)		1 (7.7)	0.45 (0.05, 4.28)	

Continued

clusters derived from basic characteristics of injection drug users. Similar to other studies, we demonstrated the advantages of using multiple drug use indicators to analyze injection drug use.[38,84] We discuss the implications of these results with respect to injection drug use and address the potential contribution of using similar data-analytic approaches for public health investigations in general.

Cluster Analysis and injection Drug Use

HBV and HCV prevalence in clusters marked by Talwin and Ritalin use was high. We have previously observed high HCV and HBV prevalence among Talwin and Ritalin users in this population, regardless of syringe-sharing behavior.[52] Communal drugs or filters may explain this observation, in that Talwin and Ritalin are prepared at room temperature.[31,32,85] The association found between Talwin and Ritalin use and injection in hotel rooms was demonstrated in a previous study as well,[51] further validating our methodology.

Another notable result was the existence of a cluster of female injection drug users with a very low prevalence of blood-borne pathogens. This group was composed predominantly of non-Aboriginal crystal methamphetamine and cocaine users. Despite having the highest percentages of injection drug users who shared syringes (69%), binged (75%), and injected on the street (63%) in the 6 months prior to the study, this cluster did not include any HIV- or HBV-positive members, and significantly fewer of its members were HCV positive (relative to the reference cluster). Further analyses showed that members of this group were significantly younger than were the other female injection drug users and, subsequently, had injected for fewer years on average.

Our finding that crystal methamphetamine use was associated with younger age and risky syringe behavior is consistent with the results of other studies[86]; however, to the best of our knowledge, our study is the first to demonstrate the existence of high-risk female injection drug users with a low prevalence of blood-borne pathogens who inject crystal methamphetamine. Social network analyses of sexually transmitted infections have demonstrated the importance of mixing patterns in promoting transmission.[87–89] Therefore, the potential opportunity for

TABLE 3—*Continued*

6	8 (28.6)	6.80* (1.31, 35.23)	11 (57.9)	7.43* (1.99, 27.77)	
7	7 (20.0)	4.25 (0.82, 22.11)	7 (18.0)	1.18 (0.34, 4.15)	
Total	30 (12.8)		29 (16.2)		
Injection in hotel		.008			.012
1 (Ref)	9 (31.0)	1.00	15 (46.9)	1.00	
2	4 (22.2)	0.63 (0.16, 2.48)	8 (34.8)	0.60 (0.20, 1.82)	
3	12 (33.3)	1.11 (0.39, 3.17)	4 (25.0)	0.38 (0.10, 1.42)	
4	18 (41.9)	1.60 (0.59, 4.32)	12 (32.4)	0.54 (0.20, 1.45)	
5	14 (30.4)	0.97 (0.36, 2.66)	4 (30.8)	0.50 (0.13, 1.98)	
6	20 (71.4)	5.56** (1.78, 17.31)	15 (79.0)	4.25* (1.15, 15.65)	
7	15 (42.9)	1.67 (0.59, 4.68)	19 (48.7)	1.08 (0.42, 2.75)	
Total	92 (39.1)		77 (43.0)		
Injection in street		.572			.003
1 (Ref)	8 (27.6)	1.00	6 (18.8)	1.00	
2	6 (33.3)	1.31 (0.37, 4.70)	6 (26.1)	1.53 (0.42, 5.53)	
3	11 (30.6)	1.16 (0.39, 3.40)	10 (62.5)	7.22*** (1.88, 27.75)	
4	18 (41.9)	1.89 (0.68, 5.22)	7 (18.9)	1.01 (0.30, 3.39)	
5	13 (28.3)	1.03 (0.37, 2.92)	4 (30.8)	1.93 (0.44, 8.42)	
6	8 (28.6)	1.05 (0.33, 3.33)	11 (57.9)	5.96*** (1.67, 21.25)	
7	7 (20.0)	0.66 (0.21, 2.10)	8 (20.5)	1.11 (0.34, 3.64)	
Total	71 (30.2)		52 (29.1)		

Note. OR = odds ratio; CI = confidence interval; HBV = hepatitis B virus. The following variables were not significantly associated with cluster membership and thus are not included here: education, HIV status, injecting someone as a service, injecting someone as a favor, bingeing in past 6 months, ease in obtaining syringes, injection at a friend's residence, injection at a shooting gallery, and injection in a vehicle.
*P < .05; **P < .01; ***P < .001.

pathogens to affect the members of this vulnerable group will depend on the extent to which they are sociobehaviorally connected to other injection drug users, whose prevalence of blood-borne pathogens may be higher.[2,7,23,29,90,91]

The observation of this high-risk cluster also has significant policy implications. Although structural interventions are important in decreasing attributable risk,[4–6] structural changes coupled with interventions that target more narrowly defined groups may be more effective in reducing transmission of blood-borne pathogens.[15,20]

The dramatic increase in HIV incidence seen in Vancouver, British Columbia, during the 1990s may be particularly illustrative of the importance of identifying and assessing heterogeneity among injection drug users. The unique profile and high prevalence of cocaine injectors[2,69] were important factors in the observed increase in HIV.[18,44,81,92] SEPs were designed so that clean syringes were provided only as used syringes were returned in a one-to-one ratio, and services were limited during the evening. This policy made access to clean syringes difficult for cocaine injectors because they frequently injected during hours when no service was available.[11,13,44] Our findings suggest that similar attention to intervention design may be warranted for young female crystal methamphetamine users, to ensure that appropriate structural interventions are available to lower their infection risk.

Cluster Analysis and Public Health Practice

Although we used cluster analysis specifically to explore aspects of injection drug use in our study population, our results also help to illustrate the utility of this approach for public health investigations in general. Various authors[35,93–95] in the social sciences have discussed the need to use contextual methods in data analyses, in addition to simply using contextual ideas (theories, models, and frameworks). In particular, Luke[35] has argued that a relatively narrow array of analytic techniques have been traditionally used in the social sciences. According to Luke, although these statistical approaches have clearly generated usable and useful results, they may not reveal the full complexity of the effects of the physical, social, economic, political, and cultural environments on human behavior and health.

As one of the social contextual methods discussed by Luke,[35] cluster analysis is a technique that has developed useful subtypes and generated understanding of patterns within multivariate data for a diverse range of fields.[45,57,96–99] For example, an early classification of alcohol abuse by Goldstein and Linden[100] influenced a rich literature on alcoholic subtypes.[101–103] This literature has subsequently informed knowledge around diagnosis, etiology, and treatment options for alcoholics.[104,105]

With respect to public health, the development of objective and empirically derived typologies has been one of the more useful applications of cluster analysis. As many studies suggest, once subtypes of formerly homogeneous groups are hypothesized and (most important) validated, targeted prevention, intervention, and treatment efforts can be mobilized.[37,99,106–108] As noted by Houck et al., "prevention efforts are most successful when they are compatible with their target audiences."[37(p627)] In addition, although in theory other multivariable techniques (e.g., logistic regression) could have been used to analyze our data set, it is unlikely that our results could have been produced without strong a priori hypotheses, such as those generated by this technique. We endorse the viewpoint that cluster analysis can serve a complementary, as opposed to competing, role alongside traditional statistical tools.

However, some caution is warranted in the use of cluster analysis for typology development. As mentioned by Howell et al.,[109] cluster analysis as a technique will always reveal clusters in data; validation in other samples, substantive theoretical support, and sound expert opinion should ultimately determine whether identified clusters have clinical significance. For example, the validity of our clusters is supported by their consistency with the plausibility of the patterns identified (e.g., the low rate of infectivity among participants in the crystal methamphetamine cluster was

consistent with the length of time they had injected drugs, despite their high potential for infection) and by the identification of patterns consistent with those identified through other techniques (e.g., the association between Talwin and Ritalin use, hepatitis prevalence, and injection in hotel rooms[51,52]).

When plausible and consistent results are obtained, such as those identified here, the need to validate clusters does not necessarily mean that public health interventions should be withheld until that validation occurs. In our study area, with reference to female crystal methamphetamine users, the imminent and precarious infection risk posed by a combination of high-risk behaviors should be sufficient justification for an urgent public health outreach response.

Limitations

There were some limitations of our study. First, because the sampling methodology used was nonrandom, the generalizability of our data to injection drug users in Winnipeg or other locales may be limited. Second, all information was self-reported and therefore subject to recall or social desirability biases. Third, the data were cross-sectional, and thus causality cannot be determined.

Fourth, small cell sizes may have resulted in unstable statistical outcomes. Fifth, there is a limit to how much can be inferred from quantitative data; for example, low prevalence rates of blood-borne pathogens may be attributable to conscientious partner restriction.[30] Qualitative studies may be warranted to more fully explore the underlying social context of some of the patterns identified through techniques of this type.

Sixth, we acknowledge subjectivity in the choice of clustering variables. It can be argued, for example, that blood-borne pathogen infection status is an important predictor of risk behavior and thus could be considered a clustering variable. However, from a public health investigation perspective, assessment of infection status may not necessarily be rapid.

Finally, using different linkage methods may result in different clusters being discovered.[45,53,61,62] We recommend the use of a few different similarity measures in cluster analyses. The similar pattern of results we obtained using multiple measures increases the robustness of our findings. As well, the potential artificiality of our cluster solutions must be emphasized; we do not purport to have discovered "true" clusters in the sense of all members of a given cluster forming a single connected social network. We sought to determine whether cluster analysis could provide new knowledge by discerning patterns in our sample through the use of important clustering variables.

Conclusions

Studies have suggested that blood-borne pathogen infections are increasing in younger populations.[69,110] Using a novel technique (with respect to research on blood-borne pathogens), we discovered a cohort of noninfected female crystal methamphetamine users with a high potential for pathogen transmission. Studies that further expand understanding of the timing, progression, and escalation of drug use and sharing behaviors in young people[38] may be essential in informing interventions designed to prevent the bridging of blood-borne pathogens into this and similar cohorts. ■

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Contributors

S.Y. Shaw was lead author and conducted all of the analyses described. L. Shah constructed and cleaned the database and assisted with the data analysis. A.M. Jolly and J.L. Wylie were responsible for study design and implementation. All of the authors provided input on interpretation of results and the writing of the article.

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Human Participant Protection

This study was approved by the Health Research Ethics Board of the University of Manitoba and the Winnipeg Regional Health Authority Research Review Committee. Participants provided written or oral informed consent.

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