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ORIGINAL ARTICLE

Geospatial Analysis of Acute Poisonings at Mashhad, Iran in 2013

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Abstract

Background: Geospatial distribution analysis is a highly useful tool, especially in the field of health research and health economics. We aimed to study the geospatial distribution of poisoned patients and the risk factors in Mashhad, Iran.
Methods: This was a retrospective cross-sectional study of patients treated at the Medical Toxicology Center, Imam Reza Hospital, Mashhad, Iran, which is the only referral center in northeast of Iran, in 2013. Negative binomial and Poisson approach via generalized linear mixed models were performed to investigate the association between socio-demographic characteristics with the number of reported cases of poisoning.
Results: A total of 5064 poisoned patients (52% females) were included. Most of the poisoned patients were within the age group of 20-29 years old (41.4%). Pharmaceutical agents were the most common cause of poisonings (64.6%). The local test of spatial autocorrelation (Moran's I) confirms that the poisoning had cluster pattern in Mashhad. Number of poisoning events were found to be associated with population density (RR= 1.00011; 95% CI 1.0001-1.00013), and the frequency of people with less than high school education (RR=1.49; 95% CI 1.32-1.68).
Conclusion: The geospatial factors may have impact on the number of acute poisoning events in a city. Some parts of a city may exhibit spatial clustering in poisoning events. Once clusters are found, interventions can be focused to specific geographic locations and would be helpful for healthcare policymakers to focus on prevention programs.

Keywords: Poisoning; Iran ; Spatial Analysis; Spatial Autocorrelation

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INTRODUCTION

Poisoning is a medical emergency and significant cause of morbidity and mortality (1). The pattern of poisoning is different in various parts of Iran (2) and showed an increased prevalence in Northeast of Iran during 2004-2013 (3). Poisoning, either deliberate or accidental caused mainly by drug abuse/ addiction, is prevalent in Iran and pharmaceutical drug poisoning is the third leading cause of suicide-related deaths in the country (2, 3). Pharmaceutical drugs, illicit drugs, and chemicals are in easy access in almost any part of the country (2). Acute poisoning is one of the common causes of hospitalization, and drug poisoning is reportedly the second cause of death among hospitalized patients in Iran (4). Poisonings due to opioid abuse have shown a growing trend in many countries including Iran (5, 6).

The pattern of poisoning in each region depends on various factors, including poisons availability, socio-economic conditions, cultural and religious beliefs (7, 8). Regarding the rapid growth of urban communities along with easy access to drugs and poisons, it is necessary to study the poisoning in various social classes. Intoxication patterns according to municipal planning areas can help identifying the risk factors and early detection of poisoning (9).

Geospatial distribution analysis is a highly useful tool, especially in the field of health research and health economics (10). Despite being helpful for toxicologists and public health planners, too few studies have been done in this regard in Iran. The objective of this study was to model poisoning and corresponding risk factors using a geospatial analysis in Mashhad, the second major city of Iran, in 2013.

METHODS

Catchment area

The geographical scope of this study is the city of Mashhad, the second most populous city in Iran (2.8 million

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inhabitants as reported in the 2011 national census of Iran (11, 12). It is a fast-growing city, which is located in northeast of Iran. This city is one of the most popular tourist destinations in the country that prospered within a religious and cultural context. It is situated at a latitude of 35’N till 37’N and longitude of 59’E till 60’E, with an area of 328 km^2. The city plan is divided into 13 municipal districts. In the present study, the whole planning area was divided into 1000m×1000m segmental grids.

Study design and subjects

In this cross-sectional study, retrospective extraction of data from medical records of poisoned cases treated at the Medical Toxicology Centre (MTC) in Imam-Reza Hospital, Mashhad, Iran in the year of 2013 was performed. MTC comprising of a toxicology emergency service and a toxicology ward is the only referral center of poisoned patients in Mashhad; which therefore, accepts all poisoning cases in this region. After the protocol was approved by the Ethics Committee of MUMS (ir.mums.rec.1394.0731) Patient’s information (including sex, age, marital status, causes of poisoning and location of poisoning event) was extracted from the medical records. Cases with incomplete data were excluded from the study. Some patients were admitted repeatedly due to one Poisoning incidence. We aggregated the information of each of these patients as a unique record. The causes of poisoning were classified based on the International Classification of Diseases, 10th Revision (ICD-10) (13).

Statistical analysis

One of the most commonly used methods in geospatial analysis is spatial generalized linear mixed model. The correlation between observations is addressed by adding random effects, and independent assumption of observation changes to conditional independence. Suppose that $\mu_{s(i)}$ is the mean value of some individuals present at the location segment *i*. Spatial generalized linear mixed model is given by the following equation:

$$g(\mu_{s(i)})) = x_{s(i)}^{T}\beta + u_{s(i)},\ i = 1,..n$$

In this equation, β is a *p*-dimensional vector of regression coefficients and *g*(.) is the link function. Moreover, x and u are the spatial fixed effect and the spatial random effect of the model, respectively.

In count data, we assume that the link function is in the logarithm form, $g(\mu) = \log(\mu)$. If the variance is greater than the mean (over-dispersion), a negative binomial model could be an alternative model to assess the association between covariates and the outcome (14, 15). Local Indicators of Spatial Association (LISA) Statistic was performed to measure the local spatial autocorrelation and clustering tendency, across the area concerning poisoned cases. This statistic provides information related to the location of spatial clusters and outliers and the types of spatial correlation (16). A clustered or dispersed spatial pattern is illustrated by a positive or negative Moran’s I value along with a z-score falling between 1.96 and 1.96.

Spatial generalized linear mixed model with a negative binomial distribution and a logarithmic link function was performed. Spatial random effect and community-level characteristics fixed effects have been added in the model via spatial generalized linear mixed models using spaMM package in R software (version 3.2.4) (17). The dependent variable was the number of poisoned cases, which observed in 1000m×1000m segmental grids. Fixed effects were: community-level socio-demographic (including percentage of population aged 20 to 30 years old (As the highest risk group), population density, and suburbia); economic characteristics (including unemployment ratio, percentage of population who placed in less than high school education group); and health center-related data (the number of public health centers). These variables were drawn from the Resource Files for Investigation of the Iran Census in the year 2011(11, 12).To extrapolate estimates to the grid segment scale, the intersect tool in ArcGIS found the value of each variable inside a given grid segment. There was widespread over-dispersion on the right tail of the distribution where the average population count was 17.12, and the variance was 231.14. In addition, twelve percent of the counts were recorded as zero.

RESULTS

Description of the study population

A total of 5064 poisoned cases, with a mean age of 27.3 ± 14.6 years were included in this study. The majority of poisonings occurred in the age group of 20-29 years (2029 cases; 41.4%) followed by 10-19 and 30-39 age groups (882 cases; 17.4% for both groups). With relatively equal sex distribution, women were slightly involved more (female/male: 52/48%). The majority of cases (72.1%) were living inside the city boundary. In the present study, the most common causes of poisoning were drugs (3273 cases; 64.6%), followed by opioids (1161 cases; 22.9%) (Table 1).

Table 1. Demographic characteristics of poisoned patients, Mashhad, 2013

Patient Characteristics		Frequency (%)
Sex		
	Male	2429 (48.0)
	Female	2635 (52.0)
Age (year)		
	0-9	442 (8.7)
	10-19	882 (17.4)
	20-29	2099 (41.4)
	30-39	882 (17.4)
	40-49	359 (7.1)
	50-59	174 (3.4)
	60 ≤	225 (4.4)
Marital status		
	Married	2545 (50.3)
	Single	2312 (45.8)
	Divorced	135 (2.7)
	Widow	60 (1.2)

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Table 2. Continued.

Patient Characteristics	Frequency (%)
Residential zone	
Urban area	3650 (72.1)
Suburbia	1414 (27.9)
Causes of poisoning	
Drugs (Pharmaceutical products)	3273 (64.6)
Opioid overdose	1161 (22.9)
Pesticides	228 (4.5)
Alcohol intoxication	201 (4.0)
Carbon monoxide	56 (1.1)
Venomous animal exposures	45 (0.9)
Others	100 (2.0)

Sociodemographic characteristics of Mashhad municipal districts

The most populous districts of Mashhad are districts 2, 3 and 9, where the highest number of poisoning events occurred. The greatest number of primary healthcare centers and drug stores are located in district 1 followed by district 2 and 8 and an association between the number of poisoning events and the number of these facilities does not seem to be factual. Although a linear correlation between the number of poisoning event and poverty scale or deprivation from access to urban services cannot be drawn, it seems that districts with worse poverty situation and poorer access to urban services had higher number of events (Table 2). In addition, district 2 and 3 with the highest number of poisoning events were among the districts with highest rate of under high school education.

Geospatial analysis of poisoning

Figure 1 shows the geospatial distribution of poisoned cases on a 1000 m × 1000 m grid cells. As the map demonstrates, marginal segments had fewer poisoning cases compared to interior segments. If the municipality district boudaries are superimposed on the figure 1, it can be seen that the majority of acute poisonings occurred in the districs with more dense populations (including districts 2 and 3) as well as those with higher poverty scale and less developed urban services (Table 2).

Figure 2, which shows the number of poisoned patients per resident population per segment, gives a more accurate picture of geospatial situation of poisoning per population, as marginal segments had more frequent poisning cases per the number of population, implying the greater harms and social hazard of marginalized populations.

Spatial autocorrelation analysis resulted in Moran's *I*-statistic of 0.07 and a *z*-score of 18.30 indicates a significant spatial autocorrelation ($P < 0.001$), implying that similar values are located in neighbor segments. In other words, segments with similar number of poisoning tend to locate closer to each other. The results of Moran's index on the spatial distribution of poisoning in the city of Mashhad is shown in figure 3.

Table 2. Data of municipal districts of Mashhad based on 2011 census

District	No. of poisoning events	Population, No. (%)	No. of primary healthcare centers	No. of drugstores*	Under high school education No. (%)	Poverty scale**	Access to urban services***
1	302 (6.0)	176,039 (6.3)	150 (23.5)	114 (25)	67,473 (38.3)	Very low	Intermediate
2	867 (17.1)	434,729 (15.7)	72 (11.3)	44 (10)	212,470 (49.0)	Middle to High	Intermediate
3	692 (13.7)	367,027 (13.2)	44 (6.9)	31 (7)	192,023 (52.3)	Middle to High	deprived
4	430 (8.5)	246,296 (8.9)	48 (7.5)	34 (7)	126,939 (51.5)	High	deprived
5	264 (5.2)	168,154 (6.1)	12 (1.9)	8 (2)	83,913 (49.9)	Middle to High	deprived
6	432 (8.5)	230,289 (8.3)	34 (5.3)	22 (5)	116,142 (50.4)	Very High	Relatively deprived
7	410 (8.1)	229,940 (8.3)	32 (5.0)	23 (5)	120,767 (52.4)	Middle	Less developed
8	187 (3.7)	94,227 (3.3)	69 (10.8)	51 (11)	40605 (44.5)	Middle	Less developed
9	590 (11.7)	300,539 (10.9)	63 (9.9)	44 (10)	120,046 (40.2)	Low	Developed
10	450 (8.9)	265,205 (9.6)	42 (6.6)	30 (6)	123,509 (46.6)	High	Intermediate
11	332 (6.6)	192,355 (6.9)	50 (7.8)	41 (9)	75,135 (39.1)	Middle	Less developed
12	64 (1.3)	40,002 (1.4)	3 (0.5)	2 (0)	18,407 (46.0)	Middle to High	Developed
13	44 (0.9)	21,456 (0.8)	20 (3.1)	16 (3)	9,807 (45.7)	Low to Middle	Relatively deprived
Total	5064	2,766,258	639	460 (100)	130,072,36 (47.3)		

* Based on the study by: Einy A, et al.(12)
** Based on the study by: Farhadikhah, H, et al. (18)
*** Based on the study by: Hataminejad H, et al. (19),

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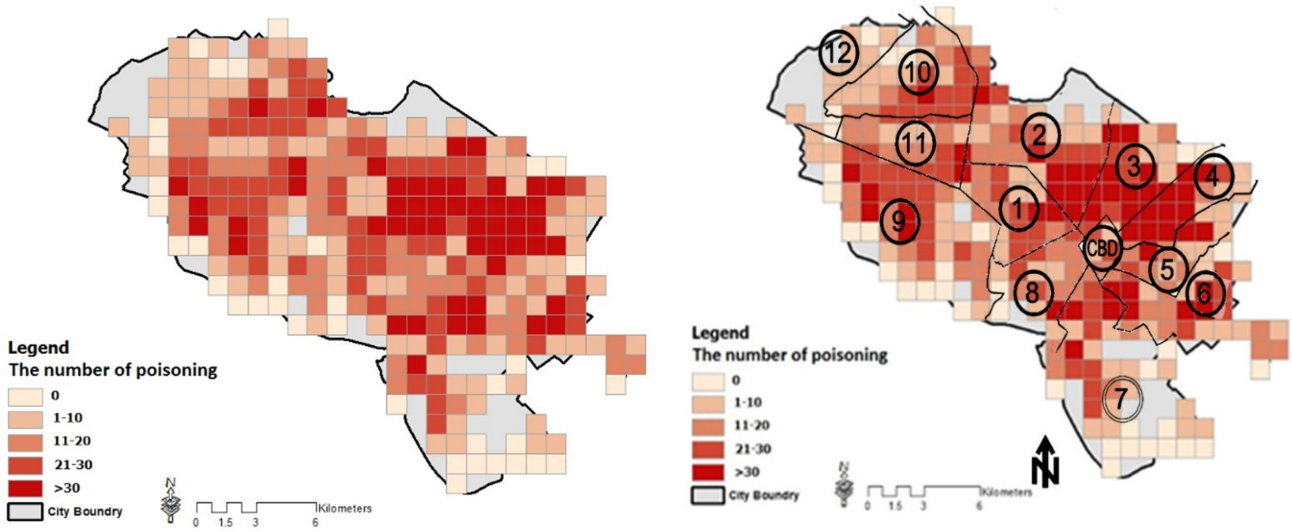

Figure 1. Geospatial distribution of poisoned cases in Mashhad (2013) on a 1000m×1000m grid cells (Left) and with superimposed municipality districts (right)

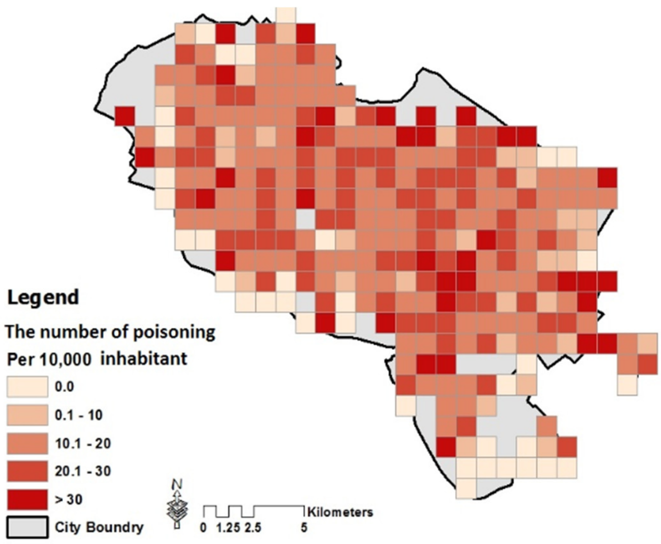

Figure 2. Number of poisoned cases per 10000 on a 1000m×1000m grid cells in Mashhad, 2013

As shown in figure 3, distribution of poisonings could be categorized into two spatial clusters with the highest density in the central part of the city (corresponding to districts 2, 3 and 4), i.e. high-high cluster; along with the North-West and South-East parts of the city, i.e. low-low clusters. Table 3 shows the causes of poisoning in the high-high cluster revealing that pharmaceutical agents, especially psychiatric drugs, were the most prevalent cause of intoxication.

It is worth mentioning that there are three or more drugstores in more than 40% of area of High-High cluster. In contrast, there is no drugstores in the most parts in the Low-Low cluster.

Fitted Models and Evaluation

The outcome is the number of poisoned cases per segment. We have used univariate negative binomial regression model to examine the association between each covariate and the response variable. As a result, significant covariates via univariate analysis at the significance level of < 0.05 were identified as: percentage of subjects within the age group of 20-30 years old, population density, residential zone and frequency of subjects educated less than high school. Multivariable analysis was then performed to account for the potential confounders and calculate the adjusted results. Rate

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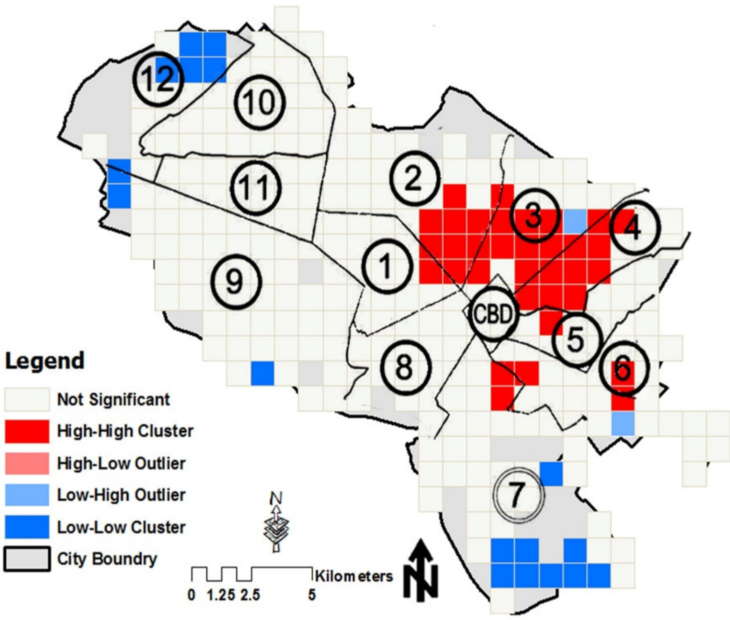

Figure 3. Spatial clusters and outliers of poisoning based on Moran's index in Mashhad, 2013

Table 3. Cause of Intoxication in High-High cluster

Cause of intoxication	Frequency %
Psychiatric drugs	133 (23.0)
Opioids	104 (18.0)
Stimulants and Hallucinogens	232 (40.0)
Other drugs	35 (6.0)
Pesticides	35 (6.0)
Alcohols	23 (4.0)
Caustics	9 (1.5)
Carbon monoxide poisoning	6 (1.0)
Toxic heavy metal	3 (0.5)

ratios (RR) for the community-level characteristics in our model indicated that poisoning frequency was positively correlated to the population density (Table 4). According to this model, rate of "less than high school education" was positively associated with the number of poisoning patients and for every one percent increase in the proportion of individuals with "less than high school education", the number of poisoned cases increased by 49% (RR=1.49; 95% CI 1.32-1.68).

DISCUSSION

Human health can be affected by environmental and socio-economic factors. Geodemographic features may have impact on the susceptibility to poisoning. In this study, we aimed to employ spatial statistical methods to analyze the factors influencing the poisoning in city districts of Mashhad, Iran.

It was found that some social and environmental parameters have impact on the incidence of poisoning. Accordingly, the highest frequency of poisoned cases were young people at the age group of 20-29 years old. Shadnia et al (6), Nhachi et al (20), and Srivastava et al (21), have also reported the same age group as the most common age group for poisoning. The most common cause of poisoning was medications in this study which is consistent with several previous studies(5, 22-24). This pattern was also reported from other parts of Iran (2). In addition, previous epidemiologic poisoning reports from the city of Mashhad have shown the pharmaceutical agents as the most common causes of poisoning (3, 25). Easy access to various drugs in our society is one of the main reasons (2, 25). The accessibility of prescribed and nonprescribed drugs in the developed countries has been linked with a significantly increased number of patients needing hospital admissions for drug-related poisonings.

The geographical distribution of poisoning showed that some areas had disproportionately higher numbers of poisoning in Mashhad. We found that the rate of poisoned cases was higher in the northeast parts of the city. This spatial variability of poisonings may depend on the neighborhood associations because neighboring locations may have similarities such as social parameters, poisoning agent availability, poisoning agent access or environmental exposures.

Results obtained from local test of spatial autocorrelation (Moran's I) confirms that the poisoning exhibits geospatial dependence, showing a cluster pattern in the city of Mashhad. These clusters show that there are potential mutual values

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Table 4. Risk factors of the number of poisonings, generalized linear mixed models via multivariate Poisson and negative binomial distribution

Population Characteristics*	Poisson		Negative binomial	
	Adj. RR (95% CI)	p value	Adj. RR (95% CI)	p value
Age 20-30 (years)	0.98 (0.96, 1.00)	0.05	0.98 (0.96, 1.01)	0.07
Population density	1.00012 (1.0001, 1.00013)	<0.0001	1.00011 (1.0001, 1.00013)	<0.0001
Less than high school education	1.69 (1.20, 1.92)	0.02	1.49 (1.32, 1.68)	0.01
Spatial random effect	Estimate		Estimate	
λ	0.29		0.28	
ρ	0.10		0.10	
Goodness-of-fit				
-2logL	1974		1966	
AIC	1987.7		1981	

* Adj. RR= Adjusted rate ratio; CI=Confidence Interval; AIC=Akaike information criterion; logL=log-Likelihood
We used the goodness-of-fit measurements (Akaike information criterion (AIC) and -2logLikelihood statistic) for model selection. The AIC/-2logL was 1987.7/1974 and 1981/1966 for Poisson and negative binomial model, respectively.

(autocorrelation). Finding the reasons behind these associations is crucial. Similar to our study, Kerry et al., (26) and Rossen et al., (27) have confirmed the results from comprehensive tests of spatial autocorrelation and existence of spatial correlation in the frequency of poisoning cases.

Investigating the poisoning factors in districts with spatial autocorrelation showed that pharmaceutical agents, especially psychiatric drugs, were the most common poisoning agent. One of the reasons for self-medication is the sale of drugs without prescription by pharmacies (28). Hence, patient-pharmacy relationship should be monitored more rigorously. Legislation in delivering the over-the-counter drugs (shape and number) is necessary along with the implementation of a proper pharmacovigilance system. Moreover, there are several recommendations that psychoactive drugs should be prescribed on minimum essential numbers and prescription of large number of drugs due to increased risk of suicide should be avoided (29). The second most prevalent poisoning agent class in this study was opioids, which are more easily available in this part of the country owing to the closeness to Afghanistan borders, as the rank one country of the world for opioid substance production (30). Followed by drugs, pesticides such as organophosphorus insecticides and phosphide toxins were the next leading cause of poisoning, although vending these materials to public is illegal and this requires more attention.

The present study demonstrated how to conduct count regression models to determine the factors predicting the frequency of poisoning. Count models are typically under the class of nonlinear regression models (31). The most commonly used model for count data is Poisson model, where the mean and variance are assumed to be equal.

Since this method is not ideal for over-dispersed data (variance is higher than mean), negative binomial model—with an additional parameter to handle the over-dispersion—is considered (32). A previous study in Mashhad by Ayati et al (33), which compared Poisson model with negative binomial regression model based on the AIC criteria, claimed that the negative binomial regression model is a better fit to the data when compared with Poisson model.

Results obtained from the model showed that the population density was positively correlated with the incidence of poisoning in Mashhad, resembling the reports from Nguyen et al (34), and Kerry et al (26) in Pennsylvania and Utah states of the U.S., respectively.

The regression model also showed a positive relation between percent with less-than-high-school education factor and incidence of poisoning. These findings were consistent with reports of Hall et al., (OR=1.2, 95% CI 0.4-3.1) (35).

This study is not without limitations. We used hospital information system and patient files are not without errors. However, we do not believe that these are systematic errors. On the other hand, we believe this is the first study in this country which investigates the spatial analysis and modeling of poisoning and related risk factors.

CONCLUSION

The geospatial risk factors for acute poisonings in a city might be areas with denser population, higher poverty scale and lower urban development. In addition, districts with lower educational status are more vulnerable to have higher poisoning events. The northeast of Mashhad exhibited spatial clustering in poisoning events. Once clusters are found, interventions can be focused to specific geographic locations. The findings of this study (identified factors related to the occurrence of poisoning) would be helpful for healthcare policymakers to focus on the scope of prevention programs.

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