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Identifying High-Risk Populations for Sexually Transmitted Infections in Chinese Men Who Have Sex With Men: A Cluster Analysis

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Background. This study aimed to identify subpopulations of Chinese men who have sex with men (MSM) with distinct sexual behavioral patterns and explore their correlations with sexually transmitted infections (STIs).

Methods. We recruited 892 eligible MSM in Xi'an, China, collecting sociodemographic, sexual behavior, and STI data. Cluster analysis identified distinct sexual behavioral patterns, allowing us to examine STI differences across clusters.

Results. Among the 892 MSM analyzed, 3 clusters were identified. Cluster 1 (n = 157) exhibited high-risk sexual behavioral patterns, including the highest median number of sexual partners (5 vs 1 in cluster 2 vs 3 in cluster 3, $P < .001$), lowest consistent condom use for insertive anal sex (0% vs 64.12% vs 99.76%, $P = .004$) and receptive anal sex (9.22% vs 67.71% vs 98.91%, $P = .006$), highest uncertainty of partners' STIs (77.07% vs 57.89% vs 64.5%, $P < .001$), all recent partners being casual, longest length of sequential sexual acts (6 vs 5 vs 5, $P = .045$), and highest rates of gonorrhea (20.38% vs 10.09% vs 14.99%, $P = .019$) and chlamydia (16.56% vs 8.33% vs 13.21%, $P = .045$). Cluster 2 (n = 228) showed the lowest engagement in high-risk behaviors and STIs, characterized by the fewest sexual partners, highest certainty of partner's STIs, and all recent partners being regular. Cluster 3 (n = 507) showed moderate levels of high-risk behaviors and STIs, with the highest consistent condom use during anal sex.

Conclusions. This study identified 3 subpopulations of Chinese MSM with distinct sexual behavioral patterns. Targeted public health interventions to the most at-risk subpopulations of MSM are essential for STI prevention.

Keywords. cluster analysis; men who have sex with men; prevalence; sexual behavioral patterns; sexually transmitted infections.

Neisseria gonorrhoeae (NG) and *Chlamydia trachomatis* (CT) infections pose a significant global health concern within the realm of sexually transmitted infections (STIs) [1]. Gonorrhea primarily manifested as a purulent urogenital infection, contributing to a global incidence of 82 million per year [2]. In China, a cumulative count of 1 936 211 cases of gonorrhea infection was reported from 2005 to 2020, yielding an average yearly incidence rate of 8.987 per 100 000 persons (range, 6.817–13.872) [3]. Chlamydia infects >127 million people worldwide annually [2]. A nationwide report from 105 STI laboratory surveillance sites in China revealed an escalating trend in genital chlamydia infection, increasing from 37.18 per 100 000 individuals in 2015 to 55.32 per 100 000 individuals in 2019, signifying an average annual increase of 10.44% [4].

Men who have sex with men (MSM) have been recognized as a high-risk group for STIs in China [5–7]. A study in Yunnan province, China, reported a collective gonorrhea infection of 13.2% among MSM, with specific infection rates of 8.1%, 6.8%, and 1.4% for the oropharynx, anorectum, and urethra, respectively; for chlamydia, the overall infection rate reached 18.2%, with rates for the oropharynx, anorectum, and urethra at 2.4%, 15.5%, and 3.7%, respectively [8]. Results of a multisite study in Shenzhen, Nanjing, and Wuhan indicated that the overall prevalence of CT infection was 18.2% among MSM, most commonly at the anorectal site (15.6%), followed by urethral (3.2%) and oropharyngeal sites (1.6%) [9]. The prevalence of STIs in the MSM population is much higher than in the general population, posing a serious risk to both individuals and society.

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Given that sexual contact remains the primary mode of transmission for gonorrhea and chlamydia infections, it underscores the significance of analyzing sexual behavior to understand the transmission of STIs. Although MSM are often viewed as a homogeneous group, variability exists within sexual experiences among MSM [10]. Sexual experiences include sexual behaviors (eg, anal sex) and relationship factors (eg, number of male sexual partners), and the intersection of these aspects may confer different STI risks [6, 11, 12]. Previous studies have focused on the contribution of individual sexual behavior to STIs without identifying the aggregate characteristics of these behaviors [6, 13, 14]. In addition, prior studies also discuss the relationship between single sexual behaviors and STIs—for example, that kissing elevates the risk of oropharyngeal infections, engaging in oral sex increases the risk of oropharyngeal and urogenital STIs [15], and rimming increases oropharyngeal and anorectal infections [16]. However, MSM often engage in diverse sexual experiences, and there are also various sexual behaviors during single sexual intercourse. It is important to investigate sexual behavioral patterns, which can help facilitate a comprehensive understanding of the STI risks among MSM.

The use of cluster analysis to identify sexual behavioral patterns holds significant potential for exploring STIs. A Portuguese study used a hierarchical clustering method to examine sexual behavioral patterns among MSM. By describing and comparing the differences in the prevalence of STIs reported by different clusters, the study identified that a risky cluster consisting of factors beyond sexual behaviors, including the number of male sexual partners, alcohol consumption, substance abuse, and condom use, alongside 6 additional variables, has increased the vulnerability of MSM to STIs [17]. Cluster analysis provides a new approach to identifying distinct populations with homogeneous sexual behavioral patterns. This study aims to use cluster analysis to identify differences in sexual behavioral patterns among MSM in China and explore their correlations with STI risk.

METHODS

Study Sampling, Recruitment, and Data Collection

The study employed a site-based recruitment approach, focusing on the Xi'an Tong Jian community, a well-established gay community with prior collaborative efforts. This choice was made to ensure high reliability and smooth progression, given the specific study population. Eligible participants were invited to complete an online behavioral questionnaire, developed and refined with expert input and guidance from community partners. The questionnaire focused on closed questions on sociodemographic details, sexual behaviors, access to STI and AIDS services, and histories of STI and AIDS testing and infections.

Data were collected from January to September 2022, using a structured questionnaire administered by trained peers from community organizations. Community staff played a crucial role in ensuring the reliability and authenticity of responses by guiding participants through the online questionnaire process. To maintain data quality, research and community staff were available throughout data collection to address participant queries. Following valid questionnaire completion, participants were sequentially sampled for each of the 2 STIs and subjected to stringent sample storage criteria. Subsequently, participants' samples were sent to the only testing institution and the resulting test reports were issued. Community staff completed comprehensive training to ensure uniform data collection standards and minimize biases.

Study Inclusion and Exclusion Criteria

Inclusion criteria were (1) age ≥18 years; (2) being male at birth and having had sex with men in the last 3 months; (3) self-reported human immunodeficiency virus (HIV) negative or uncertain about their HIV infection status; (4) informed consent was signed and willing to participate in this study. Subjects with severe mental illness, language impairment, or intellectual disability and those deemed unfit for the investigation by the investigators were excluded from the study. A total of 1169 MSM participated in our survey; of the 277 individuals excluded from this study, 25 were missing test results for gonorrhea and/or chlamydia, 58 did not report their age, and 194 self-reported no male sexual partner over the last 3 months. Thus, 892 MSM were ultimately included in the analysis.

Variables

STIs. The outcome variables of concern in the study were the final infection status (negative or positive) of gonorrhea and chlamydia infections, respectively, determined by parallel testing of 3 anatomic sites: oropharynx, urogenital tract, and anus.

Sexual Behavioral Pattern. Sexual behavioral pattern in this study was obtained through cluster analysis. The final list of clustering variables included (1) number of male sexual partners in the last 3 months; (2) whether the male sexual partner was a regular partner in the last sexual intercourse (no vs yes; a regular partner was defined as a sexual partner with whom the participant has engaged in sexual activity for a period of at least 3 months) [18, 19]; (3) whether the male sexual partner in the last sexual intercourse was diagnosed with STIs (no, yes, uncertain, or refuse to answer); (4) frequency of condom use in receptive anal intercourse in the last 3 months (never, often, always); and (5) frequency of condom use in insertive anal intercourse in the last 3 months (never, often, always).

Sexual Behavior. Sexual behaviors in the last sexual intercourse and the last 3 months include 10 different types: kissing, insertive oral sex, receptive oral sex, masturbation, insertive masturbation, receptive masturbation, insertive rimming, receptive rimming, insertive anal intercourse, and receptive anal intercourse. A sexual behavior pair is a combination of 2 different sexual behaviors that occur next to each other in a single sexual intercourse. A pattern of sequential sexual acts depicts the progression of different sexual behaviors in a single sexual intercourse, set in a specific order [20]. The length of a pattern of sequential sexual acts is measured by the number of steps it contains (in this study the length range was 1–12).

Cluster Analysis

Figure 1 shows the cascade of variables included in each step of the cluster analysis, from the inclusion of all variables to the exclusion of some factors that did not meet the inclusion criteria. We screened out the factors associated with gonorrhea and chlamydia infections from a pool of multiple factors related to sexual behaviors by excluding variables with low variance and using bivariate analysis. These identified factors aided the determination of cluster variables in the subsequent phase.

To determine the optimal number of clusters, we conducted multiple iterations of k-medoids cluster analysis based on the Gower distance [21]. The Gower distance effectively normalizes mixed data, producing distance measures ranging from 0 to 1. This robust metric minimizes outlier influence, making it well-suited for mixed data analysis [22, 23].

The partitioning around medoids (PAM) algorithm is a commonly used implementation of k-medoids clustering [24, 25]. Initially, k-medoids are randomly chosen from n sample points, with the remaining points assigned to the nearest medoid. The algorithm iteratively refines the clusters by selecting new medoids that minimize the criterion function within each cluster [26, 27]. The above steps are repeated until all the medoids no longer change or the maximum number of iterations is reached, producing the final k categories (Supplementary Material 2).

For visualization and evaluation of the clustering model, we applied the t-distributed stochastic neighbor embedding algorithm to reduce the data to 2 dimensions, enhancing the discernibility of cluster patterns and relationships. Given the presence of a single binary variable, this clustering method may primarily group individuals based on their male sexual partner status in the last sexual intercourse. If this is observed, we will use a secondary hierarchical clustering, providing a comprehensive analysis of diverse sexual behavioral patterns within the study population.

Categorical variables were reported as frequencies and percentages, with group comparisons using the χ^2 test. Normally distributed continuous variables were reported as mean ± standard deviation and compared using analysis of variance. Nonnormally distributed continuous variables were reported as median with interquartile range (Q1–Q3) and compared using the Kruskal-Wallis test. The RStudio 4.3.3 statistical software package was used for data analysis, with P values <.05 taken as statistically significant.

Sensitivity Analyses. Sensitivity analyses were conducted to examine the validity of the variables identified by clustering. First, univariate logistic regression analyses were performed for each of the 5 variables, assessing their individual associations with STI status (negative or positive). Subsequently, these 5 variables were included as covariates in a multivariate logistic regression model with STI status as the outcome. Additionally, we utilized mixed-effects logistic regression to examine the validity of the 5 identified variables, which evaluate the correlation between observed individuals within the cluster.

RESULTS

Clustering Based on Sexual Behaviors

In the initial cluster analysis step, participants were categorized into 2 groups (Supplementary Figure 1): those whose most recent sexual partner was a regular partner (n = 228) and those whose partner was not a regular partner (n = 664). In the second step, the non–regular partner group was further divided into 2 subgroups (Supplementary Figure 2), resulting in 3 distinct clusters (cluster 1, n = 157; cluster 2, n = 228; cluster 3, n = 507) (Figure 2).

Differences in Sociodemographic and Sexual Behavioral Characteristics Across Clusters

The study examined the sociodemographic and sexual behavioral characteristics of 892 individuals, categorized into 3 clusters, as detailed in Table 1. The median age of overall participants was 33 years, with no significant differences in age and marital status across clusters. Significant variations were found in monthly personal income and educational level.

Cluster 1, the smallest group with 157 individuals, reported a median of 5 (interquartile range [IQR], 2–8) male sexual partners in the last 3 months. No one reported consistent condom uses for insertive anal sex, and only 9.22% did for receptive anal sex during this period. All individuals had a casual male sexual partner in their last sexual intercourse; 77.07% were uncertain about their partner's STI status, and 14.01% reported that their partner had an STI diagnosis.

Cluster 2, consisting of 228 individuals, had a median of 1 (IQR, 1–2) male sexual partner in the last 3 months. Consistent condom use was reported by 64.12% for insertive and 67.71% for receptive anal sex. All individuals in cluster 2 had a regular sexual partner in their last sexual intercourse; 57.89% were uncertain about their most recent sexual partner's STI status, while 6.14% reported their partner had an STI diagnosis.

Cluster 3, the largest group with 507 individuals, reported a median of 3 (IQR, 1–7) male sexual partners in the last 3 months. This cluster had the highest rates of consistent condom use during insertive (99.76%) and receptive (98.91%) anal sex. All individuals in cluster 3 had a casual male sexual partner in their last sexual intercourse; 64.5% were uncertain about

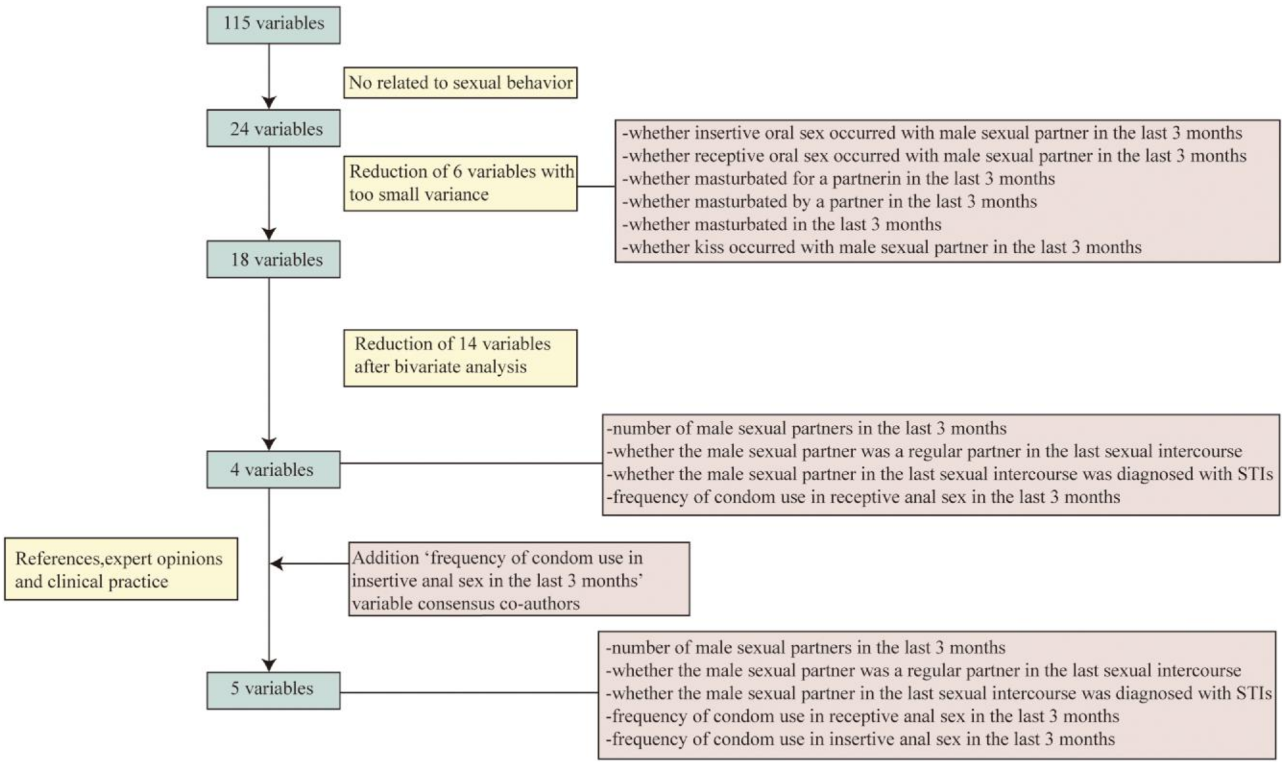

Figure 1. Flowchart of sexual behavior–related variables selection for cluster analysis. Abbreviation: STI, sexually transmitted infection.

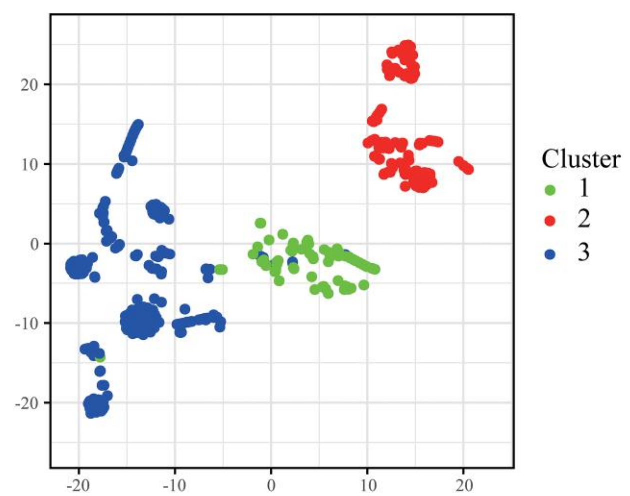

Figure 2. The t-distributed stochastic neighbor embedding (t-SNE) visualization of 3 clustering results.

their most recent sexual partner's STI status, and 10.45% reported their partner had an STI diagnosis.

Overall, cluster 1 had a significantly higher median number of male sexual partners compared to clusters 2 and 3 (5 vs 1 in cluster 2 vs 3 in cluster 3, $P < .001$). Cluster 1 also had the lowest rates of consistent condom use for both insertive (0% vs 64.12% vs 99.76%, $P = .004$) and receptive (9.22% vs 67.71% vs 98.91%, $P = .006$) anal sex. Clusters 1 and 3 reported that their most recent sexual partners were all casual male sexual partners, whereas cluster 2 exclusively reported regular male sexual partners. Additionally, cluster 1 had the highest proportion of individuals uncertain about their most recent sexual partner's STI status (77.07% vs 57.89% vs 64.5%, $P < .001$). It also had the highest proportion of individuals with current preexposure prophylaxis (PrEP) use (28.66% vs 9.65% vs 6.90%, $P < .001$) and exhibited higher engagement in various sexual behaviors over the last 3 months.

Differences of Sexual Behaviors and Sexual Behavior Pairs Across Clusters

Data on the sexual behaviors of 861 participants in their last sexual intercourse were analyzed, with 10 types of sexual behaviors (totaling 6324 events) and 88 sexual behavior pairs (totaling 3530 events) being identified. The 3 most frequent sexual behaviors were kissing (27.11%), insertive anal intercourse (16.04%), and receptive anal intercourse (10.28%). Significant differences in individual sexual behaviors were observed only for insertive oral sex, insertive masturbation, insertive rimming, and receptive anal intercourse (Supplementary Table 1; Supplementary Figure 3). Conversely, significant differences

Table 1. Sociodemographic and Sexual Behavioral Characteristics of the Clusters (N = 892)

Characteristic	Overall	Cluster 1	Cluster 2	Cluster 3	χ^2/H	*P* Value
Frequency	892	157	228	507		
Sociodemographic characteristics						
Age, y	33 (27.75–40)	32 (27–39)	33 (27–39)	33 (28–41)	3.09	.213
Marital status					3.39	.495
Single	552 (61.88)	103 (65.61)	136 (59.65)	313 (61.74)	…	
Engaged or married	256 (28.7)	37 (23.57)	68 (29.82)	151 (29.78)	…	
Separated or divorced or widowed	84 (9.42)	17 (10.83)	24 (10.53)	43 (8.48)	…	
Education level					30.62	**<.001**
High school or less	334 (37.44)	47 (29.94)	62 (27.19)	225 (44.38)	…	
College/bachelor's degree	491 (55.04)	104 (66.24)	145 (63.6)	242 (47.73)	…	
Master's degree or higher	67 (7.51)	6 (3.82)	21 (9.21)	40 (7.89)	…	
Personal monthly income (RMB)					37.83	**<.001**
<3000	152 (17.04)	23 (14.65)	31 (13.6)	98 (19.33)	…	
3001–6000	360 (40.36)	44 (28.03)	88 (38.6)	228 (44.97)	…	
6001–9000	291 (32.62)	79 (50.32)	80 (35.09)	132 (26.04)	…	
>9000	89 (9.98)	11 (7.01)	29 (12.72)	49 (9.66)	…	
Factors related to sexual behaviors						
No. of male sexual partners in the last 3 mo	2 (1–5.25)	5 (2–8)	1 (1–2)	3 (1–7)	134.73	**<.001**
Whether the male partner in the last sexual intercourse was diagnosed with STIs						
No	198 (22.2)	11 (7.01)	69 (30.26)	118 (23.27)		**<.001**
Yes	89 (9.98)	22 (14.01)	14 (6.14)	53 (10.45)	…	
Not sure	580 (65.02)	121 (77.07)	132 (57.89)	327 (64.5)	…	
Refuse to answer	25 (2.8)	3 (1.91)	13 (5.7)	9 (1.78)	…	
Frequency of condom use in insertive anal intercourse in the last 3 mo						**.004**
Never	29 (4.11)	21 (17.50)	8 (4.70)	0 (0)	…	
Often	153 (21.67)	99 (82.50)	53 (31.18)	1 (0.24)	…	
Always	524 (74.22)	0 (0)	109 (64.12)	415 (99.76)	…	
NA	186	37	58	91	…	
Frequency of condom use in receptive anal intercourse in the last 3 mo						**.006**
Never	27 (3.03)	18 (12.77)	9 (4.69)	0 (0)	…	
Often	168 (18.83)	110 (78.01)	53 (27.60)	5 (1.09)	…	
Always	597 (66.93)	13 (9.22)	130 (67.71)	454 (98.91)	…	
NA	100	16	36	48	…	
Whether the male partner was a regular partner in the last sexual intercourse						**<.001**
No	664 (74.44)	157 (100)	0 (0)	507 (100)	…	
Yes	228 (25.56)	0 (0)	228 (100)	0 (0)	…	
PrEP usage status					128.57	**<.001**
Never used	698 (78.25)	71 (45.22)	182 (79.82)	445 (87.77)	…	
Past use	92 (10.31)	41 (26.12)	24 (10.53)	27 (5.33)	…	
Current use	102 (11.43)	45 (28.66)	22 (9.65)	35 (6.90)	…	
Sexual behaviors in the last 3 mo						
Kissing	847 (94.96)	152 (96.82)	207 (90.79)	488 (96.25)	11.17	**.004**
Insertive masturbation	787 (88.23)	142 (90.45)	181 (79.39)	464 (91.52)	23.19	**<.001**
Receptive masturbation	800 (89.69)	145 (92.36)	183 (80.26)	472 (93.1)	29.47	**<.001**
Insertive oral sex	813 (91.14)	149 (94.9)	190 (83.33)	474 (93.49)	23.44	**<.001**
Receptive oral sex	831 (93.16)	150 (95.54)	192 (84.21)	489 (96.45)	38.67	**<.001**
Insertive anal intercourse	738 (82.74)	137 (87.26)	161 (70.61)	440 (86.79)	31.52	**<.001**
Receptive anal intercourse	696 (78.03)	140 (89.17)	156 (68.42)	400 (78.9)	23.87	**<.001**
Insertive rimming	416 (46.64)	58 (36.94)	95 (41.67)	263 (51.87)	13.78	**.001**
Receptive rimming	438 (49.1)	69 (43.95)	100 (43.86)	269 (53.06)	7.35	**.025**

Data are presented as No. (%), except for continuous variables, which are expressed as median (interquartile range). The χ^2 test results were significant ($P < .05$); missing χ^2 values were tested with Fisher exact test. The bolded *P* values represent statistical significance after testing.

Abbreviations: NA, the number of missing study samples in the questionnaire under this item; PrEP, preexposure prophylaxis; RMB, renminbi; STI, sexually transmitted infection.

were noted in the distribution of sexual behavior pairs across clusters. Supplementary Table 1 highlights the 22 sexual behavior pairs with frequencies exceeding 1%, with χ^2 tests indicating significant differences between clusters for most pairs. For example, in cluster 1, the proportions of pairs such as insertive oral sex–receptive anal intercourse and receptive oral sex–receptive anal intercourse were significantly higher compared to clusters 2 and 3.

Differences of Patterns of Sequential Sexual Acts Across Clusters

Data on the patterns of sequential sexual acts of 861 participants in their last sexual intercourse were analyzed, with 334 patterns of sequential sexual acts (totaling 861 events) being identified. Figure 3 illustrates the length of sequential sexual acts across clusters. The median length of sequential sexual acts for the overall population was 5 (IQR, 3–8). Cluster 1 exhibited a higher median length of 6 (IQR, 4.25–7), whereas clusters 2 and 3 both showed a median length of 5, with IQRs of 2.25–7 and 2–8, respectively. A significant difference in the lengths of sequential sexual acts across clusters is shown in Supplementary Table 2 ($P = .045$).

Differences of Gonorrhea and Chlamydia Positive Rates Across Clusters

The study identified significant variations in the positive rates of gonorrhea and chlamydia across 3 clusters, with cluster 1 exhibiting the highest rates (Supplementary Table 3; Figure 4). The overall chlamydia positive rate was 12.56%, with cluster 1 exhibiting a markedly higher rate (16.56%) compared to clusters 2 and 3 (8.33% and 13.21%, respectively, $P = .045$). Cluster 1 also showed a higher anorectal-CT positive rate (15.92% vs 6.14% vs 11.83%, $P = .008$) relative to clusters 2 and 3. For gonorrhea, the positive rate in cluster 1 was 20.38%, significantly higher than those of clusters 2 and 3 (10.09% vs 14.99%, $P = .019$). Oropharyngeal NG infections were also more prevalent in cluster 1 (14.01%) than in clusters 2 and 3 (7.02% and 7.5%, $P = .024$). Subgroup analysis of STI infection rates by sexual behavioral characteristics is presented in Supplementary Table 4.

Sensitivity Analysis

Sensitivity analyses indicated that mixed-effects models generally outperformed multivariate logistic regression models. The results presented here were mixed-effect models after adjusting for other confounders in the fixed part of the model. For the model of STI infection, type of male sexual partner in the last sexual intercourse, the number of male sexual partners in the last 3 months, and frequency of condom use in insertive anal intercourse in the last 3 months had statistically significant random effects. The results of the regression models for STI status are included in Supplementary Material 3.

DISCUSSION

Our findings revealed distinct clusters with varying patterns of sexual behaviors. High-risk sexual behavioral patterns were significantly correlated with gonorrhea and chlamydia infections. Further examination of the distribution of sexual behaviors within clusters demonstrated that the accumulation of sexual behaviors, specific sexual behavior pairs, and longer sequential sexual acts may contribute to the occurrence of STIs. This study enhances our comprehensive understanding of the relationship between sexual behaviors and STIs among Chinese MSM.

High-Risk Sexual Behavioral Pattern and STIs

This study demonstrates a significant correlation between high-risk sexual behavioral patterns (cluster 1) and STI prevalence among MSM. Our cluster analysis reveals that high-risk sexual behaviors tend to cluster rather than occur in isolation. We identified this high-risk pattern as including a higher number of male sexual partners, engaging in sexual activity with casual sexual partners, and engaging with sexual partners of uncertain STI status or those diagnosed with STIs. Importantly, this pattern was significantly associated with a higher prevalence of STIs among the studied MSM population.

Our findings go beyond simply identifying individual risk factors [17, 28, 29]; instead, we identified a distinct cluster of high-risk sexual behaviors that significantly elevates the likelihood of STI infection. This echoes the approach taken by researchers in Australia who, using clinical data from the Melbourne Sexual Health Centre, identified predictive factors for STI risk including STI symptoms, number of casual partners, and condom use to develop an STI risk prediction tool [30–32]. Similarly, the high-risk sexual behavioral patterns identified in our study can inform the development of targeted STI risk prediction tools for Chinese MSM. This information can be leveraged to guide personalized STI screening and intervention strategies, ultimately contributing to more effective STI prevention and control efforts within this population in China.

Potential Role of Sexual Behaviors in STIs Infection

This study identified a significant correlation between sexual behaviors and high-risk sexual behavioral patterns, suggesting that the cumulative engagement in these acts may increase the risk of STIs in MSM. Sexual activity does not occur in isolation but as part of a multistep process within a sequential and contextual framework [33]. Significant differences in sexual behavior pairs highlight the complexity and diversity of sexual behavioral patterns. Current public health interventions and sex education often overlook the sequences and combinations of sexual behaviors. Our findings highlight the need to consider these patterns in MSM to identify high-risk behavior pairs, warranting consideration and further exploration in subsequent studies to enhance our understanding of STI risks in MSM populations.

Another important finding is that longer sequential sexual acts could lead to an increased STI risk. This study observed that high-risk sexual behavioral patterns with higher rates of NG and CT infections have significantly longer sequential sexual acts compared to the low-risk sexual behavioral pattern with lower rates of infections. This increased risk can be attributed to the extended length of sequential sexual acts, which

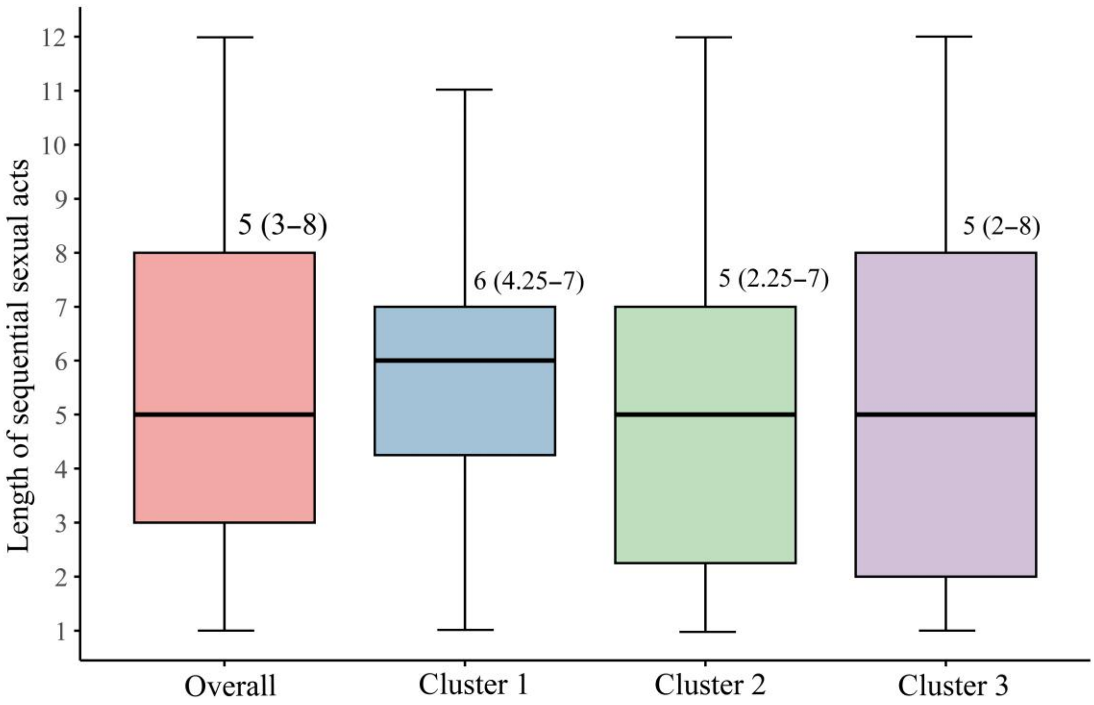

Figure 3. Boxplot of length of sequential sexual acts by cluster. Values are expressed as median (Q1–Q3); whiskers represent 1.5 times the interquartile range.

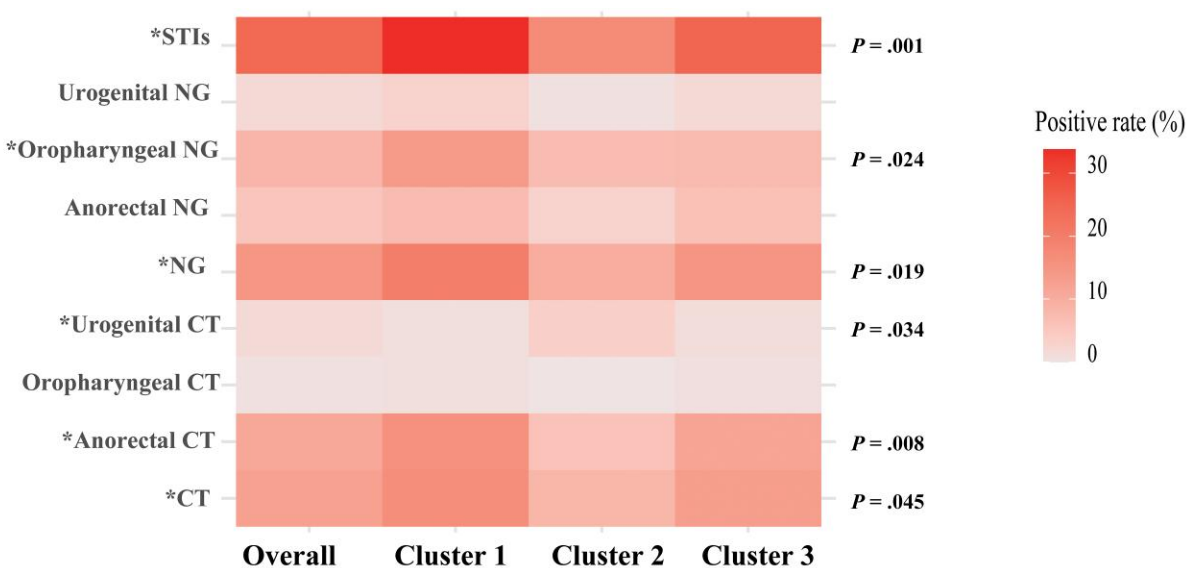

Figure 4. Heatmap of positive rates for *Neisseria gonorrhoeae* (NG) and *Chlamydia trachomatis* (CT) infections across 3 clusters. *The χ^2 test results were significant ($P < .05$), with Fisher exact test applied for expected cell counts <5; "sexually transmitted infection" (STI) was defined as a combined outcome where a positive result in either NG or CT was considered positive for STIs.

typically includes a broader spectrum of sexual behaviors. Consequently, engaging in a variety of sexual behaviors contributes to an increased incidence of anatomical sites coming into contact during sexual intercourse, coupled with a greater exchange of bodily fluids. Such conditions escalate the susceptibility to NG and CT infections. This observation aligns with prior research exploring the correlation between sexual behaviors and STIs [16, 34, 35]. Additionally, PrEP usage may influence STI risk by altering preventive behaviors. Risk compensation, a concept often observed among PrEP users, suggests that individuals may engage in reduced condom use due to a perceived lower risk of HIV and STIs [36]. This underscores the need to incorporate PrEP-related behavioral insights into public health strategies, ensuring comprehensive education and intervention programs tailored to MSM populations.

Our study has several limitations. The results of cluster analysis vary depending on the clustering method chosen and the definition of distance [37]. Therefore, it is necessary to explain the distance from and the type of algorithm used in the cluster analysis when interpreting the results. Our clustering outcomes were based on community-based recruitment of our study participants, so generalizing results for all MSM could result in slight differences. Additionally, our study's cross-sectional design captured behavioral patterns at only a single time point, limiting our ability to analyze shifts between different sexual behavior patterns over time. Future longitudinal studies are needed to examine these behavioral changes and underlying dynamics [38–40]. Our questionnaire investigated participants with queries that pertained to aspects of intimacy and sensitivity, including inquiries regarding risky sexual behaviors and sexual health status. The inherent sensitivity of these questions potentially engendered a reticence among participants, leading to instances of incomplete data. Additionally, the possibility of memory bias should not be discounted, as participants may have encountered difficulties in recalling certain facets of their experiences.

CONCLUSIONS

This study highlights the critical importance of understanding and addressing the heterogeneity of sexual behavioral patterns and their correlation with STI risk among Chinese MSM. The significant correlations observed between specific sexual behavior pairs, longer sequential sexual acts, and cluster membership emphasize the need for interventions that address not just individual behaviors, but also the context and patterns in which they occur. Future studies should delve deeper into understanding the causal relationship between these sexual behaviors and STIs based on the insights gained from this study. Our findings carry important implications for public health practice. Public health providers and researchers should integrate these high-risk sexual behavioral patterns, along with other identified risk factors for STIs, into the development of comprehensive STI risk prediction tools and targeted public health interventions.

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

Author contributions. L. Z., M. Z., and F. L. helped in assessment design, including methodology and instrument development. F. L., B. S., G. L., Y. H., and Y. L. helped in data analysis. R. Z. helped in data collection. F. L. primarily completed the writing of the manuscript. L. Z. and M. Z. read and approved the final manuscript.

Ethics approval. Ethical approval for this study was granted by the Research Ethics Board at Xi'an Jiaotong University (2021-1608). Informed consent was obtained from all individual participants included in the study.

Data and code availability. Data are not publicly available. The main codes of cluster analysis used in this study are provided in Supplementary Material 2.

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