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Examining a Syndemics Network Among Young Latino Men Who Have Sex with Men

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Abstract

Background—Although studies consistently find that syndemic indicators are additively associated with increased HIV/STI risk behavior (e.g., condomless anal sex; CAS) among men who have sex with men (MSM), information is lacking about how syndemic indicators are associated with each other. Young Latino MSM are one of the most at-risk groups for acquiring HIV in the U.S. Understanding the associations of syndemic indicators with each other and with CAS may improve understanding of how to enhance sexual and behavioral health in this population.

Method—Network analysis using the graphical LASSO (glasso) algorithm was employed to explore associations between CAS and syndemic indicators among 139 young Latino MSM. Structural and psychosocial syndemic indicators were assessed via self-report. CAS was defined as the number of partners in the past 3 months with whom one engaged in CAS.

Results—Results of the network analysis suggested the variables with the highest centrality were unstable housing, prison history, childhood sexual abuse, and CAS. Specific significant associations included links between CAS and alcohol use ($b = 0.40$), childhood sexual abuse and unstable housing ($b = -0.75$), alcohol use and childhood sexual abuse ($b = 0.40$), and substance use and intimate partner violence ($b = 0.43$).

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Compliance with Ethical Standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (San Diego State University Institutional Review Board + reference number HS-2017–0006) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Conclusion—This pattern of interconnectedness demonstrates the potential for network analysis to examine nuanced interrelationships of syndemic indicators. The specific associations in this sample raise the question whether a primary focus of interventions should address the more central syndemic indicators for this population, such as alcohol use and unstable housing, and whether this would, via downstream effects, affect other aspects of behavioral health in this population.

Keywords

Network analysis; HIV; Syndemic indicators; Men who have sex with men; Latino

Introduction

Syndemics are comprised of multiple, co-occurring psychosocial (e.g., depression, substance use, intimate partner violence) and structural (e.g., unstable housing, poverty, prison history) conditions that theoretically interact synergistically, forming a syndemic that creates worse health outcomes than would the presence of multiple conditions that are not synergistic [1]. Psychosocial syndemic indicators have been shown to be additively associated with negative health behaviors in men who have sex with men (MSM) [2–8]. Cross-sectional studies among MSM with varying demographics and age groups, and in various countries, have generally demonstrated a positive association between increasing numbers of psychosocial syndemic indicators and increased risk behaviors for HIV and other sexually transmitted infections (STI) [2–7], and for having an HIV-positive serostatus [4–8]. For example, increasing numbers of psychosocial syndemic indicators are positively related to increased risk for engaging in condomless anal sex [2–7] and having multiple sexual partners [3, 5]. Cross-sectional studies have also found that increasing numbers of psychosocial syndemic indicators are associated with having an HIV-positive serostatus [4–8].

Synergistic effects have been posited in syndemic theory as intertwined and mutually enhancing effects arising from social and health problems [1], as further described below. However, in practice, syndemic effects have been tested with a variety of approaches—most often a linear, additive approach [2–8]. A linear, additive approach is useful to enhance understanding of the relationship between syndemic indicators and HIV risk in clinical practice, such that clinicians are able to tailor their approach for their individual client within the context of increasing HIV risk with increasing numbers of syndemic indicators. A linear, additive approach is also useful in the context of low statistical power to assess for interactions, particularly in the absence of specific a priori hypotheses about which of many psychosocial and/or structural syndemic indicators would likely be most associated with each other or the outcomes. Although cross-sectional studies have generally found that psychosocial syndemic indicators are linearly and additively related to an increase in HIV and other STI acquisition risk behavior, several studies using additive models also suggest that the synergistic effects of syndemic indicators on HIV and STI risk are more nuanced [2, 8, 9]. For example, one study employed an additive approach to examine psychosocial syndemics via a categorical variable and found no difference in risk of engaging in condomless anal sex between those with zero or one indicator [2]. Yet, those with two syndemic indicators and those with three or more syndemic indicators had significantly higher risk of engaging in condomless anal sex than those with zero [2]. Similarly, two other

cross sectional-studies have shown a non-linear increase in risk for being HIV-seropositive as the number of psychosocial syndemic indicators increases beyond two or more [8, 9].

In addition, emerging longitudinal studies have investigated the temporality of the relationship between psychosocial syndemic indicators, condomless anal sex, and HIV incidence in MSM [10–12]. Two studies found additive effects of syndemic indicators on condomless anal sex and HIV acquisition over time [10, 11]. Another longitudinal study employed structural equation modeling to examine syndemic indicators and demonstrated that, across different psychosocial conditions, there are varying effects of syndemic indicators on HIV risk [12]. Taken together, these longitudinal studies support and extend the cross-sectional findings of the additive effects of psychosocial syndemic indicators on HIV acquisition risk discussed above by providing temporal evidence of these additive effects over time.

Although the extant literature provides evidence of the relationship between HIV and other STI risk behavior and increasing number of syndemic indicators, some have argued that a more nuanced approach is necessary to fully examine potential synergistic effects of syndemic indicators on health [13–15]. Several studies, for example, suggest that the additive effects might not be linear [2, 8, 9]. The findings of these studies, within an additive model, that HIV risk is significantly higher among those with two or more psychosocial syndemic indicators, compared to those with zero or one, demonstrates the non-linear and additive relationship between syndemic indicators and HIV risk, and provides preliminary evidence for synergistic effects among syndemic indicators. However, some researchers argue that, instead of additive effects, interaction effects should be examined because, statistically speaking, additive approaches do not account for the synergistic effects of syndemic indicators [13–15]. These researchers suggest that a statistically significant interaction term within a larger additive model would suggest a deviation from additive effects, and may provide statistical evidence of synergy among syndemic indicators [13]. As such, an interaction effects approach may be better able to examine the synergistic effects of syndemic indicators, as well as identify the syndemic indicators most related to increased HIV risk behavior.

One limitation of the interaction effects approach is the lack of extant literature to date on the relationships among syndemic indicators that is needed to specify interaction effects a priori. Neither an additive approach nor an interaction effects approach provides information about how the different syndemic indicators are associated with each other, and in turn, associated with HIV and other STI risk behavior, such as condomless anal sex. A better understanding of the interrelationships between syndemic indicators, as well as with sexual risk, is needed to identify one or several intervention targets that could have downstream effects on overall health burden, determine which syndemic indicators have greater contributions to synergistic effects, and potentially specify a priori interaction terms among syndemic indicators. To examine this, one longitudinal study of young MSM in Chicago employed structural equation modeling [12]. In this study, different psychosocial syndemic indicators were grouped together based on theoretical types to create latent constructs (i.e., substance use, violence, and internalizing mental health), and each construct's contribution to an overall primary syndemic component was assessed. This approach provided evidence

for variability in the effects of different psychosocial syndemic indicators on HIV and STI risk, as well as information about potential groupings of syndemic indicators, but did not show how specific psychosocial syndemic indicators are associated with each other, and whether any specific indicators are more associated with HIV and other STI risk behavior than other syndemic indicators [12]. Additionally, Starks et al. [16] examined relationships between psychosocial syndemic indicators using latent class analysis. However, the results of this study did not produce classes of syndemic indicators. Rather, the results suggested the presence of two classes derived from the number of syndemic indicators endorsed: individuals with zero to two syndemic indicators in one group and individuals with three or more in another. Accordingly, this study provides evidence for additive effects, but also did not fully examine how specific syndemic indicators are associated with each other.

A promising statistical approach for examining the interrelationships between syndemic indicators is network analysis. Network analysis has commonly been used to investigate social interactions (e.g., [17]), but has also recently been applied in the field of health psychology to examine symptoms of perinatal depression [18], and to examine interrelationships between symptoms of depression and PTSD as well as whether specific symptoms were related to sexual risk behavior [19]. However, these symptom-level network analyses do not examine the interrelationships of syndemic indicators; rather, they examine the interrelationships of symptoms within the context of one or more disorder(s). Network analysis may be helpful for examining interrelationships between syndemic indicators given its use in examining patterns of relationships among symptoms of one or several disorder(s) [18–22]. Symptom networks have also previously included variables of clinical importance in the analysis that are not symptoms of the disorders [19, 23]. In using a network approach to conceptualize disorders, individual symptoms (nodes) are examined as *components* of a disorder (the network), which interact with and reinforce one another [20, 24]. This is distinct from a latent variable model, which posits that individual symptoms (or syndemic indicators) are measures of an underlying latent construct. Therefore, network analysis is an appropriate and theoretically motivated statistical approach to examine interrelationships between syndemic indicators.

In the current study, we conducted a network analysis of syndemic indicators and condomless anal sex in young Latino MSM in San Diego, California, to examine the patterns of relationships between syndemic indicators, as well as which syndemic indicators are related to condomless anal sex. In addition, this study was conducted as a proof-of-concept. As discussed above, prior research has not specified interrelationships among syndemic indicators, and although some researchers have employed structural equation modeling and latent class analysis approaches, network analysis may be more consistent with syndemic theory given the underlying assumption that variables interact and reinforce one another. Young Latino MSM are an important risk group to examine for this purpose because they are disproportionately affected by the HIV epidemic. Indeed, recent estimates suggest that HIV incidence among young (ages 13–24 years old) Latino MSM increased approximately 19% from 2011 to 2015 in the U.S. [25], and in 2016, young (ages 13–24 years old) Latino MSM in the U.S. accounted for nearly one quarter (23%) of HIV diagnoses among all Latino MSM [26]. Further, examining the patterns of relationships between psychosocial and structural syndemic indicators and risky sexual practices may

provide an opportunity to tailor emerging biomedical and bio-behavioral HIV prevention interventions.

Method

Participants and Procedure

Eligible participants were self-identified Latino gay, bi-sexual, or same-gender loving men; were between the ages of 18–29 years old; lived in the San Diego, California area; were HIV-seronegative or had an unknown HIV serostatus; and spoke either English or Spanish. Potentially eligible men were recruited online via dating websites and mobile applications specifically for MSM (i.e., Squirr.org and Grindr). Interested individuals clicked on advertisements and provided an email address at which they could be contacted with a link to the online survey. Participants from a previous study (recruited from social media) who consented to be contacted about future studies and met eligibility criteria for the current study were also directly sent an advertisement for the study via email. After completing the survey, participants were compensated with a \$10 gift card to an Internet-based online retailer. All procedures performed were approved by the San Diego State University Institutional Review Board.

All study materials (e.g., informed consent forms, questionnaires, and recruitment materials) were presented in both English and Spanish for participants to complete study procedures in their preferred language. Measures in Spanish that were published and validated were used whenever possible, and all other measures and study materials were translated and culturally adapted from English to Spanish by bilingual members of the investigator and study staff team. Once translated, all study materials were pilot tested with bilingual community members who met criteria for study inclusion to ensure cultural and linguistic accuracy. The procedures of this study are further described elsewhere ([27]).

Measures

Condomless Anal Sex—Condomless anal sex was measured by asking participants how many men they had anal sex with in the past 3 months, and, of those, how many did they use a condom with every time. The number of partners with whom they used a condom every time was subtracted from the total number of partners in the last 3 months, providing the total number of partners with whom a participant engaged in condomless anal sex in the past 3 months. This variable was grouped into three categories: zero partners, one partner, or two or more partners, and retained as a categorical variable. The condomless anal sex variable was grouped into three categories due to the relatively low frequencies of higher numbers of partners. Consideration was given to retaining condomless anal sex as a dichotomous variable. However, based on the distribution, in order to retain additional information in the analysis, and address zero-inflation, given that a sufficient number of individuals endorsed condomless anal sex on the continuous measure that naturally fell within three categories, this variable was analyzed with three ordinal levels.

Non-injection Substance Use—Non-injection substance use was measured via items asking participants about frequency of use of substances ingested either orally, intra-nasally,

or via smoking in the past month. Substances included crack cocaine, cocaine, heroin, opiates, crystal methamphetamine, other amphetamines, hallucinogens, and sedatives or tranquilizers. Participants indicated their frequency of use in the past month on a 5-point Likert-type scale from 0 (*no use*) to 4 (*about every day*). For this analysis, the single substance with the highest frequency of use was utilized as a categorical measure of frequency of non-injection substance use. For example, if a person used cocaine about every day (a 4 on this measure) and sedatives only about once a week (a 2 on this measure), a 4 would be used as their frequency of non-injection substance use in this analysis. Given that, in the current study, eight types of non-injection substances were assessed, the non-injection substance with the highest frequency of use was retained as an indicator of one's recent substance use behavior. This methodology of analyzing substance use has been used in additive effects models of syndemics [2, 4, 5, 8, 10, 12, 16], in which a substance use variable is created by collapsing frequency of use across various classes of substances to create one value for substance use for a given individual.

Injection Drug Use—Injection drug use (IDU) was measured in the same manner as non-injection substance use, described above. However, frequency of use of substances taken via intravenous injection in the past month was queried. IDU substances included cocaine, heroin, and any other drug injected with a needle. For this analysis, we used the single IDU substance with the highest frequency of use as a categorical measure of frequency of IDU.

Alcohol Use—Alcohol use was measured as the highest number of drinks consumed on any one occasion in the past month. This variable was retained as a continuous measure of past month alcohol use. In order to improve the statistical power of the network analysis, alcohol use was not made into a categorical or dichotomous variable.

Depression—Depression was assessed via the 8-item version of the Patient Health Questionnaire (PHQ-8; [28]). Due to the online nature of the present study, the item on suicidal ideation was not included. Participants indicated responses on a 4-point Likert-type scale from 0 (*not at all*) to 3 (*nearly every day*). Participants' scores ranged from 0 to 24, and were retained as a continuous measure of depressive symptoms. The Chronbach's α for this measure was 0.74.

Intimate Partner Violence—Intimate partner violence (IPV) was measured using the HITS scale (Hurt, Insult, Threaten, Scream; [29]), which is a 4-item measure of IPV that has also been validated for use among men [30]. Participants indicated responses on a 5-point Likert-type scale of the frequency with which they experienced IPV from their main partner in the past month from 1 (*never*) to 5 (*frequently*). Scores ranged from 4 to 20 and were retained as a continuous measure of IPV. The Chronbach's α for this measure was 0.92.

Childhood Sexual Abuse—Childhood sexual abuse (CSA) was measured via 2 items using the Finkelhor [31] definition of CSA. Participants were asked to indicate whether they had experienced any sexual experiences with someone 5 or more years older before being 13 years old, and/or any sexual experiences with someone who was 10 or more years older when they were between the ages of 13 and 17 years old. Participants who responded "yes"

to having experienced either of the above were considered to have experienced CSA, and this was retained as a dichotomous measure of ever having experienced CSA.

Poverty—Participants who indicated an annual income of less than \$12,000 and who also did not identify as a current student were considered to meet criteria for poverty, which was retained as a dichotomous measure.

Unstable Housing—Unstable housing was measured via 1 item querying whether participants had experienced unstable housing in the past 6 months. Unstable housing was defined as living in a hotel, in a boarding house, in a group home, on the street, or having no fixed address. Participants who responded “yes” to any of the above were considered to have experienced unstable housing, and this was retained as a dichotomous measure.

Prison History—Prison history, or incarceration, was assessed via 1 item asking participants to indicate if they had ever been in the correctional system. Being in the correctional system was defined as having been convicted of a crime and sent to juvenile corrections, jail, prison, probation, or parole. Participants who responded “yes” to having been in the correctional system were considered to have a prison history, and this was retained as a dichotomous measure.

Acculturation—For descriptive purposes, a measure of acculturation was used. Acculturation was measured as a descriptive variable via the 24-item Bidimensional Acculturation Scale for Hispanics (BAS; [32]). The BAS is comprised of three subscales: language use, linguistic proficiency, and electronic media use. Participants indicated responses on a 4-point Likert-type scale responding to their frequency of language use and electronic media use from 1 (*almost never*) to 4 (*almost always*) as well as their linguistic proficiency from 1 (*very poor*) to 4 (*very well*). Each cultural domain (Hispanic/Latino and non-Hispanic/Latino) was measured by 12 items. An average score for each cultural domain was computed. Average scores above 2.5 on both domains indicate biculturalism. The Chronbach’s α for this measure was 0.84.

Statistical Analysis

Of the 151 participants who completed the survey, 139, for whom there were no missing data on any of the syndemic variables or condomless anal sex, were included in the current study. Network analysis was conducted in R, version 3.3.2 [33] using the following packages: qgraph [34], mgm [35], bootnet [36], IsingFit [37], polycor [38].

Prior to examining the network, polychoric correlations between syndemic indicators themselves and with condomless anal sex were estimated. Polychoric correlations are statistically appropriate for investigating linear, bivariate associations among mixed data in which at least one variable is categorical or dichotomous [39].

Network analysis is a graphical representation of relationships between variables and consists of nodes and edges. Nodes are depicted as circles representing any type of variable and edges are depicted as lines representing any type of relationship between the given variables. Darker and thicker edges represent stronger relationships, whereas lighter and

thinner edges represent weaker relationships. The relative position of a node is interpretable, such that nodes that are closer together have a stronger relationship than do nodes that are further apart in the graphical representation of the network. In the current study, the network consisted of nodes for psychosocial and structural syndemic indicators and condomless anal sex.

Nodes were connected via edges, which were bidirectional partial polychoric correlations. This partial polychoric correlation network analysis was exploratory, regularized, and employed the graphical LASSO (glasso) algorithm [40]. Partial polychoric correlations provide information on the remaining relationships between syndemic indicators and between condomless anal sex and a given syndemic indicator after statistically controlling for all other variables in the network [24]. Partial polychoric correlations are utilized in this network to examine which associations may suggest information about a potential direct causal relationship [24] among syndemics and with condomless anal sex. In addition, as this is an exploratory network analysis, with a relatively small sample size, the Extended Bayesian Information Criteria (EBIC) hyperparameter, γ , was set to zero to produce a somewhat specific (i.e., more connections, including potentially spurious connections, are estimated than would be with a larger hyperparameter), yet sensitive (i.e., more true connections are estimated than would be with a larger hyperparameter) network. A hyperparameter of zero allows for interpretation of a greater number of potential associations between syndemic indicators and condomless anal sex, and is appropriate for network analysis applications aimed at discovery as well as when sample size is small [21]. The significance of associations (i.e., edge weights) was determined by examining the bootstrapped 95% confidence intervals [36]. Network density was also included as a descriptive variable of the network itself. Network density was calculated by computing the proportion of edges present in the estimated network to the total number of possible edges given 10 nodes in the network. Densely connected networks are those with a large proportion of estimated edges to total possible edges.

In addition to the graphical representation of the network, network analysis also yields empirical information on the relative importance of a given node on the interrelationships within a network, or centrality. More central nodes are those with greater connectivity with other nodes, and, thus, are more influential in a network [24]. Network analysis yields three indices of centrality. One centrality index is *betweenness*, or the length of the path of indirect relationships among nodes, such that nodes that are high on *betweenness* lie on the shortest indirect path that connects other nodes. Another is *closeness*, or the average distance a node is from the other nodes, such that nodes that are high on *closeness* have the shortest average distance from other nodes. The last centrality index is *node strength*, or the total strength of a node's direct relationships to other nodes [22, 41]. Of these three centrality indices, *node strength* is generally interpreted as the main centrality index because it empirically indicates the most influential nodes of a network [42]. In this study, *node strength* was examined as the main centrality index to determine the most central nodes in the network.

Results

Participants ($N = 139$) were an average of 24 ($SD = 3.11$, range = 18–29) years old, and with respect to race, more than half identified as White (55.4%) and more than one quarter as Black/African-American (28.1%). Additionally, more than two thirds of the sample identified as gay (68.3%) and approximately the other third as bisexual (30.9%). The vast majority of participants (91.4%) were born in the United States (U.S.), and were U.S. citizens (96.7%). Participants were nearly bicultural, though they evidenced a higher level of acculturation on the non-Hispanic/Latino domain (mean = 2.82, $SD = 2.58$) than on the Hispanic/Latino domain (mean = 2.46, $SD = 2.42$). The average acculturation level on the Hispanic/Latino domain is below the cutoff of 2.5 and thus considered to be a low level of adherence to the Hispanic/Latino domain [32]. Nearly the entire sample (93.5%) self-reported an HIV-negative serostatus, with the remaining participants (6.5%) reporting an unknown HIV-serostatus. Additional participant demographic data are presented in Table 1. Descriptive statistics for condomless anal sex and the syndemic indicators are included in Table 2. Average maximum alcohol use was 2.96 ($SD = 3.65$, range = 0–20) drinks, the average score on the IPV measure was 9.38 ($SD = 4.56$, range = 3–18), and the mean depression score was 9.29 ($SD = 4.37$, range = 0–23). The majority of the sample did not engage in condomless anal sex (71.9%), though nearly one sixth (15.8%) had one condomless anal sex partner and approximately one eighth (12.2%) had two or more condomless anal sex partners. Nearly half of the sample (44.6%) engaged in non-injection substance use (i.e., non-injection substance use alone, not including alcohol use) at least weekly, and almost half of the sample endorsed having engaged in IDU (45.3%) with varying frequencies in the past month. Approximately one fifth (18.7%) of participants had experienced CSA. Although experiencing poverty and having a prison history were relatively low base rates in this sample (12.2% and 6.5%, respectively), nearly half (43.2%) of the participants reported having experienced unstable housing.

Polychoric correlations, as presented in Table 3, revealed a pattern of interconnectedness, with a number of statistically significant correlations between condomless anal sex and the syndemic indicators, as well as between the syndemic indicators themselves. Only alcohol use was statistically significantly positively associated with condomless anal sex ($p = 0.007$). Non-injection substance use (i.e., non-injection substance use alone, not including alcohol use) and unstable housing were statistically significantly positively associated ($p < 0.001$). The strongest statistically significant correlation evidenced between syndemic indicators was the positive relationship between non-injection substance use and IDU ($p < 0.001$). However, unstable housing was statistically significantly correlated with the most other syndemic indicators (i.e., positively with non-injection substance use [$p < 0.001$], IDU [$p < 0.001$], depression [$p < 0.001$], and IPV [$p = 0.001$], and negatively with CSA [$p = 0.002$]). Despite a number of statistically significant relationships, not all syndemic indicators were statistically significantly related to condomless anal sex or other indicators. For instance, prison history was not statistically significantly correlated with any other variable in the current study, which may be due to the low base rate of prison history in this sample.

Results of the network analysis are presented in Fig. 1. Edges are partial polychoric correlations between condomless anal sex and syndemic indicators, and between the

syndemic indicators themselves. Given the small hyperparameter of $\gamma = 0$ that was utilized, the network is, as expected, dense—37 out of 45 total possible edges (82.2%) were represented in the graphical depiction. In addition, due to the density of connections in this network, no clusters of syndemic indicators were found, as all nodes have four or more edges. Upon examination of the 95% confidence intervals, the network analysis revealed three significant positive associations (absolute edge weights): condomless anal sex and alcohol use ($b = 0.40$, $SD = 0.20$, 95% $CI[0.00068, 0.76]$), IPV and non-injection substance use ($b = 0.43$, $SD = 0.17$, 95% $CI[0.000012, 0.68]$), and alcohol use and CSA ($b = 0.40$, $SD = 0.19$, 95% $CI[0.000073, 0.73]$); as well as one significant negative association: CSA and unstable housing ($b = -0.75$, $SD = 0.13$, 95% $CI[-0.93, -0.44]$). A number of non-significant and non-zero edges are depicted in the network. As this is an exploratory analysis, and network analysis is designed to produce a sparse solution, the non-zero edges depicted in this network that did not achieve statistical significance may still be present in the true network of this sample. Given the regularization of this network, parameter estimates are penalized toward zero. As such, the 95% confidence intervals are also penalized toward zero, which may account for statistical non-significance of several associations in this network [43]. However, the evidence is strong that the eight edges that were not depicted in this network analysis were not found in this sample.

Centrality indices were also examined, shown in Fig. 2. *Node strength* and *closeness* generally followed a similar pattern, and although *betweenness* had some similarities with the other two indices, it also differed in a number of respects. Nonetheless, all centrality indices were moderately to highly correlated: *strength* and *closeness* ($r = 0.98$), *strength* and *betweenness* ($r = 0.51$), and *closeness* and *betweenness* ($r = 0.57$). However, as *node strength* is considered to be the main centrality index, it was used to examine the most central nodes in this network. Results suggest that, per *node strength*, unstable housing, prison history, CSA, and condomless anal sex were the most central nodes in the current network analysis. None of these central syndemic indicators were significantly more central than any other.

Discussion

The purpose of the present study was to demonstrate the use of network analysis as a theoretically motivated approach for examining patterns of interrelatedness among psychosocial and structural syndemic indicators and between syndemic indicators and condomless anal sex. Network analysis is well-suited for examining syndemics because it assumes that nodes in the network are interacting and reinforcing [20, 24], allowing for investigation of relationships among syndemic indicators in a manner that is consistent with syndemic theory. To date, studies of associations between syndemic indicators themselves, for which there is a paucity of research, have been inconclusive or based on theoretically derived groups [12, 16]. However, network analysis allows for examination of empirically derived relationships and/or groups.

In the current study, three significant associations among syndemic indicators and one significant association between a syndemic indicator and condomless anal sex were identified using network analysis (see Fig. 1). Alcohol use and condomless anal sex, non-

injection substance use and IPV, and alcohol use and CSA were all positively associated, whereas the experience of unstable housing was negatively associated with ever having experienced CSA. With respect to the positive relationship between alcohol use and condomless anal sex, this finding is consistent with findings from literature reviews [44], and previous quantitative research among MSM [45], including MSM recruited specifically via the Internet [46, 47], as well as qualitative research among Latino MSM [48]. The positive linear association between increasing numbers of alcoholic drinks consumed on one occasion and sexual risk taking behavior (e.g., condomless anal sex) found in this study is also consistent with results from a study of MSM recruited via the Internet, which suggested that increasing numbers of alcoholic drinks was statistically significantly associated with increased odds of having a sexual partner on that day, as well as to increased odds of engaging in risky sexual behavior [47]. Although causation and temporality cannot be established due to the cross-sectional nature of the current study, this finding indicates that alcohol use may be an important target of intervention to directly reduce condomless anal sex among young Latino MSM who exhibit sexual risk, as two studies had a moderate effect for alcohol use interventions on sexual risk [49, 50]. Alcohol use was also found to be significantly related to having experienced CSA. In this sample, almost one fifth of participants (18.7%) had experienced CSA. The positive relationship between alcohol use and CSA found in the current study extends previous research on the relationship between CSA and alcohol use [51], and suggests that alcohol use may be an important downstream effect of CSA that is also directly related to HIV and STI risk behavior (i.e., condomless anal sex).

A significant association between increasing frequency of non-injection substance use (i.e., non-injection substance use alone, not including alcohol use) and increasing frequency of experiencing IPV was also found, suggesting that those experiencing IPV more frequently are more likely to also engage in more frequent non-injection substance use. This relationship between non-injection substance use and IPV was found in this sample of young Latino MSM who reported frequent non-injection substance use: 66.2% of the sample reported ever having taken substances in the past month and 44.6% reported at least weekly use. However, in contrast to these positive associations, the results suggest a negative relationship between ever having experienced CSA and having experienced unstable housing in the past 6 months. In other words, those who had experienced CSA were less likely to have recently experienced unstable housing. This inverse relationship between CSA and unstable housing, though potentially counter-intuitive, is consistent with bivariate findings of a study among HIV-negative and HIV-positive, men and women who engage in injection drug use in Canada [52], in which a negative association between CSA and unstable housing was significant in bivariate analyses, but non-significant in multivariate analyses. Further research among young Latino MSM is needed to determine whether this negative association can be replicated as well as to explore possible mediators. It is important to note that the pattern of interrelatedness of syndemic indicators and condomless anal sex found in this study may vary across other samples, which may be more representative of young Latino MSM. As these data were collected in a specific region of the U.S. (i.e., Southern California), this sample may differ from other samples of young Latino MSM in other geographic regions of the U.S. and the world. For example, the prevalence of CSA found in

this study (18.7%) is lower than that of other estimates among Latino MSM [53], which may be different in different geographic settings or other contexts.

In addition to information about the relationships among nodes, network analysis provides information about the centrality of nodes, or which variables are more influential than others in the network. The four most central nodes were, in order and based on *node strength*, unstable housing, prison history, CSA, and condomless anal sex (see Fig. 2). This indicates that, in this network examining relationships among syndemic indicators and between syndemic indicators and condomless anal sex in a sample of young Latino MSM, unstable housing appeared to be the most influential syndemic indicator. Unstable housing was reported by nearly half of the sample (43.2%). With respect to the next two most central nodes, having ever had a prison history and having ever experienced CSA, these nodes were high on centrality despite having low base rates in this sample (6.5% reported having had a prison history and 18.7% reported experiencing CSA). The high centrality of having ever had a prison history and having ever experienced CSA may indicate the importance of these variables on the relationships among syndemic indicators when they are indeed experienced. Of note, although no significant edges with prison history were detected in this network (i.e., the 95% CI for all prison history connections contained zero), prison history could still be central given the fact that there are a number of edges depicted for it that may be present in the true network but did not reach significance. The lack of significant edges with prison history in this network was likely due to the low base rate of endorsement of prison history, and subsequently low power to find associations. Although CSA is not a structural syndemic per se, CSA, unstable housing, and prison history are all specific events in one's life that have occurred at a, or multiple, distinct time(s) in the past and/or may still be ongoing (cf. depression or substance use, which may arise but be either related to or unrelated to a specific event). The high degree of centrality of these three variables suggests that, when experienced, addressing specific life events may be important when intervening on syndemic indicators. Lastly, the fourth most central node, condomless anal sex, suggests that not only do a number of syndemic indicators have relationships with condomless anal sex, but also that network analysis is a feasible approach for examining the relationships between syndemic indicators and condomless anal sex, as it was an important node in this network.

For non-zero edges represented in the network (Fig. 1) that have 95% confidence intervals that contain zero, the interpretation of confidence intervals around a regularized estimate differs from the conventional interpretation (i.e., for estimates that have not been penalized or "shrunk" [43]). Due to the regularization, the parameter estimate is "conservative" (biased toward zero) and, in turn, the confidence intervals are also biased toward zero. Therefore, there is still some evidence of association for these non-zero edges in the network whose bootstrapped confidence intervals nonetheless contain zero, and future research of these relationships is warranted in larger samples. Examination of the non-zero edges that contain zero in the 95% confidence interval estimates reveal a number of associations among syndemic indicators and between syndemic indicators and condomless anal sex. These nonzero edges suggest that intimate partner violence, non-injection substance use and IDU, CSA, and structural syndemics (i.e., unstable housing, poverty, and prison history) may be important areas of further research to examine their relationships with condomless anal sex in this population. Additionally, some associations that we had expected did not emerge,

which would seem to contradict existing literature, and hence replication and extension is also needed for this as well.

There are several limitations of this study to note. First, due to the cross-sectional nature of the study, temporality and causality cannot be determined. Therefore, only associations are examined and discussed. Nonetheless, the study provides evidence that network analysis is feasible for examining syndemics. A second limitation of the current study is that all syndemic indicators were self-reported. Self-report may introduce bias as it is affected by one's own perception of their symptoms. In addition, the single substance (for both non-injection substance use and IDU) used most frequently was analyzed, which treats all substances assessed equally and also does not account for polysubstance use. Consideration was given to assessing classes of substances individually within the network and/or to creating a polysubstance use variable. Given the exploratory nature of the current study, a polysubstance use variable and inclusion of each individual class of substance were rejected. Polysubstance use is a more severe presentation of substance use [54, 55]. As such, information on the relationships between less severe forms of non-injection substance and other syndemic indicators would be lost. Also, the current study was not powered to assess each class of substances individually, and inclusion of each class of substances in this network represents a different research question than the exploratory aim of the current study. Future research examining the relationships of individual substances and polysubstance use to other syndemic indicators is warranted. The current study was not able to account for pre-exposure prophylaxis (PrEP) adherence in the measure of condomless anal sex. Self-reported adherence to PrEP was measured over the past month, whereas number of partners with whom one engaged in condomless anal sex was measured in the past 3 months. Regardless of PrEP adherence, in the context of syndemic theory, condomless anal sex still confers a risk for other STIs. Indeed, recent research suggests that STI incidence has increased among PrEP users [56], and therefore, condomless anal sex is an important sexual risk behavior regardless of PrEP use, though it should be noted that individuals taking PrEP may present for STI screening more frequently than those not taking PrEP. Lastly, not all measures of syndemic indicators and condomless anal sex corresponded on the time frame in which they were assessed. However, these measures are considered samples of participants' recent behavior, and the timeframe.

The results of this network analysis have a number of clinical, public health, and structural level implications. Given the direct relationship between alcohol use and condomless anal sex, as well as the relationship between alcohol use and CSA, alcohol use appears to be an important immediate target of interventions to decrease HIV and STI risk among young Latino MSM. It is also possible that experiencing CSA has downstream effects on condomless anal sex via other syndemic indicators, such as alcohol use, and these results therefore suggest that intervention on symptomatology related to having experienced CSA, such as alcohol use, could potentially reduce current condomless anal sex. Similarly, although temporality and causality cannot be examined in the current study, the relationship between increasing frequency of IPV and increasing frequency of non-injection substance use may indicate the clinical importance of addressing violent and traumatic experiences as underlying problems that may have other downstream effects. Additionally, unstable housing, prison history, and CSA evidenced a high degree of centrality in this network

analysis, despite low base rates in this sample for prison history and CSA. Taken together, the results suggest that these specific life events, when present for an individual, may be important clinical considerations in treating the complex symptomatology associated with syndemic indicators. The high centrality of unstable housing, prison history, and CSA also have a number of implications for structural level reform and or interventions to assist individuals struggling with these problems. Programs to offer affordable housing as well as housing shelters would reduce unstable housing, which was the most influential syndemic indicator in this network. Similarly, although prison history was uncommon in this sample (6.5%), prison history was among the most influential syndemic indicators. This suggests that the effects of having experienced incarceration are profound and interventions or changes are needed to address this. Legislative and policy reform to address these issues appear to be important factors in reducing HIV incidence among young Latino MSM given the high importance of these structural syndemic indicators in this network.

Overall, this study is one of the first to employ network analysis to examine the patterns of interrelatedness among syndemic indicators for those at risk for HIV, and the first that includes condomless anal sex among MSM. The current network analysis identified three significant positive relationships: alcohol use and condomless anal sex, non-injection substance use and IPV, and CSA and alcohol use; as well as one negative association: CSA and unstable housing. Additionally, network analysis indicated that the four most central, or influential, nodes in this sample were unstable housing, prison history, CSA, and condomless anal sex. Results of this study can be viewed as a proof of concept, in that they suggest that network analysis is feasible and appropriate as a first step in providing evidence for relationships among syndemic indicators and between syndemic indicators and condomless anal sex. The use of network analysis to examine patterns of interconnectedness of psychosocial and structural syndemic indicators can help identify problems that are most central to a syndemic and thus inform more parsimonious models that include the most central syndemic indicators. The findings of this study may inform future research and theories about interaction effects of syndemic indicators on condomless anal sex and other risk behavior. For instance, results of the current study suggest significant interrelationships between alcohol use and CSA, as well as between substance use and IPV, which may support specification of one or more interaction effects between substance use, alcohol use, and sexual and physical abuse/violence variables. Given the significant association between alcohol use and condomless anal sex in the current study, as well as the extant literature supporting this relationship [44–46, 48–50], alcohol use may be an important factor in the relationships of syndemics with condomless anal sex. As such, alcohol use may be a potential target of intervention among young Latino MSM that could result in decreased HIV and STI risk behavior, as well as potentially reduce the downstream effects of other syndemic indicators (e.g., CSA). Lastly, the results also suggest that structural syndemics and specific life events may be important considerations when examining and intervening on syndemics among young Latino MSM.

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Fig. 1. Network analysis of condomless anal sex and nine syndemic indicators. Blue edges represent positive associations, whereas red edges represent negative associations. Thicker and darker edges indicate stronger associations than do thinner and lighter edges. * indicates a significant edge (pairwise association) between two nodes (i.e., CAS—ALC, SUB—IPV, ALC—CSA, HOU—CSA). For full node names, refer to the legend in the figure

Fig. 2.

Centrality measures of each node in the network analysis. z-scores are presented on the x-axis for each centrality measure. Full node names are condomless anal sex (CAS), substance use (SUB), injection drug use (IDU), alcohol use (ALC), depression (DEP), intimate partner violence (IPV), childhood sexual abuse (CSA), poverty (POV), unstable housing (HOU), and prison history (PRI)

Table 1

Selected participant demographic data

Demographics	N (%)	Demographics	M (SD)
Sex			
Male	139 (100%)	Age (in years)	24 (3.11) range = 18–29
Ethnicity			
Hispanic/Latino	139 (100%)		
Race		Acculturation	
White	77 (55.4%)	Hispanic/Latino	2.46 (2.42)
Black or African-American	39 (28.1%)	Non-Hispanic/Latino	2.82 (2.58)
Native American or American Indian	6 (4.3%)		
Asian/Pacific Islander	4 (2.9%)		
Other	12 (8.6)		
Missing	1 (.7%)		
Country of birth			
United States	138 (91.4%)		
Mexico	11 (7.3%)		
Other	2 (1.3%)		
Citizenship status			
United States citizen	146 (96.7%)		
Citizen of a nation other than the United States	3 (2%)		
Decline to answer	2 (1.3%)		
Sexual identity			
Gay	95 (68.3%)		
Bisexual	43 (30.9%)		
Other	1 (.7%)		
HIV status			
Negative	130 (93.5%)		
Unknown	9 (6.5%)		
Pre-exposure prophylaxis (PrEP) use			
Took PrEP in past month	23 (16.5%)		

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Demographics	N (%)	Demographics	M (SD)
PrEP adherence among PrEP users			
0–10% adherence	0 (0%)		
20% adherence	1 (4.3%)		
30–40% adherence	0 (0%)		
50% adherence	2 (8.7%)		
60% adherence	2 (8.7%)		
70% adherence	0 (0%)		
80% adherence	2 (8.7%)		
90% adherence	11 (47.8%)		
100% adherence	5 (21.7%)		

Table 2

Descriptive statistics of syndemic indicators and condomless anal sex

Variable	<i>M</i> (<i>SD</i>)	Range
Alcohol use (in number of drinks)	2.96 (3.65)	0–20
Depression	9.29 (4.37)	0–23
Intimate partner violence (IPV)	9.38 (4.56)	3–18
	<i>N</i> (%)	
Condomless anal sex		
0 partners	100 (71.9%)	
1 partner	22 (15.8%)	
2 or more partners	17 (12.2%)	
Substance use		
No use	47 (33.8%)	
1 or 2 times	30 (21.6%)	
About once per week	19 (13.7%)	
Several times per week	33 (23.7%)	
About every day	10 (7.2%)	
Injection drug use (IDU)		
No use	76 (54.7%)	
1 or 2 times	32 (23%)	
About once per week	19 (13.7%)	
Several times per week	9 (6.5%)	
About every day	3 (2.2%)	
Childhood sexual abuse (CSA)		
Yes	26 (18.7%)	
No	113 (81.3%)	
Poverty		
Yes	17 (12.2%)	
No	122 (87.8%)	
Unstable housing		
Yes	60 (43.2%)	
No	79 (56.8%)	
Prison history		
Yes	9 (6.5%)	
No	130 (93.5%)	

Table 3

Polychoric correlation matrix

	CAS	SUB	IDU	ALC	DEP	IPV	CSA	POV	HOU	PRI
CAS	1	-	-	-	-	-	-	-	-	-
SUB	-0.22 [*]	1	-	-	-	-	-	-	-	-
IDU	-0.12	0.77 ^{***}	1	-	-	-	-	-	-	-
ALC	0.26 ^{**}	-0.10	-0.14	1	-	-	-	-	-	-
DEP	-0.16	0.34 ^{***}	0.34 ^{***}	-0.06	1	-	-	-	-	-
IPV	-0.15	0.59 ^{***}	0.44 ^{***}	-0.25 [*]	0.26 ^{***}	1	-	-	-	-
CSA	-0.02	0.05	0.02	0.17	0.12	0.03	1	-	-	-
POV	0.01	-0.11	-0.14	0.18	-0.02	0.07	-0.17	1	-	-
HOU	-0.32 [*]	0.58 ^{***}	0.53 ^{***}	-0.07	0.38 ^{***}	0.39 ^{***}	-0.44 ^{**}	-0.03	1	-
PRI	0.29	-0.14	-0.15	-0.10	0.09	0.19	0.24	-0.21	0.16	1

Full variable names are as follows: condomless anal sex (CAS), substance use (SUB), injection drug use (IDU), alcohol use (ALC), depression (DEP), intimate partner violence (IPV), childhood sexual abuse (CSA), poverty (POV), unstable housing (HOU), and prison history (PRI)

 $p < 0.001$

**
 $0.001 > p > 0.01$

*
 $0.01 > p > 0.05$