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Tobacco Use among Sexual Minority Men and Women in the United States and China

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Abstract

Tobacco Use among Sexual Minority Men and Women in the United States and China

By Jingjing Li

Tobacco use is a significant public health problem in both Western and Eastern countries. An emerging line of studies suggests that lesbians, gays, and bisexuals (LGBs) are at increased risk for tobacco use in both the US and China, especially during young adulthood. However, the distinctive, accumulative risk profiles of tobacco use across sexual minority subgroups, particularly as distinguished by sex, remain inadequately understood. Additionally, the increasingly prevalent use of alternative tobacco products (ATPs), such as little cigars and cigarillos (LCCs), e-cigarettes, and hookah, have further complicated our understanding of the at-risk populations for tobacco use. There is a lack of research that explores the distinctive patterns in the association of sexual orientation, sex, and tobacco products that may be driving the tobacco disparities among sexual minorities in both countries. To advance our knowledge base regarding tobacco-related disparities in this vulnerable population, this dissertation addresses three research aims:

Aim 1: To systematically review and meta-analyze the empirical evidence on the distinctive sexual orientation and sex patterns in tobacco use among sexual minority men and women in the US.

Aim 2: To examine the relationship of sex and sexual orientation to tobacco use among young adults in the US.

Aim 3: To examine the relationship between minority stress, depression, and tobacco use among Chinese gay men versus bisexual men.

This dissertation research was guided by Minority Stress Theory (Meyer, 2003), which acknowledges that the higher rates of tobacco use among sexual minority young adults were explained by their sexual minority status. This series of studies makes novel contributions to the existing literature by providing evidence on the distinctive profiles in LGB use of tobacco products, as well as by determining what subgroups are most at-risk for negative health behaviors and outcomes. Additionally, the information provided by this research helps health educators and researchers to better understand tobacco use in key populations cross-culturally and aid in the development of more tailored tobacco intervention programming in both US and China.

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CHAPTER 1: Overview

Tobacco use is a leading preventable cause of mortality worldwide. Each year, around 480,000 and 1,000,000 people die prematurely from diseases related to tobacco use in the US and China, respectively (Z. M. Chen et al., 2015; S. S. Hu et al., 2016; A. Jamal et al., 2016; Peto, Lopez, Boreham, Thun, & Heath, 1994). Although the rate of cigarette use was reduced largely in the US from the 1960's to the present (Control & Prevention, 2011; Jha et al., 2013; Peto et al., 1994), data from 2005 onward show a disturbing trend – an uptick in use of alternative tobacco products (ATPs) (Delnevo et al., 2014; Y. O. Lee, Hebert, Nonnemaker, & Kim, 2014; McMillen, Gottlieb, Shaefer, Winickoff, & Klein, 2015; Singh, 2016). In recent years, ATPs, such as little cigars and cigarillos (LCCs), electronic cigarettes (e-cigarettes), and hookah, have become increasingly popular in the US (S Sean Hu, 2016; Ahmed Jamal, 2016; Lauterstein et al., 2014; Y. O. Lee et al., 2014; Singh, 2016). Researchers have therefore deemed ATPs as the "second front in the war on tobacco" (Amrock & Weitzman, 2015). In addition to the rising rates of ATP use in the US, major developing Eastern countries like China, where the US exports its premium tobacco, are also experiencing a high rate in overall tobacco use (Z. Chen et al., 2015; Ng et al., 2014; Paskett, Bernardo, & Khuri, 2015; Yang, Wang, Wu, Yang, & Wan, 2015): according to the most recent large scale study (N=512,891) conducted by Chen et al. (2015), as high as 74% of Chinese males were smokers (Z. M. Chen et al., 2015). For ATP use, Fayaz-Bakhsh et al. (2011) found that 12.1% of Chinese male college students (n=925) had ever used cigars, 3.7% had ever used pipes (Fayaz-Bakhsh, Babashahy, Jarrahi, & Rafiei, 2011). Taken together, the rise of ATPs in Western countries and the continuing high rates of tobacco use in non-Western countries constitute a major world health crisis.

Tobacco-Related Disparities and Sexual Minorities

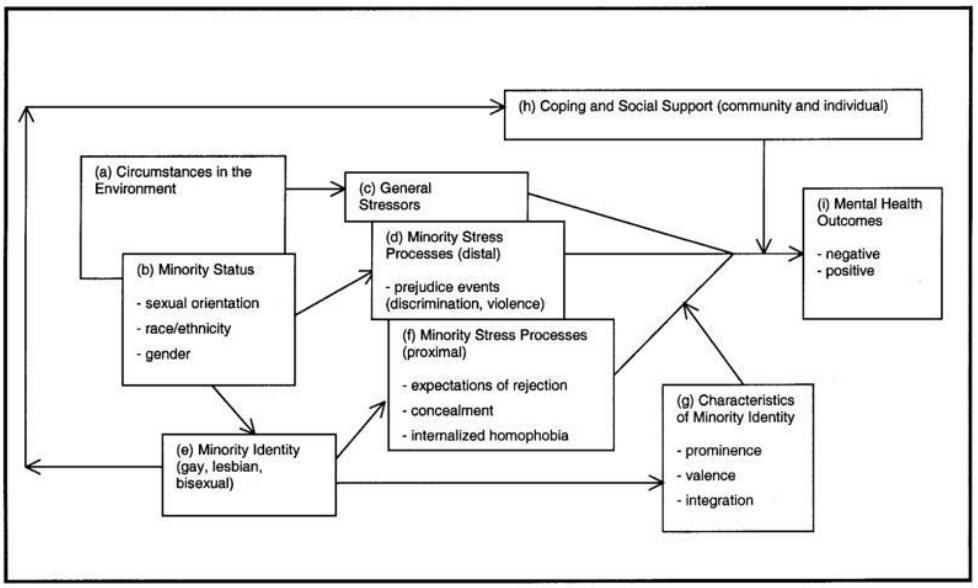
One group that appears to be at increased risk for tobacco use in both US and China is sexual minorities (including lesbians, gays, and bisexual women and men [LGBs]). More than 30,000 sexual minority individual die each year of tobacco-related diseases in the US alone (The DC Center). McElroy et al. (2011) reported that sexual minorities in the US are 1.49 times more likely to be current smokers compared with heterosexual individuals (McElroy, Everett, & Zaniletti, 2011), and findings from the 2009-2010 US National Adult Tobacco Survey (NATS) showed that LGBs had significantly higher rates of smoking than heterosexual respondents (King, Dube, & Tynan, 2012). This health disparity is even more pronounced in China than in the US. Although limited research has been done on issues related to tobacco among sexual minorities in China, a 2015 study on sexual orientation and smoking among 15-24 year olds found that LGBs were 2.2 times more likely to smoke (OR: 2.2, 95 % CI: 1.3, 3.9) (Lian, Zuo, Lou, Gao, & Cheng, 2015). A 2016 Chinese study on smoking rates among women revealed that sexual minority women reported a smoking prevalence of 74.4%, which was over 10 times higher than the 2.4% to 6.4% reported among heterosexual women (H. R. Yu, Du, G. Y., & Yang, J. Y. , 2016).

Sexual Minority Status and Adverse Health Outcomes

The current study is grounded in the Minority Stress Theory. In both US and China, ongoing cultural, religious, and society hostility towards sexual minorities exemplify a long-standing and widespread discrimination and stigma (Altman et al., 2012; Badgett, Hasenbush, & Luhur, 2017; Beyrer, 2012; Bränström & van der Star, 2013; Garcia & Koerner, 2014; Latypov, Rhodes, & Reynolds, 2013; Mavraj, 2016) and contribute to the heightened risk for adverse psychosocial and physical health outcomes among sexual minorities (Hatzenbuehler, 2017;

Hatzenbuehler & Pachankis, 2016; Herek, 2016). According to Minority Stress Theory, which is an extension of the well-established Social Stress Theory (Aneshensel, 1992), conditions such as belonging to stigmatized social categories can cause stress and may lead to negative mental and physical outcomes. Minority Stress Theory distinguishes the unique and additive stress to which individuals are exposed as a result of their minority social status, highlighting the relevant individual biological, genetic, or other nonsocial stressors. These minority statuses include sexual orientation, race/ethnicity, and gender/sex, as shown in ***Figure 1.1*** (Brooks, 1981; Meyer, 1995; Ilan H Meyer, 2003).

Figure 1.1 Diagram of the Minority Stress Theory (Meyer, 2003)



According to Minority Stress Theory (Meyer, 2003), sexual minorities are at greater risk for health problems than heterosexuals, because sexual minorities are exposed to excess stress related to a variety of stigma-related experiences that stem from their sexual minority status (Conron, Mimiaga, & Landers, 2010; Institute of Medicine, 2011; I. H. Meyer, 2003). In summary, the proposed research primarily relies on Minority Stress Theory to articulate why sexual minority

status poses a unique stressor for sexual minorities and may contribute to the documented higher rates of tobacco use among sexual minorities (Brooks, 1981; Meyer, 1995; Ilan H Meyer, 2003).

Sex Intersects with Sexual Orientation

According to the aforementioned conceptual model, sexual orientation is a significant predictor for tobacco use behavior. However, the distinctive impacts of different types of sexual orientation (e.g., heterosexuality, homosexuality, bisexuality) remain inconclusive. For example, Lee and colleagues (2009) systematically reviewed articles on tobacco use among sexual minorities in the US published from 1987 to 2007 and reported that the odds ratios (ORs) for tobacco use among sexual minorities ranged from 0.9 to 6.3 in comparison to heterosexual populations (J. G. Lee, Griffin, & Melvin, 2009). More recently, Bandiera et al. (2013) investigated sexual orientation-related disparity in tobacco use using data drawn from the 2003–2010 National Health and Nutrition Examination Surveys and found that being homosexual (aOR= 2.04, 95% CI: 1.20 - 3.48) or bisexual (aOR=2.43, 95% CI: 1.69 - 3.49) significantly correlated with tobacco use for women but not for men (Bandiera, 2013). On the other hand, Emory et al (2015) analyzed a 2013 nationally representative cross-sectional online survey of US adults (N=17087) and found that homosexual identity was significantly associated with tobacco use for both women (OR = 1.6, 95% CI: 1.0–2.7) and men (OR: 1.6; 95% CI: 1.0-2.2), while echoing that bisexuality influenced tobacco use among women (OR= 2.6, 95% CI: 1.7–3.9) but not among men (OR: 1.4; 95% CI: 0.8-2.5) (Emory et al., 2015). Collectively, the literature suggests greater tobacco disparities among sexual minority women than sexual minority men (Control & Prevention, 2014; Emory et al., 2015; J. G. L. Lee, 2014; Ward, Dahlhamer, Galinsky, & Joestl, 2014) and that tobacco-related disparities are potentially moderated by sex.

To our knowledge, no study in the US has simultaneously examined the sexual orientation/tobacco use relationship among heterosexual and sexual minority young adults and determined how much of tobacco use differences are accounted for by sex (Baskerville et al., 2017; Control & Prevention, 2014; Emory et al., 2015; Johnson et al., 2016; J. G. Lee et al., 2009; J. G. L. Lee, 2014; Lian et al., 2015; Marshal et al., 2008; Pizacani et al., 2009; Ward et al., 2014). Given that studies are more consistently assessing nuances to sexual minority status (i.e., homosexual versus bisexual) and that the literature regarding sexual minorities and tobacco use has not been systematically synthesized in recent years, it is critical and timely to update and aggregate the literature by reviewing and analyzing the recent empirical evidence regarding the associations between sexual minority status and tobacco use (**Aim 1**).

Vulnerable Transition Periods Across the Lifespan

There are distinct transition periods across the life span that may increase risk of engaging in risky behaviors among sexual minorities. For example, the transition to adulthood is a particularly vulnerable period for this group, compounding the risks already faced by sexual minorities. During this transitory period, many sexual minority individuals undergo the difficult tasks of acknowledging, defining, accepting, and disclosing their sexual identity (Charbonnier & Graziani, 2016; Floyd & Bakeman, 2006; Rosario, Schrimshaw, & Hunter, 2006; Savin-Williams & Diamond, 2000). These tasks are undertaken in addition to the normal challenges of a young adulthood that their heterosexual peers encounter (Stone, Becker, Huber, & Catalano, 2012). The stress in young adulthood is frequently high as young adults often move away from home, start work or receive low wages, or struggle with relationships or pregnancy (Aherne, 2001; Meadows, Brown, & Elder, 2006; Weden, Astone, & Bishai, 2006). Stressful life events, dramatic life changes, and escalating peer and life pressures all leave young adults particularly vulnerable to tobacco

use (Ling & Glantz, 2002; Orlando, Ellickson, & Jinnett, 2001; Pampel, Mollborn, & Lawrence, 2014; Rohrbach, Sussman, Dent, & Sun, 2005). In the US, a 2010 national study showed that young adults aged 18-25 had the highest current use prevalence of tobacco (including cigarettes, chewing tobacco, snuff, cigars, and pipe tobacco) (40.8%) compared with adolescents (10.7% among 12-17 year olds) or adults (27.2% for 26 year olds and above) (USHHS, 2011).

Young adults' use of ATPs is particularly high as well. Findings from another US national study suggest that 30% of young adults had ever used cigars; 26% had used little cigars, cigarillos, or bidis; and 18% had used hookah (Richardson, Williams, Rath, Villanti, & Vallone, 2014). This trend is echoed among Chinese young adults. In a cross-sectional survey among college students, Fayaz-Bakhsh et al. (2011) reported that 14.5% of Chinese female students (n=609) had ever smoked cigarette and 3.1% of them had ever used ATPs. Among male students (n=925), 71.1% had ever smoked and 18.2% had ever used ATPs (Fayaz-Bakhsh et al., 2011).

As multiple stressors challenge an individual's coping capabilities, tobacco use may serve as an alternative coping strategy or compensatory behavior for sexual minorities who are transitioning to young adulthood. Rath et al. (2013) provided data indicating that tobacco use among sexual minority young adults in the US is significantly higher than among their heterosexual counterparts. The authors analyzed data from the 2011 Legacy's Young Adult Cohort Study, a US nationally representative sample, and found that LGB's past 30-day cigarette use (35% and 27%, respectively) was significantly higher than heterosexuals' past 30-day cigarette use (18%; $p = .004$). Meanwhile, the prevalence of any current tobacco use among heterosexuals was 22% compared with 35% in gay/lesbians and 31% in bisexuals ($p = .04$) (Rath, Villanti, Rubenstein, & Vallone, 2013).

Given the limited number of studies that have distinguished cigarette smoking from ATP use ***and*** that have distinguished gay/lesbians and bisexuals from heterosexuals in the young adult population, additional research addressing this topic is warranted. Specifically, research is needed to examine: (1) the extent to which there are different risks of cigarette and ATP use by young adult sexual minorities in the US, and (2) whether this relationship is moderated by sex (**Aim 2**).

Sexual Minority Status and Tobacco Use in the Chinese Context

In contrast to the growing body of literature examining the impact and the heterogeneity of sexual orientation on tobacco use in Western societies, less is known about this topic in China (Lian et al., 2015; H. R. Yu, Du, G. Y., & Yang, J. Y. , 2016). However, it is plausible that sexual minority status associates with a higher risk for tobacco use in the Chinese context. According to Li (2006), Chinese society, which has been cultivated within a collective culture, highly values the sense of belonging to the "majority" (Li, 2006), which can be representative of righteousness and power, whereas minorities are marginalized or ostracized. As a result, a sexual minority who does not act like his or her peers by not getting married at a certain age will become a concern and shame to the whole family for being deviant from the majority (Wah-Shan, 2001). Qualitative research in China has suggested that Chinese sexual minorities may use substances to relieve the stress of hostile social stigma, as well as huge familial and cultural pressures (He, Wong, Huang, Thompson, & Fu, 2007). Therefore, it is important to examine whether sexual minority status may also associate with tobacco use among Chinese sexual minorities.

Men represent a disproportionate number of China's smokers. While the literature regarding tobacco use among sexual minorities in Eastern countries like China is limited, several

studies have similarly shown increased prevalence in this subgroup. For example, a study of gay and bisexual men in Shanghai, China indicated a cigarette smoking prevalence of 66% (Berg et al., 2011; F. Yu et al., 2013), approximately 15% higher than the national average, and 22%-33% higher than the city-level prevalence (China CDC, 2015).

As a developing country, China has limited public health resources. Research focusing on sexual minority's health disparity in China should identify the most at-risk subgroup to inform effective public health and policy decisions. An unsettled scientific question in China is: which sexual minority subgroup experiences the highest tobacco-related health risk and why (Emory et al., 2016; Feinstein & Dyar, 2017; Normansell & Wisco, 2017)? However, due to limited research, the answers to this question are still generally not well understood (Feinstein & Dyar, 2017). Moreover, very few tobacco use studies have been grounded in theory. Jointly, these issues hinder the development of effective interventions for sexual minority population in China. Thus, there is a critical need to explore how sexual minority status may impact tobacco use and the potential subgroup differences among Chinese sexual minorities, particularly gay versus bisexual men (**Aim 3**). This study also help advance our understanding of tobacco use behavior among key Chinese populations.

METHODS

The current research sought to address above-mentioned research aims using 1) systematic review and meta-analysis; 2) two-group multivariate regression; and 3) two-group structural equation modeling.

Systematic review and meta-analysis of tobacco use by sexual orientation and sex among youth and adults in the US

The goal of **Aim 1** is to conduct a systematic review and meta-analysis of the existing literature published in the past 10 years (i.e., studies published between 2007 and 2018) on sexual orientation and tobacco use in the US, both among youth and adults. According to Petticrew and Roberts (2006), a systematic review comprehensively identifies, assembles, and summarizes all the current knowledge on a specific topic. A systematic review is particularly useful to examine the differences between existing evidence and a hypothesis (Petticrew & Roberts, 2006). Meta-analyses can serve as a subsequent evaluation of data disseminated in multiple quantitative research studies to derive a pooled estimate (Littell, Corcoran, & Pillai, 2008). Systematic reviews and meta-analyses often work together but can also be conducted independently (Littell et al., 2008).

Systematic reviews and meta-analyses share most procedures in common. These procedures include defining the research question and determining the types of studies needed to answer research questions; conducting a comprehensive search of the literature; deciding which studies can be included or excluded based on inclusionary criteria; critically appraising the included studies; synthesizing the study findings and assessing for homogeneity; and disseminating the results (Petticrew & Roberts, 2006). In addition to these procedures, meta-analysis also involves pooling similar quantitative studies together so as to obtain a summary effect size and statistical significance (Petticrew & Roberts, 2006).

Cigarette and ATP use among US young adult heterosexuals versus sexual minorities

Aim 2 of this study was to illustrate the relationships between different sexual orientations and cigarette and ATP use among young adults in the US, which involves multiple dependent tobacco use outcomes. When determining the complex relationships between predictor, covariates, and multiple dependent variables, these questions are best addressed by multivariate

statistical techniques (Everitt, 2009). According to Everitt (2009), multivariate regression simultaneously incorporates multiple dependent variables in one model and is more efficient for the construction of the confidence intervals than calculating separate regression models for each dependent variable. If there is more than one independent variable, the mode of analysis expands to a multivariate multiple regression (Everitt, 2009). The secondary purpose of this study is to explore whether the sexual orientation/tobacco use relationship differs by sex. Thus, the sexual orientation parameter estimates among men and women samples need to be compared using a group comparison technique. Therefore, a two-group multivariate regression was conducted to accomplish **Aim 2**.

Mechanisms of tobacco use among sexual minority men in China

Aim 3 is to explore the relationship between sexual orientation and tobacco use among Chinese gay men and bisexual men, with a particular lens toward mechanisms suggested by Minority Stress Theory. Structural equation modeling (SEM) is a process that allows for testing one or more theories that are hypothesized a prior to explain the characteristics of measured variables (Hancock & Mueller, 2010). SEM can be used for model confirmatory purpose, testing alternative models, or model generation (Kline, 2015). SEM is generally a method that requires on large sample size (L. t. Hu & Bentler, 1999). The estimation of standard errors cannot be accurate when the sample size is small and researchers would also encounter greater technical problems in the analyses (Kline, 2015). Generally, the recommended sample size for SEM is about 200 participants (Barrett, 2007; Kline, 2015). However, a sample size of 200 may be still small if analyzing a complex model, using estimation other than maximum likelihood method, or the severe non-normal distribution.

Two-group SEM can be used to examine inter-group differences across sexual minority subgroups with increased rigor. The advantage of two-group SEM is that it allows the comparison of the extent of associations based on path coefficients (Lomax & Schumacker, 2004) and uses model fit indices to determine which tested paths best fit the data. This this method could help examine whether or not the underlying pathway are significantly different among sexual minority subgroups. Given the goals of Aim 3, two-group SEM is a particularly useful tool for examining how different pathways might vary across sexual orientation.

SIGNIFICANCE

Given that tobacco use is a leading preventable cause of mortality worldwide and contributes to vast numbers of deaths in the US and in China (Z. Chen et al., 2015; S. S. Hu et al., 2016; A. Jamal et al., 2016; Peto et al., 1994), understanding its impact on this particularly high-risk groups, such as sexual minorities, is critical. Moreover, the increasingly diversified tobacco product marketplace globally, the emerging data pertaining to this issue, and the increased assessment of specific sexual minority identity all provide a critical and timely need and opportunity to examine tobacco product use among sexual minority subgroups.

This research contributes to the existing literature by providing evidence regarding the distinctive profiles in sexual minority tobacco use, with a specific focus on subgroups differences in men and women and on the various tobacco products that have emerged in the market in the last decade. Moreover, this research is guided by Minority Stress Theory and, thus, will help to identify specific intervention psychosocial and behavioral targets that might inform targeted tobacco interventions for sexual minorities, with the goal of effectively reducing or preventing tobacco use in both US and China.

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CHAPTER 2: Tobacco use at the intersection of sex and sexual minority subgroup status in the US, 2007-2018: A systematic review and meta-analysis

ABSTRACT

Background: In the US, higher tobacco use prevalence has been documented among sexual minorities – or lesbian, gay, bisexual, and transgender populations (LGBT) – compared to heterosexual populations. Most recent studies note that there are important subgroup differences, with certain subgroups (e.g., bisexual women) having markedly higher prevalence of tobacco use relative to heterosexuals and other sexual minority subgroups. However, a population-level synthesis of tobacco use prevalence in sexual minorities has not been done for the past decade. Thus, this study seeks to synthesize the existing literature regarding tobacco use prevalence among sexual minority subgroups in the US.

Methods: We conducted a search of MEDLINE, Web of Science, EMBASE, and PsycINFO for studies published between 2007 and 2018 on tobacco use among sexual minorities in the US. Studies were included in the systematic review if they separated the sexes and gays/lesbians from bisexuals; studies were excluded if they did not report any tobacco use outcomes quantitatively or focused on special populations (e.g., HIV/AIDS or cancer patients). Two coders independently reviewed abstracts and full texts, extracted data, and coded study characteristics (i.e., publication year, study time period, study design, age group, sexual minority subgroup, types of tobacco products, proportion self-reported tobacco use, and quality of study). Only studies reporting current cigarette smoking prevalence estimates among sex and sexual minority subgroups were included in the meta-analysis. Using a random-effects model, age-group-specific (adult vs. youth) and overall and meta-prevalence estimates (mPs), 95% confidence intervals (CIs), and heterogeneity (I^2) were calculated for each sexual minority subgroup.

Results: Initially, 2,782 abstracts were screened for eligibility; 57 were eligible and included in the systematic review. Although studies relied on a variety of measurements to assess tobacco use, assessment for sexuality showed considerable consensus. A total of 47 studies reported the proportion of participants who were currently using cigarettes and thus were eligible for the meta-analysis. Overall mP showed that bisexual women (44.0%) had the highest prevalence estimate of current cigarette use among all subgroups, followed by bisexual men (35.5%), transgender (33.8%), lesbian (33.1%), and gay men (32.4%). Heterosexual men (24.9%) and women (21.9%) had the lowest prevalence. Though adult- and youth-specific mPs showed slightly different ordering from highest to lowest prevalence, bisexual women/girls reported the highest cigarette use among all subgroups in either age group. Significant heterogeneity was observed in overall and stratified meta-analyses.

Conclusion: This study provides numerical estimate of the prevalence of tobacco use across sexual minority subgroups in the US. These analyses synthesize evidence regarding important subgroup differences in tobacco use among sexual minority subgroups, with meta-analyses indicating high current cigarette use among bisexual women. This study adds to the knowledge base regarding sexual minorities and tobacco-related disparities and could guide future research and development of tailored tobacco intervention, with particular focus on bisexual women.

BACKGROUND

In the United States (US), tobacco use prevalence has been shown to be higher among sexual minority populations (i.e., gay, lesbian, bisexual, transgender, other non-heterosexual identity, those with same-sex sexual behaviors and/or attractions) compared to heterosexual populations, as evidenced by numerous studies published since the 1980s (Blosnich, Lee, & Horn, 2013; J. G. Lee, Griffin, & Melvin, 2009; Wheldon, Kaufman, Kasza, & Moser, 2018). Particularly relevant to the current study, a 2009 systematic review by Lee et al. (2009) examined tobacco use among sexual minorities in the US by synthesizing studies published between 1987 and 2007 (J. G. Lee et al., 2009). This analysis documented that studies generally showed a positive association between sexual minority status and current smoking. Though this analysis differentiated sexual minority women from men and gay/lesbians from bisexuals, there were very few records reporting the tobacco use prevalence in each sexual minority subgroup, as many national and state surveillance systems had not integrated sexual orientation questions until May 2007.

Unfortunately, sexual minorities have not yet been included or adequately identified in many of the national and regional health surveillance systems, and existing health data about sexual minorities are far from optimal. Nevertheless, in recent years, a growing integration of assessments of sexual orientation in national or regional surveys has enabled a more precise assessment of health disparities, such as tobacco-related disparities, among sexual minority subgroups (Patterson, Jabson, & Bowen, 2017). However, a population-level synthesis of tobacco use prevalence in sexual minorities has not yet been done for the past decade. The increasing needs for understanding the tobacco use-related health disparity in sexual minorities prompted this review to update the literature.

In addition, the past decade has marked a significant evolution of the tobacco market in the US. The use of alternative tobacco products (ATPs) falls on a continuum of health risk, with combustable tobacco presenting the greatest health risks to smokers. Both nation-wide and small-scale studies have suggested that the use of ATP is increasing rapidly across various demographic groups (Grinberg & Goodwin, 2016; Hu, 2016; Johnson et al., 2016; Kasza et al., 2017; Y. O. Lee et al., 2014; McMillen, Maduka, & Winickoff, 2012; Rath et al., 2013). However, research on ATP use among sexual minority populations is scarce (Jannat-Khah, Reynolds, Dill, & Joseph, 2017). Recently, some research has examined the distribution and patterns of ATP use in the sexual minority community. For example, using data from the 2012-2013 US National Adult Tobacco Survey on ATP use, Johnson and colleagues (2016) found that sexual minority women had significantly higher rates of cigar use (7.2% vs. 1.3%), e-cigarettes use (12.4% vs. 3.4%), and hookah use (10.3% vs. 2.5%), compared to heterosexual women. In addition, they found that sexual minority men reported higher rates of e-cigarettes use (7.9% vs. 4.7%) and hookah use (12.8% vs. 4.5%), compared to heterosexual men (Johnson et al., 2016b). Given the recency of the increased availability of ATPs in the US market, the majority of empirical studies on tobacco use among sexual minorities have overlooked or had insufficient data to examine use among ATP use in this subpopulation (Austin et al., 2004; Corliss et al., 2013; Goldbach et al., 2014; J. G. Lee et al., 2009; Marshal et al., 2008; Matthews et al., 2014; Rosario et al., 2011; Ward et al., 2014; Schauer, Berg, & Bryant, 2013).

Given the advances in assessments of sexual orientation in large survey studies and the evolution in the tobacco market, there is an opportunity and a need to examine tobacco use among subgroups of the sexual minority population. This is critical, as intervention efforts focused on tobacco use among sexual minorities (lesbians, gays, and bisexuals), though limited,

have shown modest results (Baskerville et al., 2017; Israel Berger & Mooney-Somers, 2016; Joseph GL Lee, Matthews, McCullen, & Melvin, 2014). Researchers have noted that targeted tobacco interventions are needed to reach sexual minorities more effectively (Baskerville et al., 2017; Israel Berger & Mooney-Somers, 2016), which underscores the importance of understanding of specific tobacco-related disparities among sexual minority subgroups. Thus, the goal of this study was to conduct a systematic review and meta-analysis to describe and estimate tobacco use among US sexual minorities – specified by sex and sexual minority subgroup – by pooling existing studies published between 2007 and 2018.

METHODS

We conducted a systematic review and meta-analysis based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher, Liberati, Tetzlaff, Altman, & Group, 2009). The following sections described search strategy, inclusion and exclusion criteria, study selection, and data extraction.

Search Strategy

We searched articles that simultaneously reported on tobacco use behaviors and sexual minority populations in the US. The formal search strategy for these databases was developed by a health science library research informationist at Emory University. Based on the Medical Subject Headings (MeSH) terms and the Glossary of LGBT Terms for Health Care Teams (National LGBT Health Education Center, 2018), tobacco use was identified by using a broad set of subject terms (i.e., tobacco, tobacco product*, nicotine, smoking, smoker*) and sexual minority was identified by subject terms including sexual minorit*, sexual and gender minorit*,

bisexual*, homosexual*, heterosexual*, and sexuality. After piloting and refining, a pool of 49 keyword variations was developed and used for full text search in each of the selected databases (Appendix A).

In February 2018, we searched MEDLINE (PubMed), Biosis Previews (Web of Science), EMBASE, and PsychInfo. All possible article records were collected from the four databases mentioned above. No protocol was registered for this study.

Inclusion and Exclusion Criteria

We limited our search to studies ***published*** from May 30, 2007 to February 26, 2018. We selected this time frame as we aimed to update the last systematic review on this topic which collected studies published up to May 2007 (J. G. Lee et al., 2009). We limited the language to "English" and literature type to "Article". Study inclusion criteria were articles that: 1) analyzed either observational study data and/or the baseline data of an intervention study in the US; 2) reported quantitative data analysis results of participants' tobacco use behaviors; 3) included data on sexual minorities, which could be defined by sexual orientation (e.g., LGBTQ+), by attraction (e.g., feelings/attractions toward same sex), or by sexual behavior (e.g., men who have sex with men); 4) separated gays/lesbians from bisexuals and separated men and women; and 5) included unique analyses of data (i.e., did not include more than one study analyzing the same data). The excluding criteria were: 1) conducted outside of the US; 2) qualitative studies, commentaries, books, conference abstracts, systematic reviews, reviews, or any forms not quantitative or not peer-reviewed; 3) not reporting any tobacco use outcomes; 4) not having any participants classified as sexual minorities; or 5) special populations such as HIV/AIDS or cancer patients (decided in order to reduce the confounding effects of medical conditions).

Study Selection

After excluding duplicate records from the combined database searches, two of the authors (J. Li and A. Weber) independently screened each title and abstract of these records for their relevance based on the exclusion criteria; if one or more exclusion criteria were met, they were considered ineligible. After excluding ineligible records, the two authors accessed full-text of the remaining records to assess whether they met the inclusion criteria. Disagreements were resolved through discussions.

Data Extraction

Data were extracted from the final set of articles into a summary Excel data extraction template developed by two authors, a doctoral student and faculty member (J. Li and C. Escoffery). We extracted on the following study characteristics: first author, publication year, study time period, study design and setting, study population (adult, youth, or both), total sample size, sexuality orientation/subgroup domain (identity, attraction, behavior, or combined), sexuality subgroup (gay, bisexual men, men who have sex with men [MSM], heterosexual men, lesbian, bisexual women, women who have sex with women [WSW], heterosexual women, transgender, or others), tobacco use measure (lifetime or current), type of tobacco product (cigars, smokeless, e-cigarettes, hookah, pipe), percent reporting cigarette and ATP use, and quality rating.

When a study reported multiple tobacco products or multiple prevalence estimates, we denoted all of the tobacco products or estimates in the summary table. From August 2018 to February 2019, the lead author (J. Li) abstracted data into the summary tables. From March 2019

to May 2019, another author (A. Weber) then independently reviewed extracted data for each study to ensure the accuracy of the extraction results. Throughout data extraction, discrepancies were resolved.

We (J. Li and A. Weber) used a modified version of the 14-item Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (NHLBI), developed by methodologists from National Heart, Lung, and Blood Institute (NHLBI) and Research Triangle Institute International for assessing quality rating. Eight criteria items from the original tool were used:

1) Was the research question or objective in this paper clearly stated?

2) Was the study population clearly specified and defined?

3) Was the participation rate of eligible persons at least 50%?

4) Were all the subjects selected or recruited from the same or similar populations (including the same time period)?

5) Were a sample size justification, power description, or variance and effect estimates provided?

6) Were the independent variables clearly defined, valid, reliable, and implemented consistently across all study participants?

7) Were the outcome measures or dependent variables clearly defined, valid, reliable, and implemented consistently across all study participants?

8) Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?

Each criterion was given a score ranging from 1-3 representing poor, fair, or good, respectively. All criteria items were then summed to yield an average score for each study.

Data Analysis

For the systematic review, we synthesized the characteristics of all included studies and characterized the measurements these studies used regarding tobacco use and sexuality/sexual orientation. We divided all prevalence records by: 1) adults (≥18 years old), youth (<18 years old), or both; 2) type of tobacco product used (cigarette use or alternative tobacco use), 3) tobacco use measurement (current use or lifetime use), and 4) sexuality/sexual orientation (gay, bisexual men, MSM, heterosexual men, lesbian, bisexual women, WSW, heterosexual women, transgender, or others). We identified small numbers of studies on: 1) ATP use (8 studies), 2) lifetime (vs. current) tobacco use (11 studies), 3) MSMs (5 studies), 4) WSWs (4 studies), and 5) other sexuality (3 studies). Moreover, few of these records were from population-based studies. Thus, the decision was made to only performed meta-analysis on current cigarette use among adult versus youth gay, bisexual men, heterosexual men, lesbian, bisexual women, heterosexual women. Transgender was not included in the stratification as only 1 study focusing on youth reported data on this population.

STATA 15 (StataCorp LP, College Station, TX) was used to conduct the meta-analysis and provide relevant descriptive statistics and pooled prevalence estimates. Guided by the meta-analysis handbook by Deeks (2008), we used a random-effects model to generate age-group-specific (adult vs. youth) and overall and meta-prevalence estimates (mPs), as well as the 95% confidence intervals (CIs) and heterogeneity (I^2) for each sexual minority subgroups (Deeks, Higgins, & Altman, 2008). For studies reported weighted prevalence, we obtained available standard error (SE) of these prevalence rates or calculated SE using available CIs for generating their meta-prevalence estimates (Higgins & Green, 2008). For studies reported weighted prevalence rates but did not report SE or CI, we used classic formula: square root of

[(prevalence) x (1 - prevalence)] / (square root of sample size) to calculated SE (Yamane, 1973). The overall point prevalence of current cigarette use was estimated for each sexual-orientation population with CIs and forest plots. We reported the study heterogeneity using the I^2 statistics and chi-square test of homogeneity. The value of 25%, 50% and 75% for I^2 indicated low, moderate, and high heterogeneity between studies, respectively (Higgins, Thompson, Deeks, & Altman, 2003). For chi-square test of heterogeneity, $P < .05$ was considered to be statistically significant. Because certain studies reported multiple prevalence estimates, the number of estimate records used (k) in the meta-analysis was different than the total number of included studies.

RESULTS

Figure 2.1 shows that the flowchart of the articles with a total of 2,782 records identified using the keyword search strategy. After removal of duplicate records, 918 records were left to be screened for relevance by their titles and abstracts. Of those, 166 records were assessed for full-text review. A total of 57 studies met the inclusion criteria for qualitative synthesis (systematic review). Among them, 47 reported the proportion of participants who were currently using cigarette and were included in the meta-analysis.

Study Characteristics

Overall characteristics of included studies were presented in ***Table 2.1***. The 57 studies, including a total sample size of 1,881,613 participants, were relatively homogenous regarding their study design and age group classification. The studies covered the sampling period between 1984 and 2015. Specifically, 7 studies had their sample collected prior to 2000, 29 studies had

sampling time period between 2000 and 2010, and 25 studies collected samples in or after 2010. Most of the studies (n=50; 87.7%) were cross-sectional surveys. The majority of the studies were conducted among adults (n=46; 80.7%). The remaining studies were conducted among youth (n=6; 10.5%) and among both youth and adults (n=5; 8.7%).

Regarding study quality rating, the average score of included studies was 2.4 (ranging from 1.4 to 2.9). The majority of the studies (n=49, 86.0%) scored higher than two (fair). Two studies scored lowest (1.4). One of them was a clinical report with limited descriptions of research questions and control of confounders. Another was a small cross-sectional panel study with limited information regarding the characteristics of the participants, definitions of tobacco use outcome, and reliability of the data. Meanwhile, there were 8 (14%) studies that did not report specific sampling time frame. These studies were mostly national or regional surveillance studies with clear definitions of participants and measurements.

Tobacco Use Measures

Included studies reported a variety of ways in defining tobacco use (***Table 2.2***). Many studies measured "current tobacco use". The most frequently used measurement for current tobacco use was "Having smoked 100 or more cigarettes in their lifetime and currently smoking cigarettes on some or all days" (n=23), followed by "any tobacco use in the past 30-day" (n=13). Fewer studies measured lifetime tobacco use. Lifetime tobacco use was primarily defined as "ever smoked" (n=11), followed by "having smoked 100 cigarettes in their lifetime" (n=9).

ATP Use

Table 2.1 and ***Figure 2.2a*** show that only a few studies (n=8) – mostly national or regional health surveillance reports – assessed use of ATPs, including cigars (n=8), smokeless tobacco (n=6), e-cigarettes (n=5), hookah (n=4), or pipes (n=3). Even fewer of studies reported prevalence of ATP use (n=5) (which is an insufficient sample size for meta-analysis). Available data in these five studies displayed a large variation on the prevalence of ATP use among sexual minorities. No clear pattern was observed for ATP use across sex and sexual minority subgroups. Overall, sex and sexual minority subgroups reported higher rates of cigarette use compared to ATP use. However, one recent study conducted by Coulter et al. (2017) found that transgender populations reported higher ATP use (37.5% reported current e-cigarette use, n=2369) than cigarette use (31.1% reported current cigarette use)(Coulter, Bersamin, Russell, & Mair, 2017). This e-cigarette rate of transgender (37.5%) was also the highest ATP prevalence rate identified in our review. The second highest prevalence of ATP use in our review was reported by Lee at al. (2011), that 27% of bisexual women (n=24) reported current cigar use (J. G. L. Lee, Goldstein, Ranney, Crist, & McCullough, 2011). The lowest prevalence of ATP use was reported by Gruskin et al (2007), that only 0.1% bisexual women (n=290) reported current smokeless tobacco use (Gruskin et al., 2007).

Assessments of Sexuality

Table 2.2 also shows the number of assessments for women, men, and transgender by domains of sexuality. Studies assessed sexuality mainly in three different domains – identity, behavior, or attraction – or failed to specify a measurement. Among women, 37 studies assessed sexual identity, and 11 assessed sexual behaviors. Among men, 33 studies assessed identity, and 11 assessed sexual behaviors. Some studies used a combination of two or three domains to assess sexuality. For example, Hughes, et al. combined the responses to survey questions “current

sexual attraction" and "gender of sexual partners" to classify female respondents into lesbian, bisexual, or heterosexual (Hughes, Johnson, & Matthews, 2008). As shown in ***Figure 2.2b***, most of the studies focused on lesbian (n=46), followed by bisexual women (n=41), gay men (n=36), and bisexual men (n=32). Due to a small number of studies focusing on transgender populations (n=10), we grouped these studies together.

Stratified Prevalence of Current Cigarette Use: Adults versus Youth

We conducted stratified meta-analyses for adults and youth, respectively. For adults, we identified 40 prevalence records from 32 unique studies representing 1,232,227 participants nationwide. ***Table 2.3*** describes the estimated mean prevalence of current cigarette use among adults by sexuality and sex/gender identity. Among adult women, the mean prevalence estimates were 30.3% (95% CI=25.3, 35.3; $\boldsymbol{I^2}$=97.3%; *k*=30), 38.4% (95% CI=34.4, 42.3; $\boldsymbol{I^2}$=93.8%; *k*=23), and 17.0% (95% CI=15.2, 18.9; $\boldsymbol{I^2}$=99.7%; *k*=20) for lesbian, bisexual, and heterosexual women, respectively. Among adult men, the mean prevalence estimates were 30.4% (95% CI=26.8, 34.0; $\boldsymbol{I^2}$=95.3%; *k*=26), 30.3% (95% CI=26.6, 33.9; $\boldsymbol{I^2}$=80.7%; *k*=19), and 22.0% (95% CI=18.6, 25.5; $\boldsymbol{I^2}$=99.9%; *k*=19) for gay, bisexual, and heterosexual men, respectively.

For youth, we identified 10 prevalence records from three school-based studies representing 149,914 students in grades 8 through 12 from Minnesota (data collected from 1998 to 2010), Massachusetts (data collected from 1999 to 2013), and Oregon (data collected from 2006-2008). As also shown in ***Table 2.3***, among adolescent girls, the mean prevalence estimates were 42.6% (95% CI=34.8, 50.4; $\boldsymbol{I^2}$=75.7%; *k*=10), 55.6% (95% CI=47.7, 63.6; $\boldsymbol{I^2}$=96.6%; *k*=10), and 31.4% (95% CI=20.1, 42.7; $\boldsymbol{I^2}$=99.9%; *k*=10) for lesbians, bisexuals, and heterosexuals, respectively. Among adolescent boys, the mean prevalence estimates were 38.2%

(95% CI=32.9, 43.5; I^2=74.1%; *k*=10), 43.2% (95% CI=34.8, 51.6; I^2=97.8%; *k*=10), and 30.4% (95% CI=22.2, 38.6; I^2=99.8%; *k*=10) for gays, bisexuals, and heterosexuals, respectively.

Figure 2.3 shows comparisons of the stratified (***Figure2.3a***) and overall prevalence (***Figure 2.3b***) of current cigarette use across sexuality and sex/gender identity subgroups (given only 1 study reported record of transgender youth, we did not stratified transgender estimates by age group, thus, transgender was not included in the comparison). The high-to-low order of the prevalence remained the same in the adult, youth, or overall samples. Bisexual women remained the highest in the prevalence of cigarette use and heterosexual women remained the lowest in both adult and youth. Comparing adults with youth samples, prevalence estimates in adults decreased by approximately 10 percent across all subgroups, with the largest decrease (17.0%) occurring in bisexual women and the smallest decrease (7.8%) in gay men.

Overall Prevalence of Current Cigarette Use

The meta-analysis for current cigarette use included 45 studies that represented 1,719,770 participants across the US. The overall pooled prevalence estimates for each sexual minority subgroup are presented in ***Table 2.3***. Among women, the mean prevalence estimates were 33.1% (95% CI=28.7, 37.5; I^2=96.6%; *k*=40), 44.0% (95% CI=38.8, 49.2; I^2=97.7%; *k*=33), and 21.9% (95% CI=18.9, 24.9; I^2=99.9%; *k*=30) for lesbian, bisexual, and heterosexual women, respectively. Among men, the mean prevalence estimates were 32.4% (95% CI=29.2, 35.6; I^2=94.3%; *k*=36), 35.5% (95% CI=30.2, 40.8; I^2=96.9%; *k*=29), and 24.9% (95% CI=21.5, 28.4; I^2=99.9%; *k*=29) for gay, bisexual, and heterosexual men, respectively. For transgender population, the pooled prevalence estimate of current cigarette use was 33.8% (95% CI=29.4, 38.2; I^2=88.8%; *k*=13).

Figure 2.3a shows that bisexual women had the highest prevalence of current cigarette use among all sexual-orientation subgroups. The next highest prevalence estimate was for bisexual men, nearly 9% lower than bisexual women. Transgender, lesbian, and gay had similar prevalence estimates, which were lower than bisexual men by 1.7%-3.0%. Heterosexual women and men had the lowest prevalence estimates among all groups studied here, with heterosexual men using cigarettes at a 3% higher rate than heterosexual women were. Notably, bisexual women had a prevalence of current cigarette use twice as high as heterosexual women.

Figure 2.4 includes the forest plots illustrating the prevalence of current cigarette use for each subgroup. The figures are organized by sexual minority subgroup (lesbian, bisexual women, heterosexual women, gay men, bisexual men, and heterosexual men) with forest plots for adults, youth, and overall for each subgroup.

DISCUSSION

This synthesis of the literature provides evidence that sexual minorities have a higher prevalence of cigarette use relative to heterosexuals. Based on Minority Stress Theory, sexual minority individuals experience hostile social environment relevant to their sexual orientation and thus lead to heightened stress and subsequent adverse health behaviors such as smoking (Ilan H Meyer, 2003). Lee et al. (2009) reported in smoking prevalence ranged from 25%-37% among adult sexual minority women and ranged 24%-33% among adult sexual minority men (J. G. Lee et al., 2009). The current meta-analysis of adult data produced very similar – yet slightly higher – prevalence estimates. This study also generated prevalence estimates of current cigarette use among heterosexual populations that are align with data from 2014 US Department of Health and Human Service report on smoking (US Department of Health and Human Services, 2014).

Our study also echoes the emerging recognition that significant sexual minority subgroup variation exists in cigarette use behaviors (Bernstein & Stein, 2015; Emory et al., 2016; Homma, Saewyc, & Zumbo, 2016; Spivey, Lee, & Smallwood, 2018). In particular, the current meta-analysis indicated that the prevalence of current cigarette use was highest among bisexual women, intermediate among bisexual men, transgender, lesbian, and gay, and lowest among heterosexuals. To yield more accurate health indices, it might be necessary to differentiate each sexual minority subgroups. This highlights the importance to integrate sexual orientation-related questions into the health research studies or surveillance systems as a standard practice (Patterson et al., 2017).

To our knowledge, this systematic review and meta-analysis is the first study to quantify the burden of current cigarette use among sexual minority subgroups, especially among transgender populations, in comparison with heterosexual populations in the US. Our results show that the prevalence of current cigarette use among overall transgender population was around 33.8%. This is similar to a recent national study reporting 35.5% current use of cigarette among transgender populations (Buchting et al., 2017). However, studies focusing on the transgender population and tobacco use are extremely scarce. Further study is needed to better understand the possible intragroup differences or distinctive risk profile between transgender men and women.

From our adult- and youth-specific and overall meta-analysis results, bisexual women consistently show the highest cigarette use prevalence across all subgroups. This is consistent with other studies that demonstrated the exceptionally high level of cigarette use in bisexual women compared with other sexual minority subgroups (Emory et al., 2016; Gonzales, Przedworski, & Henning-Smith, 2016; Johnson et al., 2016a; Nayak, Salazar, Kota, & Pechacek,

2017; Wheldon et al., 2018; Zaza, Kann, & Barrios, 2016). Consequently, there is an urgent need to prioritize this unique population in tobacco cessation efforts. Meanwhile, this finding also emphasizes the need to understand the underlying factors for this pronounced health disparity among bisexual women. Grounded in the Minority Stress Theory (I. H. Meyer, 2003), Feinstein and Dyar (2017) suggested that bisexually identified individuals experience unique minority stressors such as negative attitude from monosexual individuals (heterosexual and gay/lesbian), which contribute to their elevated rates of substance use problems compared to both heterosexuals and gay/lesbians (Feinstein & Dyar, 2017). Existing research also examined the effects of contextual factors such as peer influences and neighborhood factors that could impose negative health effects on sexual minorities (Johns et al., 2013; Pachankis, Hatzenbuehler, & Starks, 2014; Sivadon, Matthews, & David, 2014).

Compared to adult populations, youth in our review showed higher rates of cigarette use across all subgroups. Earlier studies showed that two out of five sexual minority high school students used at least one tobacco product and 33% transgender students actively used cigarette (Newcomb, Heinz, Birkett, & Mustanski, 2014). Researchers have found that the sexual minority youth experienced higher rate of tobacco-related diseases such as asthma compared to heterosexuals (Gartrell, Bos, Peyser, Deck, & Rodas, 2012). Importantly, sexual minority youth often continue their use of tobacco while transitioning into adulthood (Newcomb et al., 2014). However, sexual minority youth are less likely to use smoking quitlines, and few existing tobacco cessation were focusing on this vulnerable population (I. Berger & Mooney-Somers, 2017; Dickson-Spillmann, Sullivan, Zahno, & Schaub, 2014; Eliason, Dibble, Gordon, & Soliz, 2012; Matthews, Cesario, Ruiz, Ross, & King, 2017). Our finding highlights the need for urgent attention and effective intervention targeting sexual minority youth.

Despite ATP use being a growing public health concern in the US, our ability to conduct meaningful synthesis on ATP use across sexual minority subgroups was limited by the small number of studies including ATPs. Although we found high heterogeneity in the prevalence of ATP use among sexual minorities, there are reasons to believe that, compared to heterosexuals, ATP use may be higher among sexual minorities. For example, one recent study (Emory et al., 2016) analyzed samples from a 2013 nationally-representative cross-sectional online survey of 17,087 US adults on tobacco use and found bisexual women and men reporting the highest level of current use of e-cigarettes (11.3%), small cigars (18.4%), and regular cigars (6.6%), followed by gay males (e-cigarettes=7.8%, small cigars=5.2%, regular cigars=4.9%) and lesbian females (e-cigarettes=5.1%, small cigars=9.6%, regular cigar=3.9%), with the lowest prevalence among heterosexuals (e-cigarettes=4.8%, small cigars=6.2%, regular cigars=5.4%). Given the potential increased risk of ATP use among sexual minorities, there is a need to investigate how newer forms of tobacco products contribute to the sexual minority health disparities. Future research should consider ATP use and this line of research may well contribute to improving tobacco cessation effects and improving sexual minority health further by identifying their actual risk profiles.

Similar to the systematic review conducted by Lee et al. (2009), variation in the tobacco use measurement remain substantial across studies (J. G. Lee et al., 2009). Over half of the studies included in this review used “currently smoking cigarettes on some or all days”, “currently smoking”, “smoke one or more cigarette daily”, and “used in past 5-day”, which were arguably consistent in measuring the frequency of current tobacco use. Regarding the measurements used to decide lifetime tobacco use, studies mainly used “ever” (frequency) and “having smoked 100 cigarette in their lifetime” (quantity), which were less consistent.

There was also some variability in regard to assessments of sexual orientation. In 2009, Badgett and colleagues from the Williams Institute Sexual Minority Assessment Research Team recommended researchers to consider three domains when assessing "sexuality": 1) identity, 2) sexual behavior, and 3) attraction. "Sexual minority" was therefore defined as "people who are attracted to or have had experience with same-sex sex partners, or someone who identifies as lesbian, gay, or bisexual" (Badgett, 2009). Our findings show that, in the past decade, around 80% of studies concerning sexual minorities used identity, possibly because identity is the least sensitive domain to be included in public survey instruments. But a growing number of national and regional surveillance survey measured all three domains of sexuality, thus could reflect the associations between multiple aspects of sexuality and tobacco use disparity. Future research could consider including all three domains of sexuality to explore potentially different levels of and mechanisms for health risk related to sexuality. Together, variation in tobacco and sexuality measure may partly explain the heterogeneity across studies in the meta-analysis results.

Strengths and Limitations

Strengths of this analysis include independent search and data abstraction by two researchers; inclusion of a relatively large number of studies for each of the sexual minority subgroups; use of different definitions for sexual minority populations, and subgroup meta-analyses stratified by age-group. There are several limitations to the current study. First, there were only 8 records on cigar use, 6 records on smokeless use, and even less records on e-cigarette, hookah, and pipe, so we were unable to conduct meta-analysis on ATP studies. Second, the search terms we used centered on "sexual minority" and did not focus on "transgender" explicitly. The search results included transgender populations as a byproduct of

this study and were not exhaustive of those articles that could be found in the literature. Cautions are needed when comprehending our results on transgender. Third, since there were limited studies for each sexual orientation and sex/gender identity subgroup, we only stratified studies by age group, and did not stratify by sampling methods, sampling period, sampling locations, or year of publication to account for the high heterogeneity between studies. In addition, our youth samples only came from three statewide studies, and two of the three studies collected their data over a long period of time. Thus, the youth estimates do not reflect up-to-date prevalence. Notably, two studies on youth reported weighted prevalence but did not report standard error or confidence interval. In our meta-analysis, we calculated SE for these two studies using standard SE formula and treated them as random sampled studies. As such, our estimates might be biased towards unknown direction. However, considering one study used stratified random sampling (Watson, Goodenow, Porta, Adjei, & Saewyc, 2017) and another was census survey (Homma et al., 2016), we estimate that the bias should be minimum. Nonetheless, caution should be taken when interpreting the youth prevalence estimates. Third, while many of the included studies used nationally representative samples, others used convenience sampling to recruit participants. Therefore, the representativeness of our estimates might be limited. Fourth, we did not search gray literature or web reports and thus might miss some relevant ATP prevalences among sexual minority groups.

CONCLUSIONS

The current study examined 57 articles published between 2007 and 2018, qualitatively synthesized measures of tobacco use and sexuality, and quantitatively synthesized cigarette use prevalence among the overall, youth, and adult samples of sexual minority subpopulations. This review provides important evidence regarding the high prevalence of cigarette use in sexual

minorities relative to their heterosexual counterparts and highlights the particularly high rates of use among bisexual women. The limited data available studies regarding ATP use suggest the potential for higher risk among sexual minorities, but even more so for additional research addressing this understudied topic. These data are critical for accurately assessing the current health challenges and disparities experienced by sexual minorities and developing effective interventions and programs targeting tobacco-related disparities in high-risk subgroups (e.g., bisexual women). This study also adds nuance to the knowledge base regarding how researchers conceptualize and measure sexual minority status in the past decade.

Table 2. 1 Descriptive statistics and characteristics for studies measuring the prevalence of tobacco use in sexual minorities in the US (n=57)

Author, year	Study time period[a]	Study design	Adult Youth, or both[b]	Total N (% male)	Sexuality domain[c]	Sexual orientation subgroup n[d]	Tobacco use measure	Type of tobacco product	Tobacco use prevalence (%)	Included in meta-analysis	Quality rating[e]
Blosnich, 2011	2008-2009	cross-sectional survey	A	10201 (35.6)	Identity	G=1117; BM=578; HM=1455; L=683; BW=1925; HW=2818; O (men)=477 O (women)=1034	Lifetime; Current	Cigarette	**Lifetime-** G (19.0); BM (21.0); HM (16.0); L (22.1); BW (22.4); HW (15.7); O [men] (13.9) O [women] (18.0) **Current-** G (27.5); BM (26.5); HM (19.7); L (26.1); BW (31.5); HW (14.5); O [men] (24.2) O [women] (19.6)	Y	3.0
Blosnich, 2016	2003-2011	panel survey (only included first observation)	A	988 (50.2)	Behavior	MSM=248; HM=248; WSW=246; HW=246	Current	NR	MSM (25.6); HM (20.8); WSW (24.9); HW (20.2)	Y	2.4
Cochran, 2013	2003-2010	cross-sectional survey	A	11744 (48.6)	Combined	G=109; BM=85; MSM=125; HM=5390; L=71; BW=188; WSW=263; HW=5513	Current	Cigarette	G (28.9); BM (36.6); MSM (28.9) HM (29.6); L (35.8); BW (44.8); WSW (41.4); HW (21.8)	Y	2.8
Conron, 2010	2001-2008	cross-sectional survey	A	67359 (39.4)	Identity	G=926; BM=194; HM=25387;	Lifetime; Current	Cigarette	**Lifetime-** G (24.9); BM (14.9);	Y	2.6

						L=719; BW=432; HW=39701			HM (25.3) L (31.8); BW (23.8); HW (24.3) **Current-** G (32.5); BM (35.4); HM (20.6) L (26.3); BW (36.9); HW (19.4)		
D'Avanzo, 2016	2009-2011	longitudinal cohort study (only included baseline data)	A	598 (100)	Behavior	MSM=598	Lifetime; Current	Cigarette	**Lifetime-** 70.0 **Current-** 30.0	Y	2.4
Dibble, 2007	1999-2002	cross-sectional survey	A	29 (0)	Identity	L=29	Lifetime	Cigarette	7.4	Y	1.9
Dilley, 2010	2003-2006	cross-sectional survey	A	79500 (38.8)	Identity	G=495; BM=234; HM=29978; L=583; BW=555; HW=47250	Current	Cigarette	G (29.5); BM (38.7); HM (19.2) L (29.8); BW (38.1); HW (16.6)	Y	2.5
Drescher, 2018	NR	cross-sectional survey	A	335 (NA)	Identity	G=133; BM= NR; HM=NR; L=79; BW=NR; HW=NR; T women = 22; T men =28	Current	Cigarette	G (59.4); BM (NR); HM (NR); L (51.9); BW (NR); HW (NR); T women (59.0); T men (64.3)	Y	2.5
Emory, 2016	2013	cross-sectional survey	A	17087 (44.5)	Identity	G=326; BM=123; HM=7153; L=175; BW=291; HW=9010	Current	Cigarette/ E-cigarette /Regular cigar/	**Cigarette:** G (28.9); BM (NR); HM (NR); L (27.4); BW (NR);	Y	2.5

								Small Cigar	HW (NR) **E-cigarette:** G (7.8); BM (NR); HM (NR); L (5.1); BW (NR); HW (NR) **Regular cigar:** G (4.9); BM (NR); HM (NR); L (3.9); BW (NR); HW (NR) **Small cigar:** G (5.2); BM (NR); HM (NR); L (9.6); BW (NR); HW (NR)		
Fallin, 2015	2009-2010	cross-sectional survey	A	118590 (36.9)	Identity	G=867; BM=276; HM=42663; L=692; BW=491; HW=65739	Current	Cigarette	G (25.9); BM (33.7); HM (15.9); L (22.4); BW (32.0); HW (13.2);	Y	2.6
Garland-Forshee, 2014	2005-2008	cross-sectional survey	A	42746 (38.5)	Identity	G=268 BM=123 HM=16084 L=347 BW=322 HW=25602	Current	Cigarette	G (22.9) BM (31.4) HM (18.6) L (22.5) BW (37.3) HW (15.3)	Y	2.8
Gonzales, 2016	2013-2014	cross-sectional survey	A	68814 (48.2)	Identity	G=624; BM=162; HM=29792;	Current	Cigarette	G (27.4) BM (24.1) HM (19.1)	Y	2.9

						L=524; BW=353; HW=37054			L (25.1) BW (26.2) HW (14.7)		
Gonzales, 2017	2014-2015	cross-sectional survey	A	308546 (41.9)	Identity	G=2366; BM=1501; HM=125476; L=1718; BW=2705; HW=174780	Current	Cigarette	G (27.1); BM (25.6); HM (19.6); L (27.7); BW (28.5); HW (15.5)	Y	2.6
Gruskin, 2007	2003-2004	cross-sectional survey	A	1718 (41.7)	Identity/ Behavior	G=548; BM=85; MSM=83; L=329; BW=290; WSW=383	Lifetime; Current	Cigar; Smokeless	**Lifetime-Cigar**: G (2.2); BM (13.5); MSM (17.1); L (2.8); BW (1.9); WSW (3.3) **Smokeless:** G (0.6); BM (10.6); MSM (5.8); L (1.6); BW (0.0); WSW (0.0) **Current-Cigar:** G (1.2); BM (7.1); MSM (8.3); L (1.6); BW (0.4); WSW (2.0) **Smokeless:** G (0.3); BM (3.2); MSM (0.0); L (0.0); BW (0.1);	Y	2.5

									WSW (0.0)		
Hughes, 2008	1994-1996	cross-sectional survey	A	829 (0)	Combined	L=550; HW=279	Lifetime; Current	Cigarette	**Lifetime-** L (61.0) HW (54.0) **Current-** L (19.0) HW (19.0)	Y	2.4
Johns, 2013	2011	cross-sectional survey	A	471 (0)	Identity	L=258 BW=154; O=59	Current	Cigarette	L (83.7); BW (76.0); O (42.4)	Y	2.4
Johnson, 2016	2012-2013	cross-sectional survey	A	60192 (NR)	Identity	G=NR; BM=NR; HM=NR; L=NR; BW=NR; HW=NR; O=NR	Lifetime; Current	Cigarette/ E-cigarette /Hookah/ Pipe/Cigar / Smokeless	NR	N. Did not report subgroup N.	2.5
Jordan, 2015	2011	cross-sectional survey	A	3687 (NA)	Identity	G=1179; BM=NR; L=1039; BW=NR; T=138	Lifetime; Current	Cigarette	**Lifetime-** G (15.0); BM (NR); L (12.6); BW (NR); T (10.9) **Current-** G (34.9); BM (NR); L (45.3); BW (NR); T (39.1)	Y	2.0
Jun, 2010	2011	cross-sectional survey	A	62668 (0)	Identity	L=492; BW=221; HW=61955	Lifetime	Cigarette	L (33.6) BW (36.9) HW (22.7)	Y	2.3
Kerr, 2014	2009-2011	cross-sectional survey	A	65281 (34.2)	Identity	G=751; BM=473; HM=21071; L=538; BW=1579; HW=40869	Lifetime; Current	Cigarette/ Hookah/ Cigar/ Smokeless	**Lifetime-Cigarette:** G (41.7); BM (45.5); HM (32.1); L (47.0); BW (52.9);	Y	2.6

									HW (26.0) **Hookah:** G (33.8); BM (41.2); HM (31.9); L (33.8); BW (40.4); HW (25.2) **Cigar:** G (28.0); BM (38.9); HM (37.9); L (32.2); BW (36.0); HW (17.8) **Smokeless:** G (10.7); BM (15.2); HM (20.5); L (9.1); BW (11.1); HW (5.4) **Current-Cigarette:** G (23.2); BM (25.4); HM (17.8); L (25.3); BW (30.7); HW (12.2) **Hookah:** G (12.4); BM (17.5); HM (11.1); L (10.4); BW (13.4); HW (6.9)		

									Cigar: G (7.3); BM (14.8); HM (14.7); L (10.4); BW (11.1); HW (4.0) **Smokeless:** G (2.8); BM (4.7); HM (9.4); L (1.7); BW (2.1); HW (1.4)		
Lee, 2011	NR	cross-sectional survey	A	386 (69.7)	Identity	G=245; BM=24; L=89; BW=28	Current	Cigarette/ Cigar/ Smokeless	**Cigarette:** G (38.0); BM (46.0); L (46.0); BW (48.0); **Cigar:** G (9.0); BM (13.0); L (12.0); BW (27.0); **Smokeless:** G (3.0); BM (17.0); L (3.0); BW (4.0);	Y	2.1
Lehavot, 2011	NR	cross-sectional survey	A	1244 (0)	Identity	L=45; BW=361 O=838	Lifetime; Current	Cigarette	NA	N. Did not report prevalence	2.1
Lehavot, 2012	NR	cross-sectional survey	A	1381 (0)	Identity	L=46; BW=400; O=935	Current	Cigarette	NA	N. Did not report	2.1

										prevalence	
Levinson, 2012	2005-2008	cross-sectional survey	A	1633 (50.2)	Identity	G=733; BM=87; L=624; BW=140; T=33; O=16	Lifetime; Current	Cigarette	NA	N. Did not report prevalence	2.4
Lindley, 2012	2007-2008	cross-sectional survey	A	14412 (46.6)	Identity/ Behavior/ Attraction	G=114; BM=40; MSM=141; HM=6272; L=69; BW=185; WSW=115; HW=6126	Current	Cigarette	NA	N. Did not report prevalence	2.9
Lombardi, 2008	1984-1985	cross-sectional survey	A	691 (100)	Behavior	G=691	Current	Cigarette	42.3	Y	1.9
Matthews, 2011	2004	cross-sectional survey	A	171 (0)	Combined	L=134; BW=23; O=14	Current	Cigarette	L (35.1); BW (39.1); O (28.6)	Y	2.1
Matthews, 2017	2010-2012	cross-sectional survey	A	726 (0)	Identity	L=517; BW=183	Lifetime; Current	Cigarette	**Lifetime-** L (29.4) BW (29.5) **Current-** L (27.3) BW (38.3)	Y	2.0
Matthews, 2018	2001	cross-sectional survey	A	953 (0)	Identity	L=303; HW=502; O=148	Current	Cigarette	NR	N. Did not report prevalence	2.1
Max, 2016	2003-2013	cross-sectional survey	A	198635 (41.9)	Identity	G=2505; BM=911; HM=79881; L=1667; BW=1706; HW=111965	Current	Cigarette	G (21.1); BM (29.0); HM (18.9); L (20.9); BW (25.2); HW (11.6)	Y	2.8

McCabe, 2017	2012-2013	cross-sectional survey	A	35974 (43.7)	Identity/ Behavior/ Attraction	G=321; BM=144; MSM=545; HM=15190; L=265; BW=422; WSW=426; HW=19454	Current	Cigarette/ E-cigarette /Chewing tobacco/ Pipe/Cigar / Other	**Cigarette:** G (35.7); BM (45.2); MSM (28.3); HM (26.0); L (35.3); BW (44.9); WSW (30.4); HW (20.2) (Note: other products were grouped into 'Any tobacco use', thus did not have separate prevalence)	Y	2.4
McElroy, 2011	2008	cross-sectional survey	A	2907 (NR)	Identity	G=865; BM=92; HM=NR; L=975; BW=234; HW=NR; T=70; O=148	Lifetime; Current	Cigarette	**Lifetime-** G (18.0); BM (16.0); HM (NR); L (20.0); BW (13.0); HW (NR); T (10.0); O (NA) **Current-** G (34.0); BM (27.0); HM (NR); L (37.0); BW (40.0); HW (NR); O (NA)	Y	2.5
Meyer, I.H. 2017	2014	cross-sectional survey	A	691 (NA)	Identity	T=691	Current	Cigarette	22.7	Y	2.5
Mitchell, 2017	2012-2015	panel survey (only included	A	19492 (44.0)	Identity	G=264; BM=26 HM=6745;	Current	NR	G (5.7); BM (3.9); HM (1.8);	Y	1.4

		2015 panel data)				L=169; BW=90 HW=9350			L (6.1); BW (13.1); HW (3.6)		
Myers, S.C. 2017	2004-2014	Experimental study (only included baseline data)	A	121 (NA)	NR	T women = 91 T men =30	Lifetime	NR	T women (43.0); T men (50.0)	Y	1.4
Pachankis, 2011	NR	daily diary	A	192 (100)	Identity	G=136; HM=56	Current	Cigarette	NA	N. Did not report prevalence	2.1
Pizacani, 2009	2003-2005	cross-sectional survey	A	85316 (39.2)	Identity	G=543; BM=263; HM=32464; L=647; BW=639; HW=50293	Lifetime; Current	Cigarette	**Lifetime-** G (58.3); BM (65.7); HM (49.8); L (56.8); BW (58.7); HW (41.0) **Current-** G (31.7); BM (35.9); HM (20.3) L (29.5); BW (35.9); HW (17.3)	Y	2.6
Reisner, 2013	2011	Mixed methods (only included quantitative data)	A	73 (39.2)	Identity	T=73	Lifetime; Current	Cigarette	**Lifetime-** 33.8 **Current-** 14.2	Y	2.1
Rhodes, 2009	2004-2006	cross-sectional survey	A	4167 (100)	Identity	G=206; HM=3961	Current	Cigarette	G (39.0) HM (30.0)	Y	2.8
Rhodes, 2012	2008	cross-sectional survey	A	190 (100)	Behavior	MSM=190	Lifetime; Current	Cigarette	**Lifetime-** 36.3 **Current-** 38.9	Y	1.9

Shires, 2016	2008-2009	cross-sectional survey	A	4241 (NA)	Identity	T=4241	Current	Cigarette	27.2	Y	2.8
Smalley, 2016	NR	cross-sectional survey	A	3279 (27.9)	Identity	G=751; L=951; T female=82; T male =126; O =117	Current	NR	G (19.4); L(21.2); T female (23.9) T male (25.0) O (11.0)	Y	2.0
Talley, 2016	2010-2013	cross-sectional survey	A	332 (0)	Identity	L=26; BW=22; HW=203; O=81	Lifetime	Cigarette	L (65.0) BW (77.0) HW (40.0) O (NA)	Y	2.3
Trocki, 2009	1999-2001	cross-sectional survey	A	7264 (46.4)	Combined	G=57; BM=27; MSM=83; HM=3201; L=36; BW=50; WSW=87; HW=3723	Current	Cigarette	G (35.7); BM (20.0); MSM (25.7); HM (22.8) L (23.1); BW (44.4); WSW (34.1) HW (19.1)	Y	2.8
Wheldon, 2018	2013-2014	cross-sectional survey	A	31548 (50.7)	Identity/ Behavior/	**18-24 years old:** G=114; BM=94; MSM=137; HM=4296; L=121; BW=423; WSW=144; HW=3796 **25 years and older:** G=199; BM=144; MSM=240; HM=10963; L=198; BW=419; WSW=206; HW=10311	Current	Cigarette/ E-cigarette /Hookah/ Pipe/Cigar / Smokeless	**18-24 years old:** **Cigarette:** G (35.7); BM (27.2); MSM (31.8); HM (27.9); L (32.3); BW (44.3); WSW (31.8); HW (18.2) **25 years and older:** **Cigarette:** G (43.3); BM (50.4); MSM (43.2) HM (45.8); L (50.5); BW (57.7); WSW (48.7);	Y	2.5

									HW (35.5)		
Ylioja, 2018	NR	cross-sectional survey	A	566 (NA)	Identity	G=198; BM=NR; L=119; BW=NR	Current	Cigarette	G (16.7); BM (NR); L (14.3); BW (NR)	Y	2.3
Bernstein, 2015	2001-2012	cross-sectional survey	Y	86 (0)	Identity	L=21; HW=65	Current	Cigarette	NA	N. Did not report prevalence	1.9
Coulter, 2017	2013-2014	cross-sectional survey	Y	316766 (48.2)	Identity	G=NR; BM=NR; HM=NR; L=NR; BW=NR; HW=NR; T=2369	Current	Cigarette/ E-cigarette	**Cigarette:** T (31.1) **E-cigarette:** T (37.5) Others NR	Y	2.8
Hatzenbuehler, 2011	2006-2008	cross-sectional survey	Y	31852 (47.3)	Identity	G=183; BM=278; HM=15076; L=118; BW=834; HW=15363	Current	Cigarette	G (33.3); BM (37.1); HM (22.2); L (28.0); BW (43.6); HW (16.7)	Y	2.8
Homma, 2016	1998-2010	cross-sectional survey	Y	**1998:** 18456 (50.5) **2001:** 17278 (49.2) **2004:** 17637 (48.7) **2007:** 19185 (50.3)	Behavior	**1998:** MSM=148; BM=1176; HM=7999; WSW=45; BW=367; HW=8721 **2001:** MSM=142; BM=1008; HM=7347; WSW=56; BW=515; HW=8210	Current	Cigarette	**1998:** MSM (52.1); BM (63.3); HM (56.3); WSW (55.8); BW (75.8); HW (63.9); **2001:** MSM (35.0); BM (54.6); HM (47.0); WSW (40.0); BW (67.3); HW (52.9);	Y	2.6

				2010: 19504 (49.9)		**2004:** MSM=172; BM=1010; HM=7412; WSW=82; BW=575; HW=8386 **2007:** MSM=250; BM=1744; HM=7659; WSW=112; BW=658; HW=8762 **2010:** MSM=268; BM=1632; HM=7832; WSW=138; BW=765; HW=8869			**2004:** MSM (34.5); BM (50.9); HM (38.5); WSW (48.1); BW (66.7); HW (44.6); **2007:** MSM (35.7); BM (40.1); HM (34.1); WSW (31.7); BW (56.9); HW (36.3); **2010:** MSM (31.0); BM (31.0); HM (29.5); WSW (34.3); BW (50.0); HW (29.5)		
Rosario, 2008	1993-1995	cross-sectional survey	Y	76 (0)	Combined	L=NR BW=NR	Current	Cigarette	NA	N. Did not report subgroup N.	2.0
Watson, 2017	1999-2013	cross-sectional survey	Y	**1999**: 8201 (50.6) **2003:** 6850 (49.1) **2007:** 5676 (49.8)	Identity	**1999:** G=37; BM=60; HM=4054; L=15; BW=133; HW=3902 **2003:** G=41; BM=46; HM=3279; L=25;	Current	Cigarette	**1999:** G (64.0); BM (51.8); HM (26.9); L (45.2); BW (63.8); HW (27.7) **2003:** G (41.1); BM (38.5); HM (19.6); L (75.1);	Y	2.5

				2011: 5275 (50.5)		BW=153; HW=3306 **2007:** G=64; BM=52; HM=2712; L=36; BW=182; HW=2630 **2011:** G=47; BM=54; HM=2565; L=35; BW=177; HW=2397			BW (55.4); HW (19.5) **2007:** G (39.6); BM (39.7); HM (16.7); L (43.8); BW (44.5); HW (13.7) **2011:** G (26.4); BM (21.5); HM (13.2); L (37.0); BW (31.3); HW (8.9)		
Bauer, 2010	2002	cross-sectional survey	B	6087 (0)	Combined	L=62; BW=192; WSW=90; HW=5086	Current	Cigarette	L (22.0); BW (38.5); WSW (46.1) HW (19.4)	Y	2.6
Corliss, 2014	2005-2007	cross-sectional survey	B	64397 (NR)	Identity/ Behavior	G=NR BM=NR MSM=NR HM=NR L=NR BW=NR WSW=NR HW=NR O=NR	Lifetime; Current	Cigarette	NR	N. Did not report subgroup N.	2.5
Herrick, 2010	2004-2005	cross-sectional survey	B	137 (0)	Combined	L=66; BW=62; WSW=137	Lifetime; Current	Cigarette	**Lifetime-** L (NR) BW (NR) WSW (74.0) **Current-** L (NR) BW (NR) WSW (39.0)	Y	1.8

Ott, 2013	1999-2007	longitudinal cohort study (only included 2007 data)	B	8652 (35.4)	Identity	G=93; BM=23 HM=2697; L=78; BW=126; HW=4373;	Current	Cigarette	G (40.9); BM (43.5); HM (24.5); L (37.2); BW (45.2); HW (15.8)	Y	2.6
Storholm, 2011	NR	cross-sectional survey	B	578 (100)	Behavior	MSM=580	Current	Cigarette	36.3	Y	1.8

[a] NR=Not reported; NA=Not applicable
[b] A=Adult; Y=Youth; B=Both
[c] Combined= A measurement using a mixture of two or more dimensions of sexuality
[d] G=gay, BM=bisexual men, MSM=men who have sex with men, HM=heterosexual men, L=lesbian; BW=bisexual women; HW=heterosexual women; WSW=women who have sex with women; T=transgender; O=others (including unsure, unknown, queer, pansexual, asexual, intersex, etc)
[e] Average score using the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (Good=3, Fair=2, Poor=1)

Table 2. 2 Summary of assessments (N=57)

Tobacco Use		
Definition	**Measure**	**Number of studies**
Current use	Having smoked 100 or more cigarettes in their lifetime and currently smoking cigarettes on some or all days	23
	Any use in past 30-day	13
	Any use in past 5-day	1
	Any use in past 12-month	3
	Smoke one or more cigarette daily	7
	Currently smoking	8
	Other/non-specified	2
Lifetime use	Having smoked 100 cigarettes in their lifetime	9
	Ever smoked	11
	Other/non-specified	2
Sexuality		
Sex/gender identity	**Sexuality domains**	**Number of studies**
Women		**47**
	Identity	37
	Behavior	11
	Attraction	3
	Combined	7
Men		**40**
	Identity	33
	Behavior	11
	Attraction	3
	Combined	2
Transgender		**10**
	Identity	8
	Non-specified	2
Other/not specify	Non-specified	**11**

Table 2. 3 Pooled prevalence of current cigarette use in the US, by sexuality and sex/gender identity, 2007-2018 (N=47)

		Overall Pooled Prevalence Among Adults (aged 18 or older)					
Sex/gender identity	**Sexuality**	**k**	**Point Estimate (%)**	**95% Confidence Interval**	**Min-Max (%)**	**Heterogeneity I^2 (%)***	***p* value**
Women	Lesbian	30	30.3	25.3-35.3	6.1-83.7	97.3	<.001
	Bisexual	23	38.4	34.4-42.3	13.1-76.0	93.8	<.001
	Heterosexual	20	17.0	15.2-18.9	3.6-35.5	99.7	<.001
Men	Gay	26	30.4	26.8-34.0	5.7-59.4	95.3	<.001
	Bisexual	19	30.3	26.6-33.9	3.9-50.4	80.7	<.001
	Heterosexual	19	22.0	18.6-25.5	1.8-45.8	99.9	<.001
Transgender	Aggregated**	13	33.8	29.4-38.2	14.2-64.3	88.8	<.001

		Overall Pooled Prevalence Among Youth (under the age of 18)					
Sex/gender identity	**Sexuality**	**k**	**Point Estimate (%)**	**95% Confidence Interval**	**Min-Max (%)**	**Heterogeneity I^2 (%)**	***p* value**
Women	Lesbian	10	42.6	34.8-50.4	28.0-75.1	75.7	<.001
	Bisexual	10	55.6	47.7-63.6	31.3-75.8	96.6	<.001
	Heterosexual	10	31.4	20.1-42.7	8.9-63.9	99.9	<.001
Men	Gay	10	38.2	32.9-43.5	26.4-64.0	74.1	<.001
	Bisexual	10	43.2	34.8-51.6	21.5-63.3	97.8	<.001
	Heterosexual	10	30.4	22.2-38.6	13.2-56.3	99.8	<.001

		Overall Pooled Prevalence Among All Participants					
Sex/gender identity	**Sexuality**	**k**	**Point Estimate (%)**	**95% Confidence Interval**	**Min-Max (%)**	**Heterogeneity I^2 (%)**	***p* value**
Women	Lesbian	40	33.1	28.7-37.6	6.1-83.7	96.6	<.001
	Bisexual	33	44.0	38.8-49.2	13.1-76.0	97.7	<.001
	Heterosexual	30	21.9	18.9-24.9	3.6-63.9	99.9	<.001
Men	Gay	36	32.4	29.2-35.6	5.7-64.0	94.3	<.001
	Bisexual	29	35.5	30.2-40.8	3.9-63.3	96.9	<.001
	Heterosexual	29	24.9	21.5-28.4	1.8-56.3	99.9	<.001
Transgender	Aggregated**	13	33.8	29.4-38.2	14.2-64.3	88.8	<.001

* I^2 = the variation across studies that is attributable to heterogeneity rather than chance; k = number of prevalence estimates used; min–max = minimum to maximum

** Because only 9 studies (included 13 prevalence records) reported tobacco use prevalence in transgender populations, so we aggregated all records for transgender.

Figure 2.1 Summary of literature search flow chart

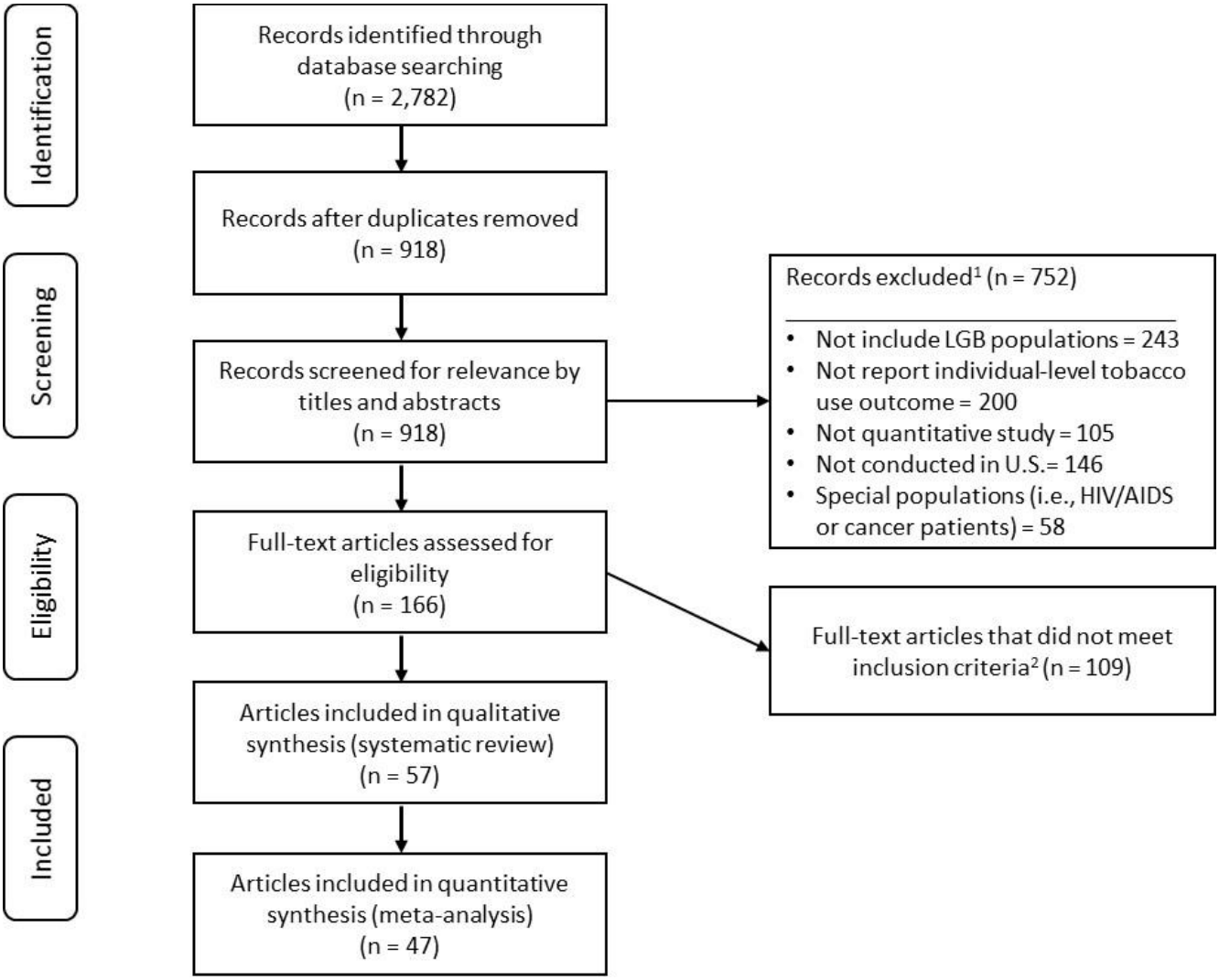
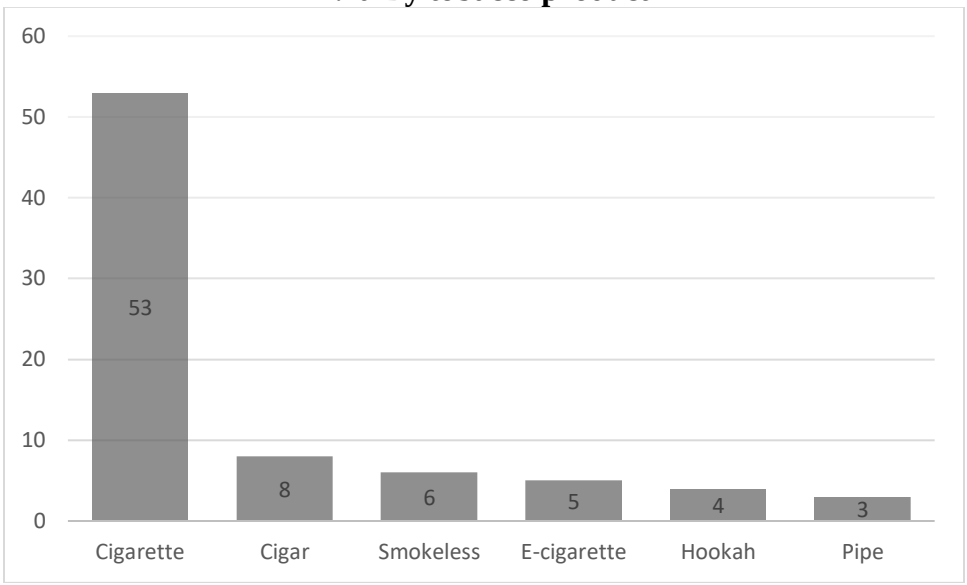


Figure 2. 2 Number of studies by tobacco products and by sexual minority subgroups (N=57)

2.2a By tobacco product



2.2b By sexual minority subgroups

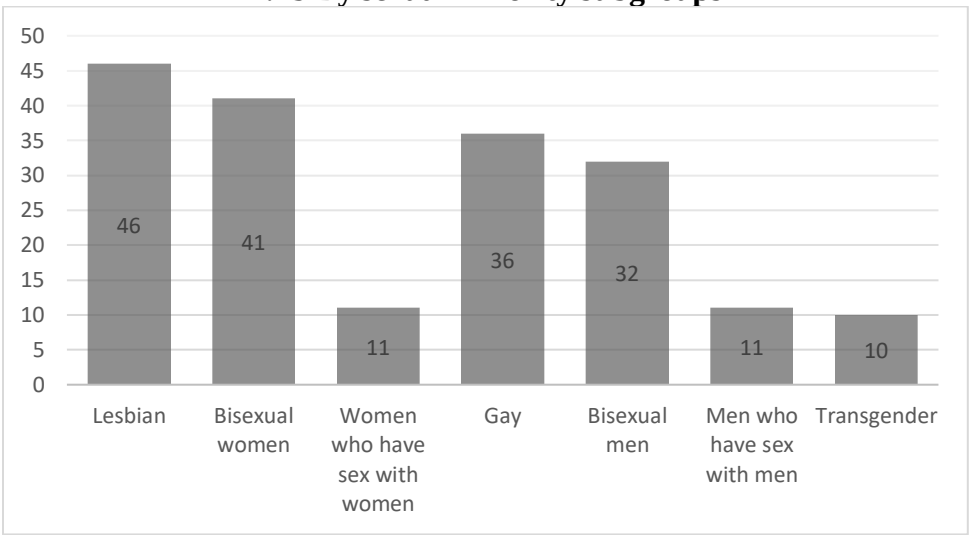
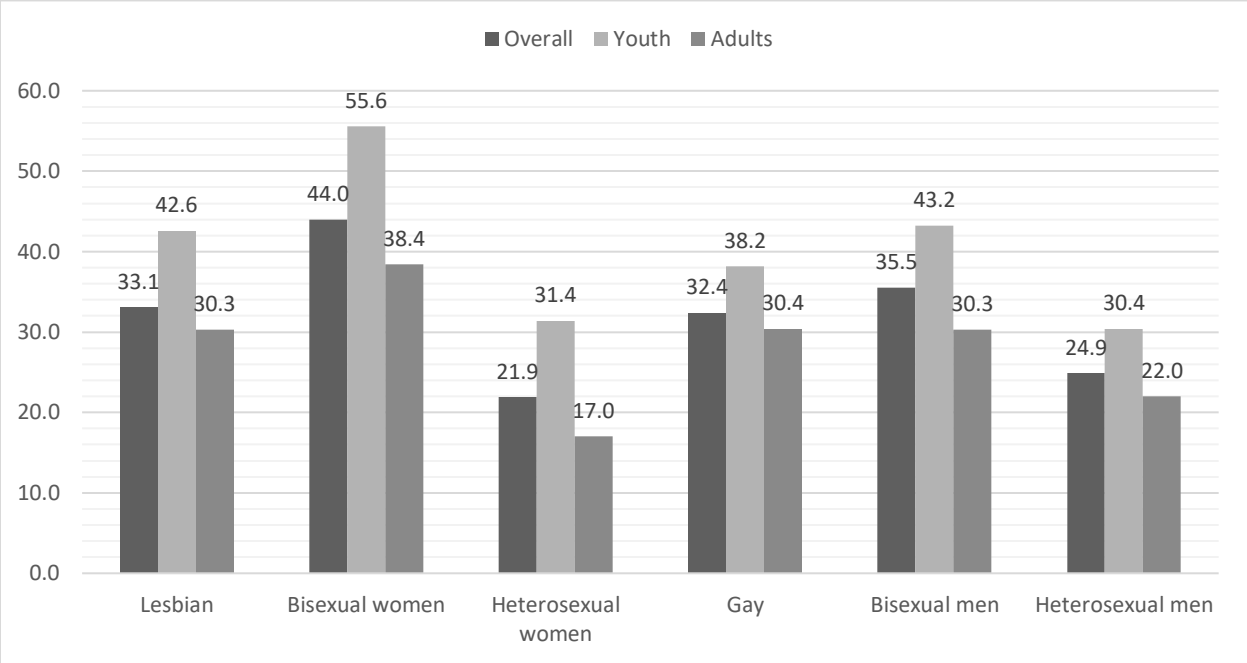


Figure 2. 3 Point estimate prevalence of current cigarette use in the US, by sexuality and sex/gender identity, 2007-2018 (N=47)

3a. By age group



3b. Among all participants

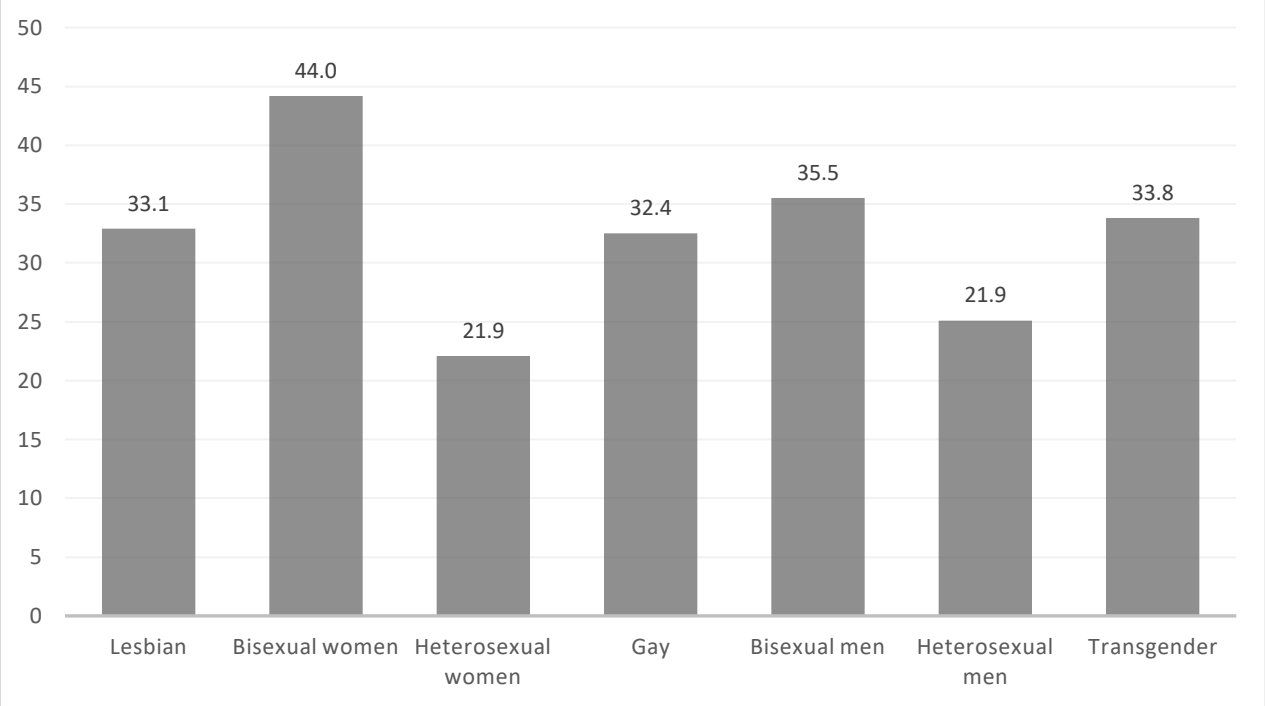
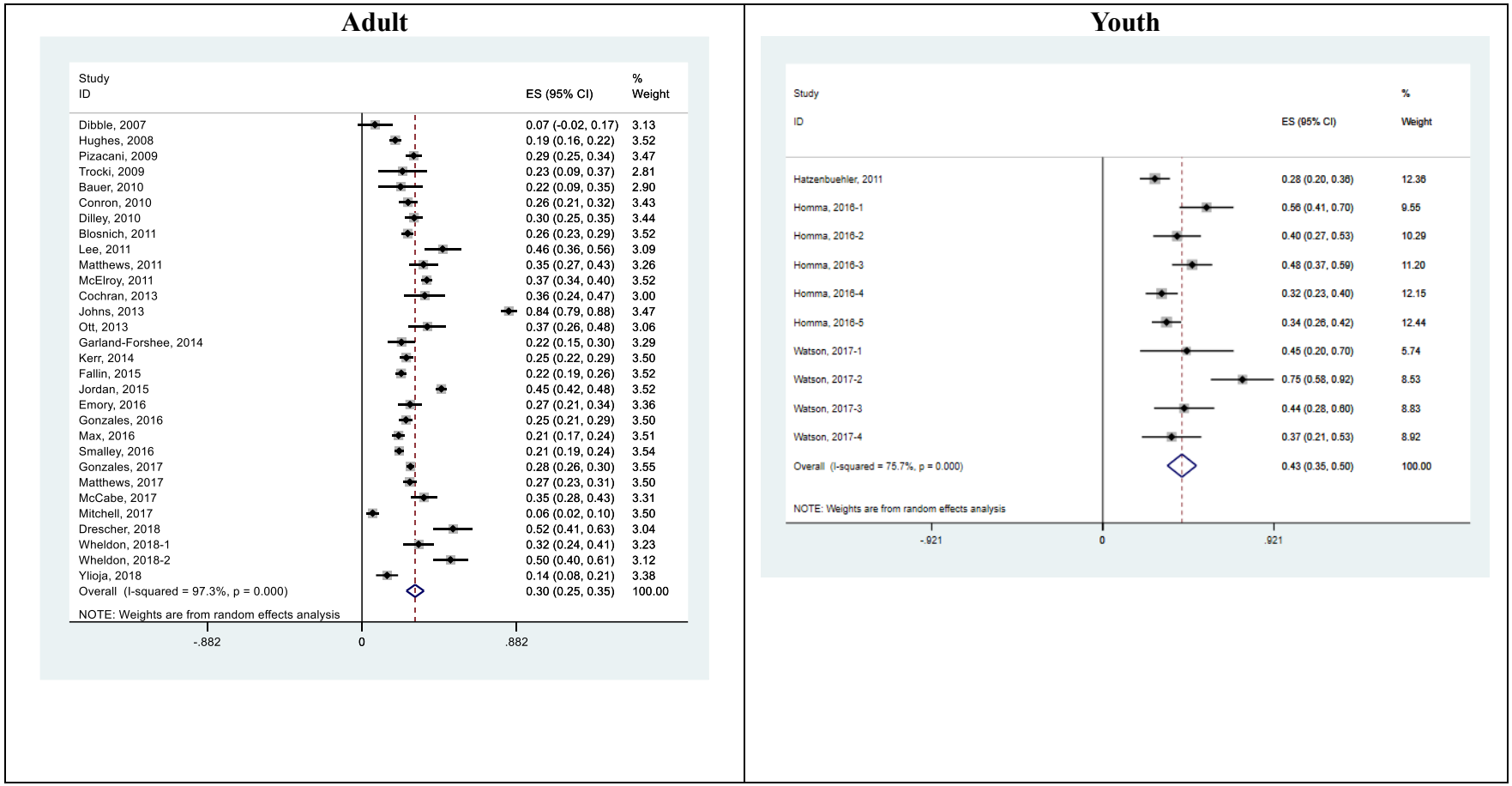
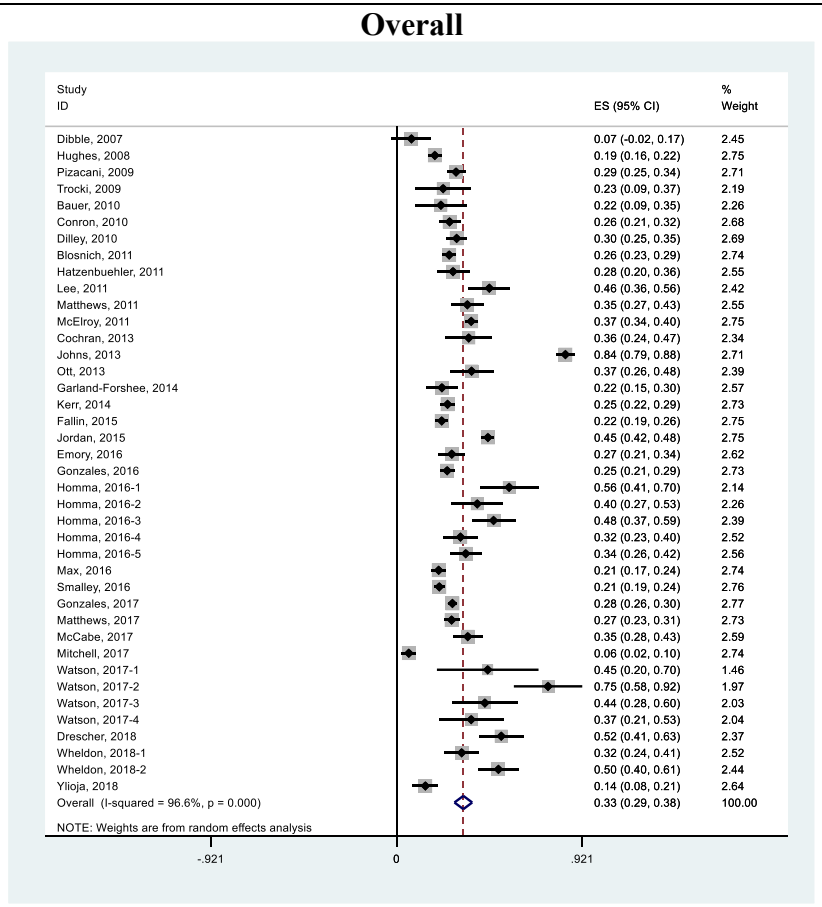


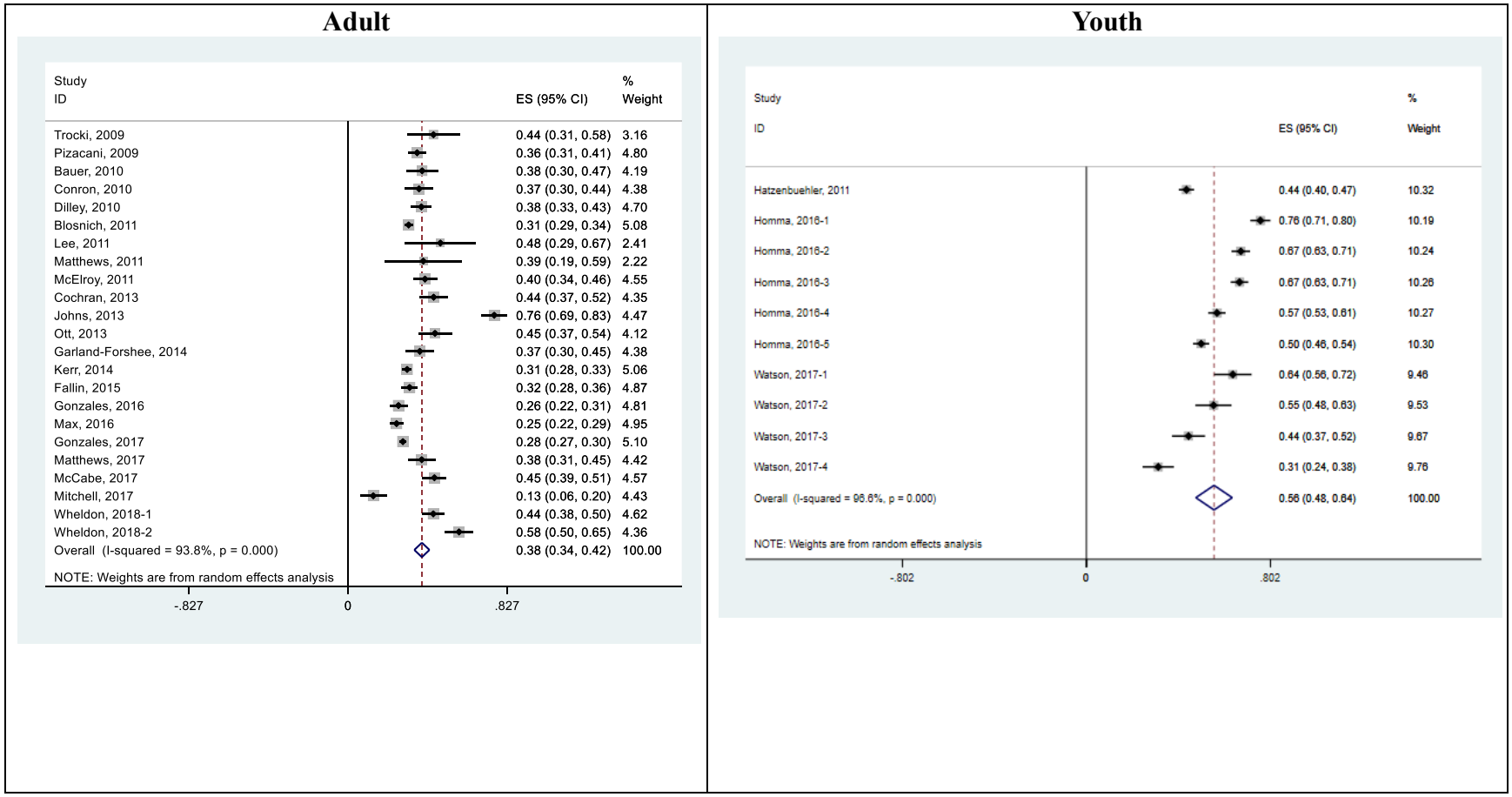
Figure 2. 4 Forest plot from meta-analysis of studies reporting current cigarette use prevalence in the US, by sexuality and sex/gender identity, 2007-2018 (N=47)

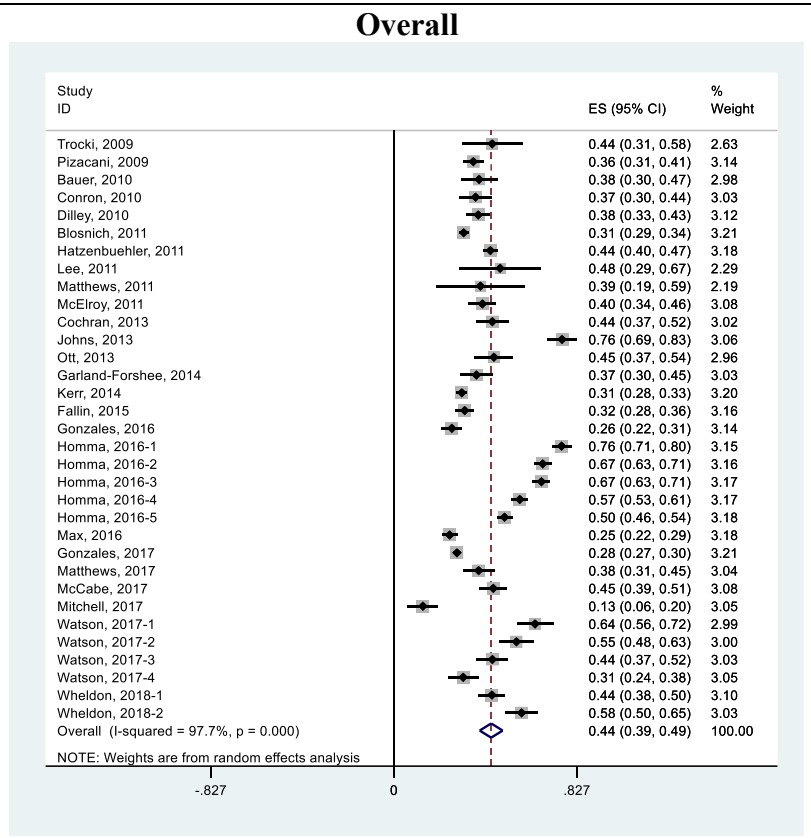
4a. Lesbian



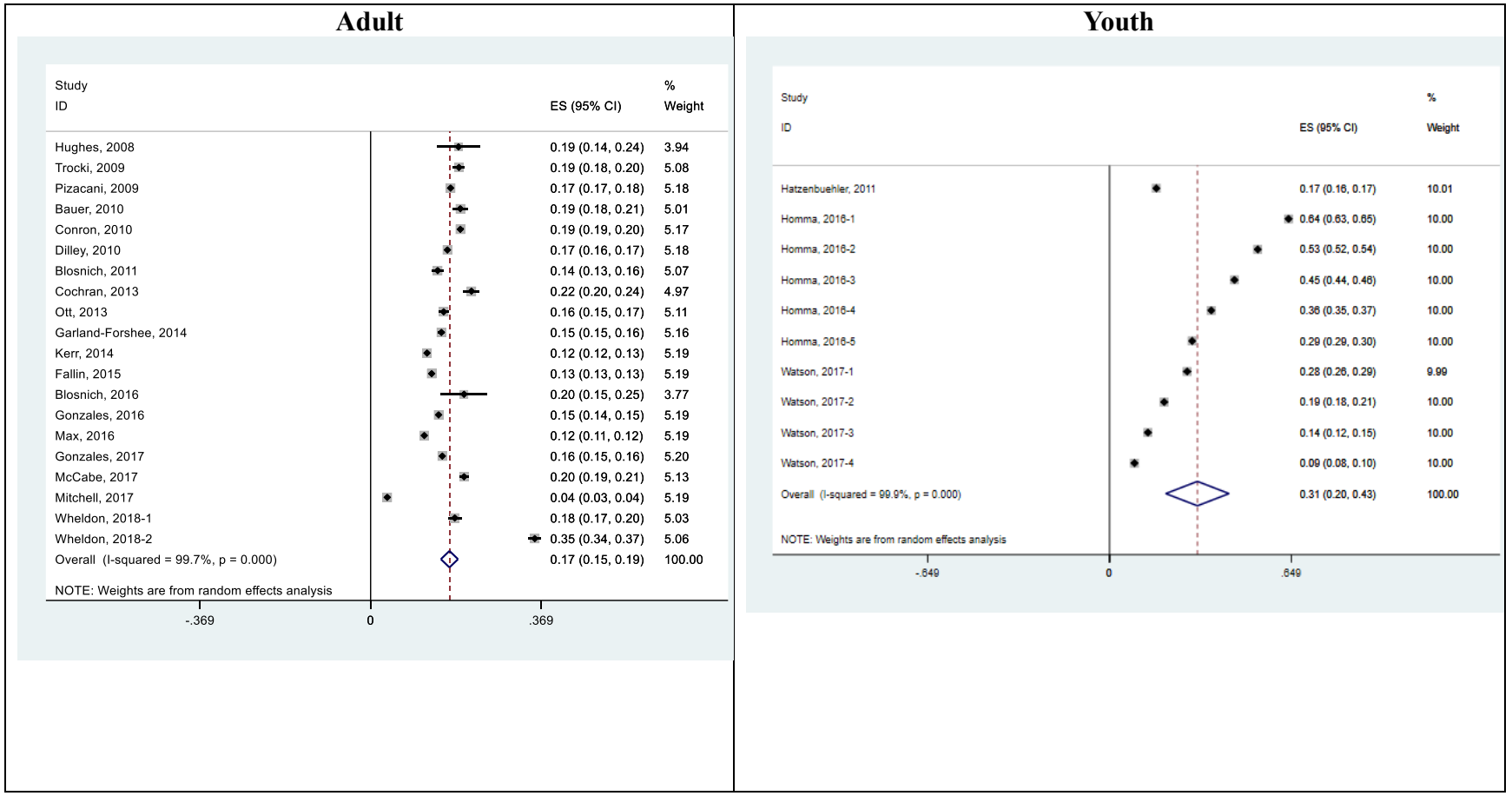

Overall
Study ID
ES (95% CI)
% Weight
Dibble, 2007 0.07 (-0.02, 0.17) 2.45
Hughes, 2008 0.19 (0.16, 0.22) 2.75
Pizacani, 2009 0.29 (0.25, 0.34) 2.71
Trocki, 2009 0.23 (0.09, 0.37) 2.19
Bauer, 2010 0.22 (0.09, 0.35) 2.26
Conron, 2010 0.26 (0.21, 0.32) 2.68
Dilley, 2010 0.30 (0.25, 0.35) 2.69
Blosnich, 2011 0.26 (0.23, 0.29) 2.74
Hatzenbuehler, 2011 0.28 (0.20, 0.36) 2.55
Lee, 2011 0.46 (0.36, 0.56) 2.42
Matthews, 2011 0.35 (0.27, 0.43) 2.55
McElroy, 2011 0.37 (0.34, 0.40) 2.75
Cochran, 2013 0.36 (0.24, 0.47) 2.34
Johns, 2013 0.84 (0.79, 0.88) 2.71
Ott, 2013 0.37 (0.26, 0.48) 2.39
Garland-Forshee, 2014 0.22 (0.15, 0.30) 2.57
Kerr, 2014 0.25 (0.22, 0.29) 2.73
Fallin, 2015 0.22 (0.19, 0.26) 2.75
Jordan, 2015 0.45 (0.42, 0.48) 2.75
Emory, 2016 0.27 (0.21, 0.34) 2.62
Gonzales, 2016 0.25 (0.21, 0.29) 2.73
Homma, 2016-1 0.56 (0.41, 0.70) 2.14
Homma, 2016-2 0.40 (0.27, 0.53) 2.26
Homma, 2016-3 0.48 (0.37, 0.59) 2.39
Homma, 2016-4 0.32 (0.23, 0.40) 2.52
Homma, 2016-5 0.34 (0.26, 0.42) 2.56
Max, 2016 0.21 (0.17, 0.24) 2.74
Smalley, 2016 0.21 (0.19, 0.24) 2.76
Gonzales, 2017 0.28 (0.26, 0.30) 2.77
Matthews, 2017 0.27 (0.23, 0.31) 2.73
McCabe, 2017 0.35 (0.28, 0.43) 2.59
Mitchell, 2017 0.06 (0.02, 0.10) 2.74
Watson, 2017-1 0.45 (0.20, 0.70) 1.46
Watson, 2017-2 0.75 (0.58, 0.92) 1.97
Watson, 2017-3 0.44 (0.28, 0.60) 2.03
Watson, 2017-4 0.37 (0.21, 0.53) 2.04
Drescher, 2018 0.52 (0.41, 0.63) 2.37
Wheldon, 2018-1 0.32 (0.24, 0.41) 2.52
Wheldon, 2018-2 0.50 (0.40, 0.61) 2.44
Ylioja, 2018 0.14 (0.08, 0.21) 2.64
Overall (I-squared = 96.6%, p = 0.000) 0.33 (0.29, 0.38) 100.00
NOTE: Weights are from random effects analysis
-.921
0
.921

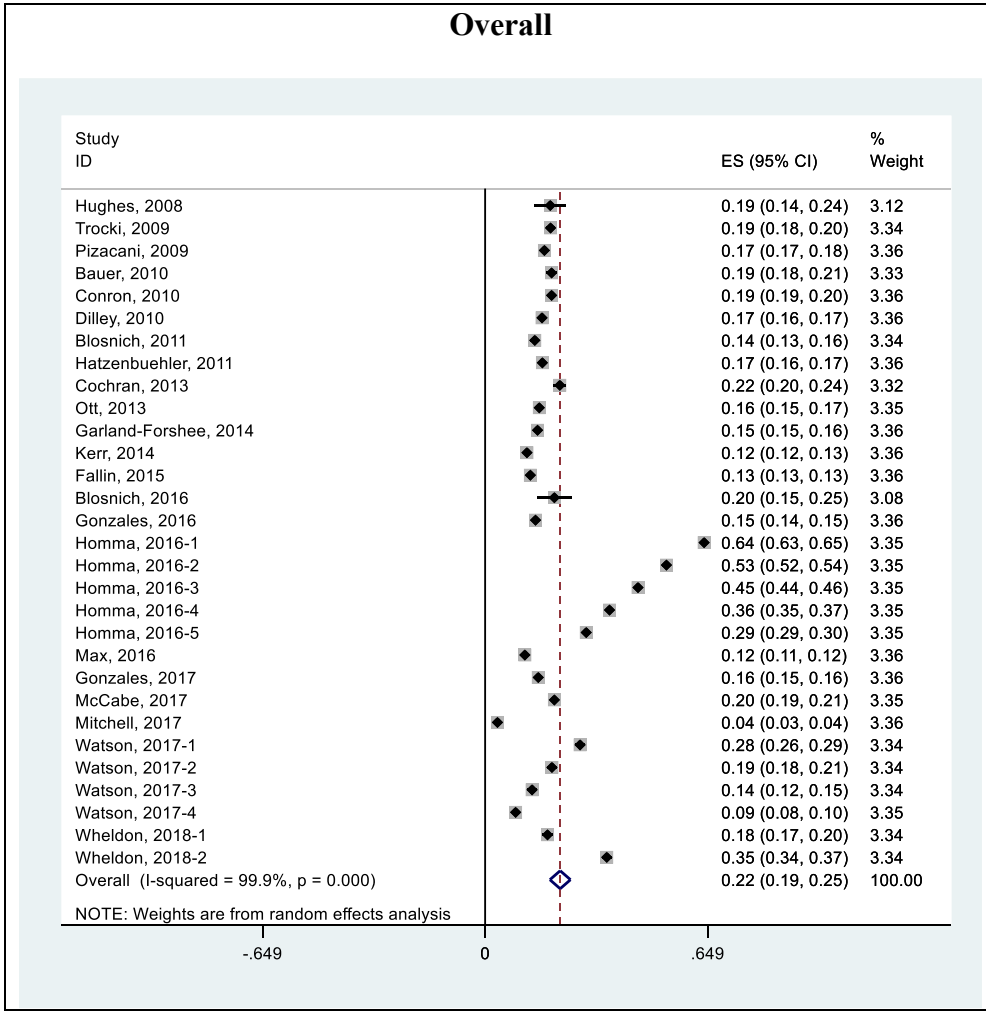
4b. Bisexual women



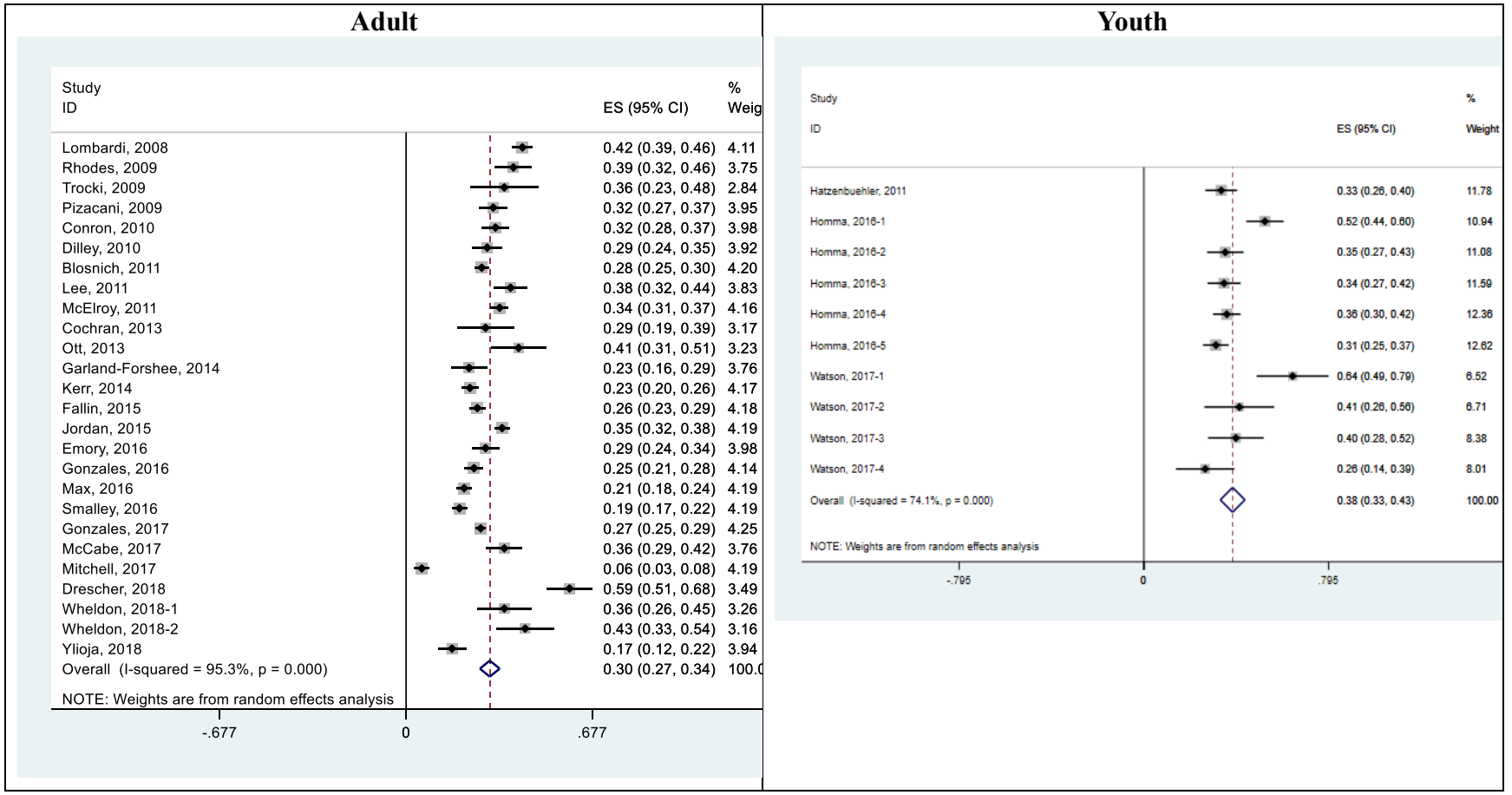

Overall
Study ID
ES (95% CI)
% Weight
Trocki, 2009 0.44 (0.31, 0.58) 2.63
Pizacani, 2009 0.36 (0.31, 0.41) 3.14
Bauer, 2010 0.38 (0.30, 0.47) 2.98
Conron, 2010 0.37 (0.30, 0.44) 3.03
Dilley, 2010 0.38 (0.33, 0.43) 3.12
Blosnich, 2011 0.31 (0.29, 0.34) 3.21
Hatzenbuehler, 2011 0.44 (0.40, 0.47) 3.18
Lee, 2011 0.48 (0.29, 0.67) 2.29
Matthews, 2011 0.39 (0.19, 0.59) 2.19
McElroy, 2011 0.40 (0.34, 0.46) 3.08
Cochran, 2013 0.44 (0.37, 0.52) 3.02
Johns, 2013 0.76 (0.69, 0.83) 3.06
Ott, 2013 0.45 (0.37, 0.54) 2.96
Garland-Forshee, 2014 0.37 (0.30, 0.45) 3.03
Kerr, 2014 0.31 (0.28, 0.33) 3.20
Fallin, 2015 0.32 (0.28, 0.36) 3.16
Gonzales, 2016 0.26 (0.22, 0.31) 3.14
Homma, 2016-1 0.76 (0.71, 0.80) 3.15
Homma, 2016-2 0.67 (0.63, 0.71) 3.16
Homma, 2016-3 0.67 (0.63, 0.71) 3.17
Homma, 2016-4 0.57 (0.53, 0.61) 3.17
Homma, 2016-5 0.50 (0.46, 0.54) 3.18
Max, 2016 0.25 (0.22, 0.29) 3.18
Gonzales, 2017 0.28 (0.27, 0.30) 3.21
Matthews, 2017 0.38 (0.31, 0.45) 3.04
McCabe, 2017 0.45 (0.39, 0.51) 3.08
Mitchell, 2017 0.13 (0.06, 0.20) 3.05
Watson, 2017-1 0.64 (0.56, 0.72) 2.99
Watson, 2017-2 0.55 (0.48, 0.63) 3.00
Watson, 2017-3 0.44 (0.37, 0.52) 3.03
Watson, 2017-4 0.31 (0.24, 0.38) 3.05
Wheldon, 2018-1 0.44 (0.38, 0.50) 3.10
Wheldon, 2018-2 0.58 (0.50, 0.65) 3.03
Overall (I-squared = 97.7%, p = 0.000) 0.44 (0.39, 0.49) 100.00
NOTE: Weights are from random effects analysis
-.827
0
.827

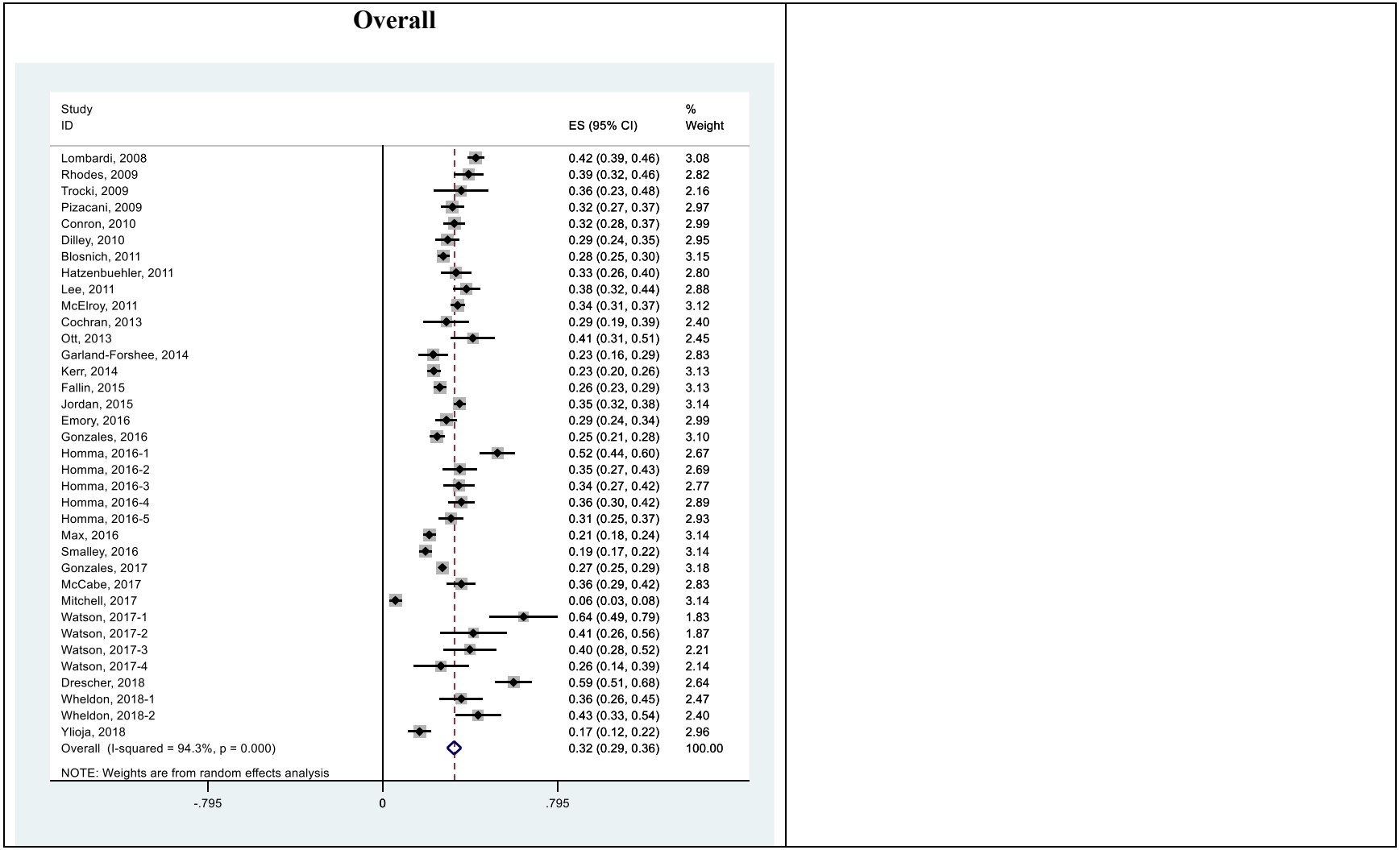
4c. Heterosexual women



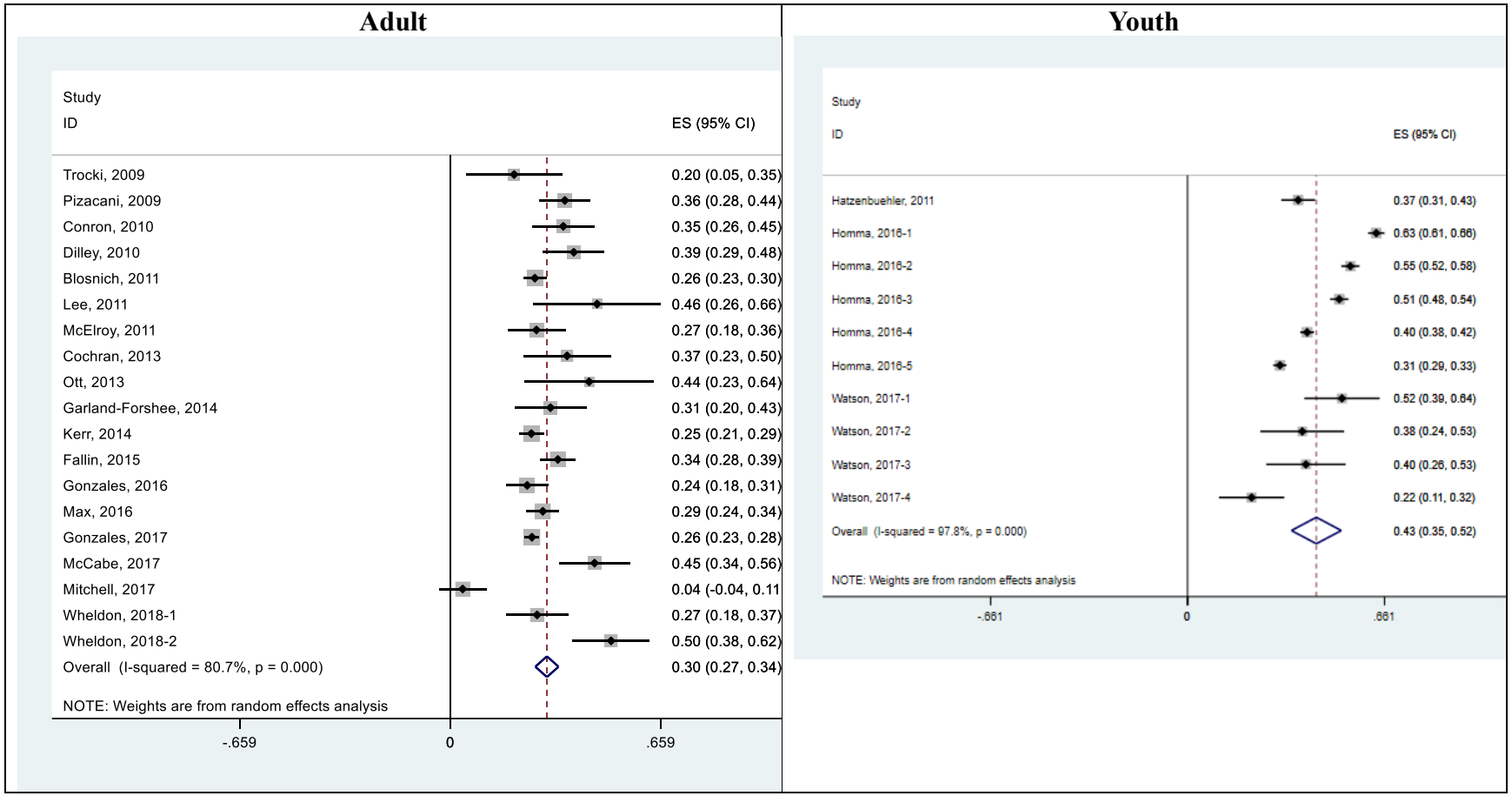

Overall
Study ID
ES (95% CI)
% Weight
Hughes, 2008 0.19 (0.14, 0.24) 3.12
Trocki, 2009 0.19 (0.18, 0.20) 3.34
Pizacani, 2009 0.17 (0.17, 0.18) 3.36
Bauer, 2010 0.19 (0.18, 0.21) 3.33
Conron, 2010 0.19 (0.19, 0.20) 3.36
Dilley, 2010 0.17 (0.16, 0.17) 3.36
Blosnich, 2011 0.14 (0.13, 0.16) 3.34
Hatzenbuehler, 2011 0.17 (0.16, 0.17) 3.36
Cochran, 2013 0.22 (0.20, 0.24) 3.32
Ott, 2013 0.16 (0.15, 0.17) 3.35
Garland-Forshee, 2014 0.15 (0.15, 0.16) 3.36
Kerr, 2014 0.12 (0.12, 0.13) 3.36
Fallin, 2015 0.13 (0.13, 0.13) 3.36
Blosnich, 2016 0.20 (0.15, 0.25) 3.08
Gonzales, 2016 0.15 (0.14, 0.15) 3.36
Homma, 2016-1 0.64 (0.63, 0.65) 3.35
Homma, 2016-2 0.53 (0.52, 0.54) 3.35
Homma, 2016-3 0.45 (0.44, 0.46) 3.35
Homma, 2016-4 0.36 (0.35, 0.37) 3.35
Homma, 2016-5 0.29 (0.29, 0.30) 3.35
Max, 2016 0.12 (0.11, 0.12) 3.36
Gonzales, 2017 0.16 (0.15, 0.16) 3.36
McCabe, 2017 0.20 (0.19, 0.21) 3.35
Mitchell, 2017 0.04 (0.03, 0.04) 3.36
Watson, 2017-1 0.28 (0.26, 0.29) 3.34
Watson, 2017-2 0.19 (0.18, 0.21) 3.34
Watson, 2017-3 0.14 (0.12, 0.15) 3.34
Watson, 2017-4 0.09 (0.08, 0.10) 3.35
Wheldon, 2018-1 0.18 (0.17, 0.20) 3.34
Wheldon, 2018-2 0.35 (0.34, 0.37) 3.34
Overall (I-squared = 99.9%, p = 0.000) 0.22 (0.19, 0.25) 100.00
NOTE: Weights are from random effects analysis
-.649
0
.649

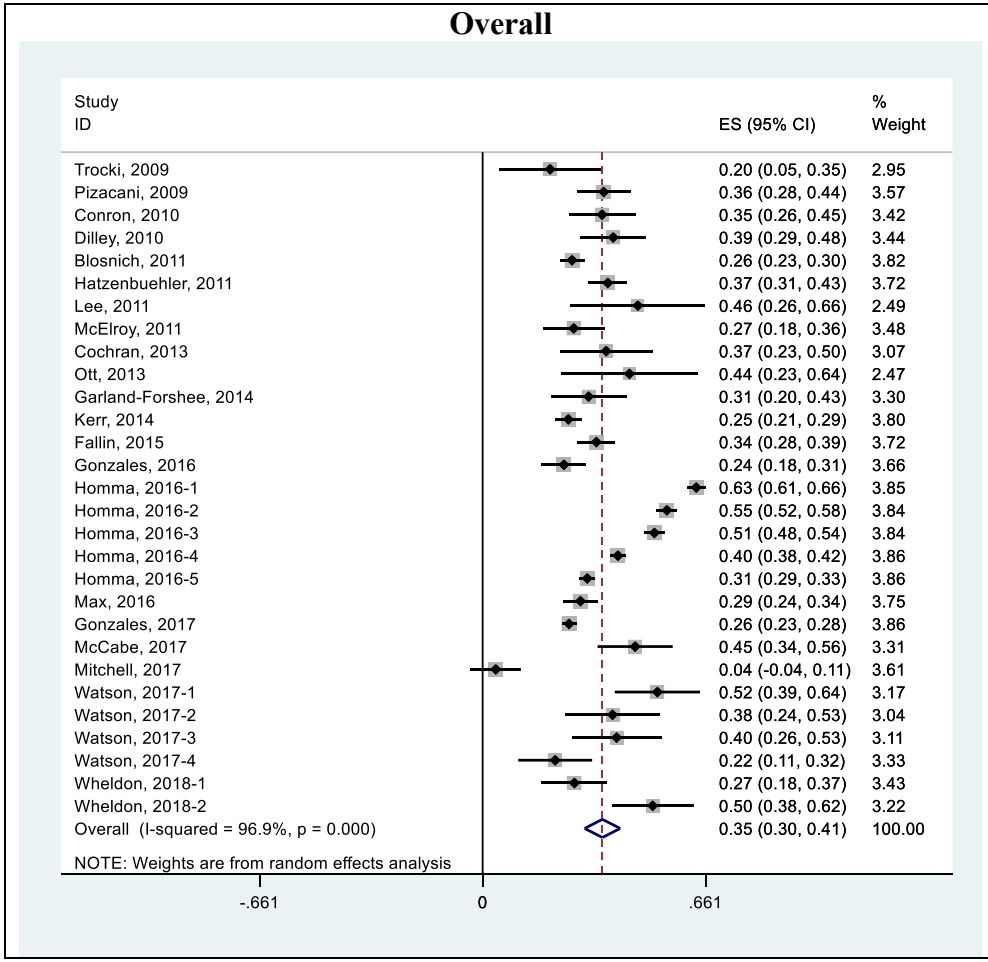
4d. Gay men


Adult
Study
ID
ES (95% CI)
%
Weig
Lombardi, 2008 0.42 (0.39, 0.46) 4.11
Rhodes, 2009 0.39 (0.32, 0.46) 3.75
Trocki, 2009 0.36 (0.23, 0.48) 2.84
Pizacani, 2009 0.32 (0.27, 0.37) 3.95
Conron, 2010 0.32 (0.28, 0.37) 3.98
Dilley, 2010 0.29 (0.24, 0.35) 3.92
Blosnich, 2011 0.28 (0.25, 0.30) 4.20
Lee, 2011 0.38 (0.32, 0.44) 3.83
McElroy, 2011 0.34 (0.31, 0.37) 4.16
Cochran, 2013 0.29 (0.19, 0.39) 3.17
Ott, 2013 0.41 (0.31, 0.51) 3.23
Garland-Forshee, 2014 0.23 (0.16, 0.29) 3.76
Kerr, 2014 0.23 (0.20, 0.26) 4.17
Fallin, 2015 0.26 (0.23, 0.29) 4.18
Jordan, 2015 0.35 (0.32, 0.38) 4.19
Emory, 2016 0.29 (0.24, 0.34) 3.98
Gonzales, 2016 0.25 (0.21, 0.28) 4.14
Max, 2016 0.21 (0.18, 0.24) 4.19
Smalley, 2016 0.19 (0.17, 0.22) 4.19
Gonzales, 2017 0.27 (0.25, 0.29) 4.25
McCabe, 2017 0.36 (0.29, 0.42) 3.76
Mitchell, 2017 0.06 (0.03, 0.08) 4.19
Drescher, 2018 0.59 (0.51, 0.68) 3.49
Wheldon, 2018-1 0.36 (0.26, 0.45) 3.26
Wheldon, 2018-2 0.43 (0.33, 0.54) 3.16
Ylioja, 2018 0.17 (0.12, 0.22) 3.94
Overall (I-squared = 95.3%, p = 0.000) 0.30 (0.27, 0.34) 100.0
NOTE: Weights are from random effects analysis
-.677
0
.677
Youth
Study
ID
ES (95% CI)
%
Weight
Hatzenbuehler, 2011 0.33 (0.26, 0.40) 11.78
Homma, 2016-1 0.52 (0.44, 0.60) 10.94
Homma, 2016-2 0.35 (0.27, 0.43) 11.08
Homma, 2016-3 0.34 (0.27, 0.42) 11.59
Homma, 2016-4 0.36 (0.30, 0.42) 12.36
Homma, 2016-5 0.31 (0.25, 0.37) 12.62
Watson, 2017-1 0.64 (0.49, 0.79) 6.52
Watson, 2017-2 0.41 (0.26, 0.56) 6.71
Watson, 2017-3 0.40 (0.28, 0.52) 8.38
Watson, 2017-4 0.26 (0.14, 0.39) 8.01
Overall (I-squared = 74.1%, p = 0.000) 0.38 (0.33, 0.43) 100.00
NOTE: Weights are from random effects analysis
-.795
0
.795

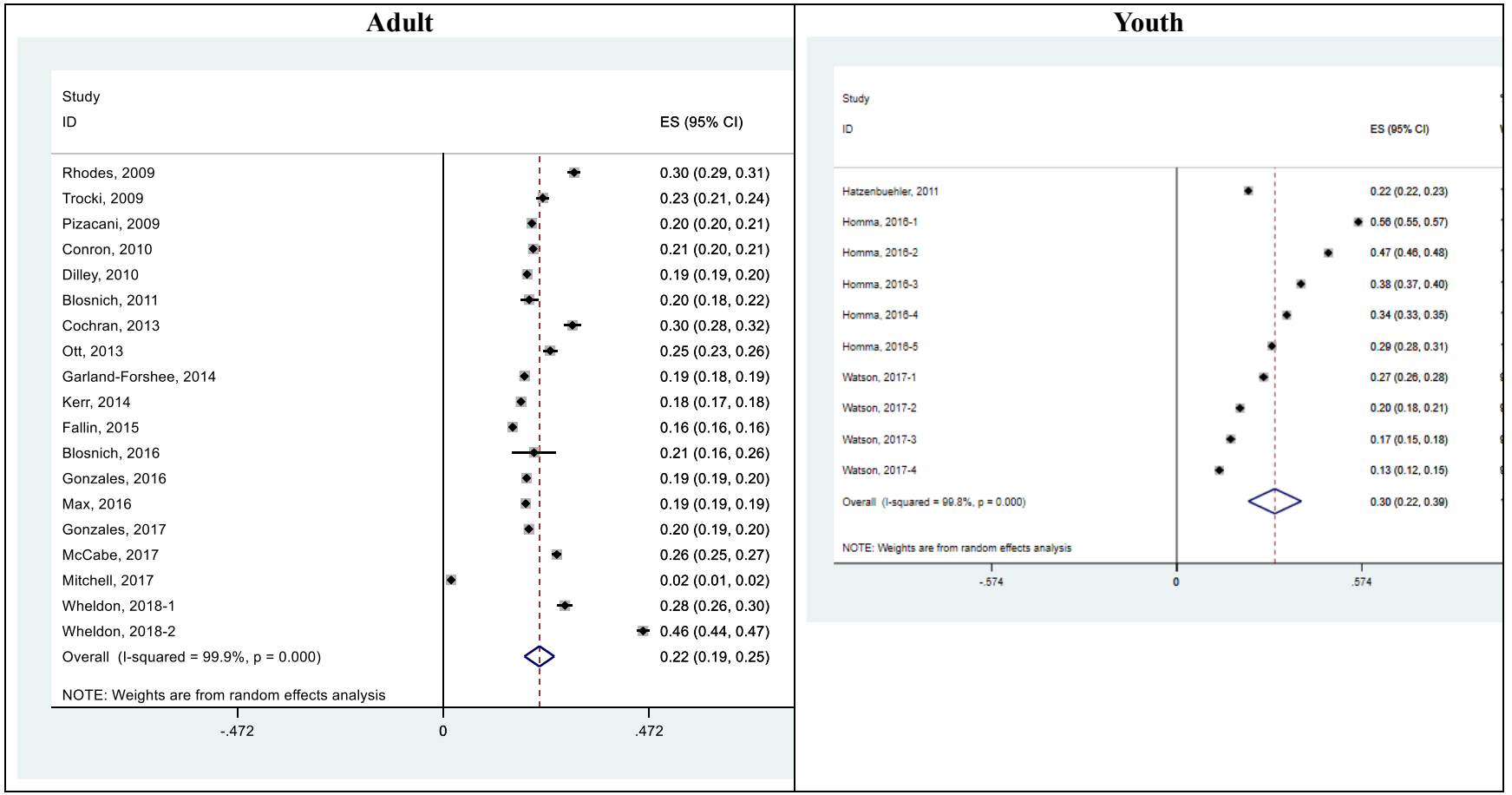

Overall
Study ID
ES (95% CI)
% Weight
Lombardi, 2008 0.42 (0.39, 0.46) 3.08
Rhodes, 2009 0.39 (0.32, 0.46) 2.82
Trocki, 2009 0.36 (0.23, 0.48) 2.16
Pizacani, 2009 0.32 (0.27, 0.37) 2.97
Conron, 2010 0.32 (0.28, 0.37) 2.99
Dilley, 2010 0.29 (0.24, 0.35) 2.95
Blosnich, 2011 0.28 (0.25, 0.30) 3.15
Hatzenbuehler, 2011 0.33 (0.26, 0.40) 2.80
Lee, 2011 0.38 (0.32, 0.44) 2.88
McElroy, 2011 0.34 (0.31, 0.37) 3.12
Cochran, 2013 0.29 (0.19, 0.39) 2.40
Ott, 2013 0.41 (0.31, 0.51) 2.45
Garland-Forshee, 2014 0.23 (0.16, 0.29) 2.83
Kerr, 2014 0.23 (0.20, 0.26) 3.13
Fallin, 2015 0.26 (0.23, 0.29) 3.13
Jordan, 2015 0.35 (0.32, 0.38) 3.14
Emory, 2016 0.29 (0.24, 0.34) 2.99
Gonzales, 2016 0.25 (0.21, 0.28) 3.10
Homma, 2016-1 0.52 (0.44, 0.60) 2.67
Homma, 2016-2 0.35 (0.27, 0.43) 2.69
Homma, 2016-3 0.34 (0.27, 0.42) 2.77
Homma, 2016-4 0.36 (0.30, 0.42) 2.89
Homma, 2016-5 0.31 (0.25, 0.37) 2.93
Max, 2016 0.21 (0.18, 0.24) 3.14
Smalley, 2016 0.19 (0.17, 0.22) 3.14
Gonzales, 2017 0.27 (0.25, 0.29) 3.18
McCabe, 2017 0.36 (0.29, 0.42) 2.83
Mitchell, 2017 0.06 (0.03, 0.08) 3.14
Watson, 2017-1 0.64 (0.49, 0.79) 1.83
Watson, 2017-2 0.41 (0.26, 0.56) 1.87
Watson, 2017-3 0.40 (0.28, 0.52) 2.21
Watson, 2017-4 0.26 (0.14, 0.39) 2.14
Drescher, 2018 0.59 (0.51, 0.68) 2.64
Wheldon, 2018-1 0.36 (0.26, 0.45) 2.47
Wheldon, 2018-2 0.43 (0.33, 0.54) 2.40
Ylioja, 2018 0.17 (0.12, 0.22) 2.96
Overall (I-squared = 94.3%, p = 0.000) 0.32 (0.29, 0.36) 100.00
NOTE: Weights are from random effects analysis
-.795
0
.795

4e. Bisexual men

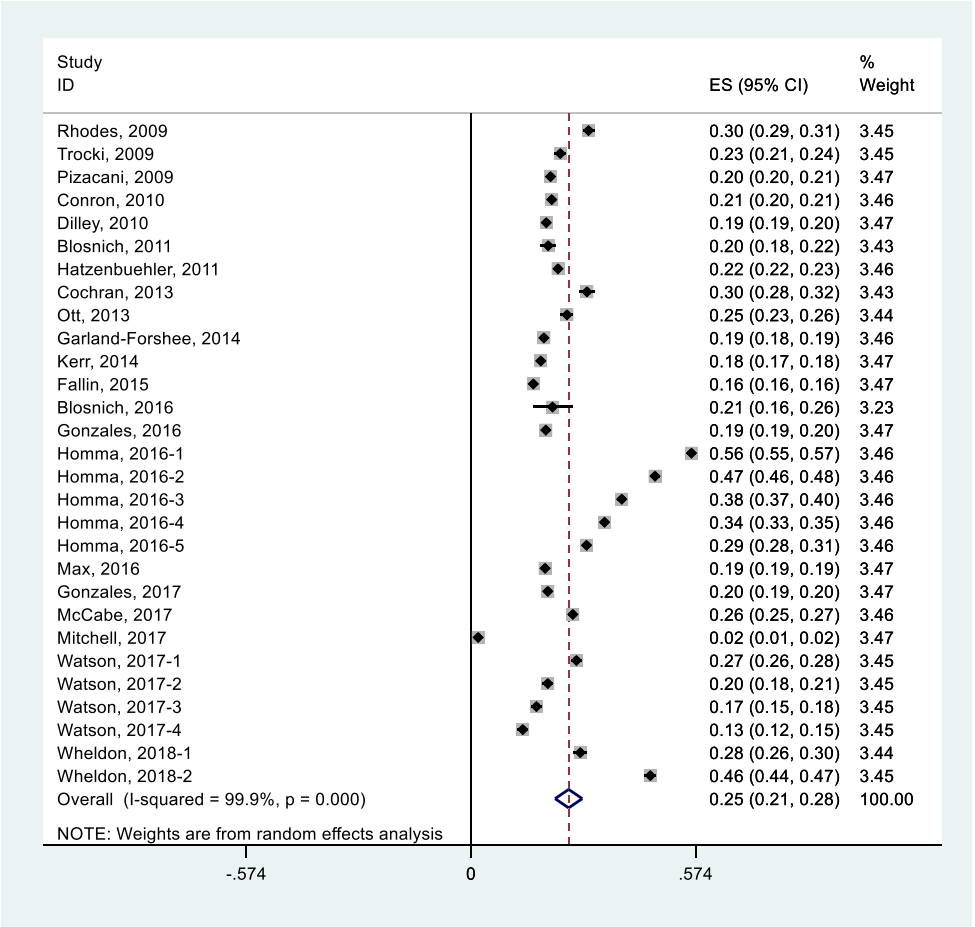



Overall
Study ID
ES (95% CI)
% Weight
Trocki, 2009 0.20 (0.05, 0.35) 2.95
Pizacani, 2009 0.36 (0.28, 0.44) 3.57
Conron, 2010 0.35 (0.26, 0.45) 3.42
Dilley, 2010 0.39 (0.29, 0.48) 3.44
Blosnich, 2011 0.26 (0.23, 0.30) 3.82
Hatzenbuehler, 2011 0.37 (0.31, 0.43) 3.72
Lee, 2011 0.46 (0.26, 0.66) 2.49
McElroy, 2011 0.27 (0.18, 0.36) 3.48
Cochran, 2013 0.37 (0.23, 0.50) 3.07
Ott, 2013 0.44 (0.23, 0.64) 2.47
Garland-Forshee, 2014 0.31 (0.20, 0.43) 3.30
Kerr, 2014 0.25 (0.21, 0.29) 3.80
Fallin, 2015 0.34 (0.28, 0.39) 3.72
Gonzales, 2016 0.24 (0.18, 0.31) 3.66
Homma, 2016-1 0.63 (0.61, 0.66) 3.85
Homma, 2016-2 0.55 (0.52, 0.58) 3.84
Homma, 2016-3 0.51 (0.48, 0.54) 3.84
Homma, 2016-4 0.40 (0.38, 0.42) 3.86
Homma, 2016-5 0.31 (0.29, 0.33) 3.86
Max, 2016 0.29 (0.24, 0.34) 3.75
Gonzales, 2017 0.26 (0.23, 0.28) 3.86
McCabe, 2017 0.45 (0.34, 0.56) 3.31
Mitchell, 2017 0.04 (-0.04, 0.11) 3.61
Watson, 2017-1 0.52 (0.39, 0.64) 3.17
Watson, 2017-2 0.38 (0.24, 0.53) 3.04
Watson, 2017-3 0.40 (0.26, 0.53) 3.11
Watson, 2017-4 0.22 (0.11, 0.32) 3.33
Wheldon, 2018-1 0.27 (0.18, 0.37) 3.43
Wheldon, 2018-2 0.50 (0.38, 0.62) 3.22
Overall (I-squared = 96.9%, p = 0.000) 0.35 (0.30, 0.41) 100.00
NOTE: Weights are from random effects analysis
-.661
0
.661

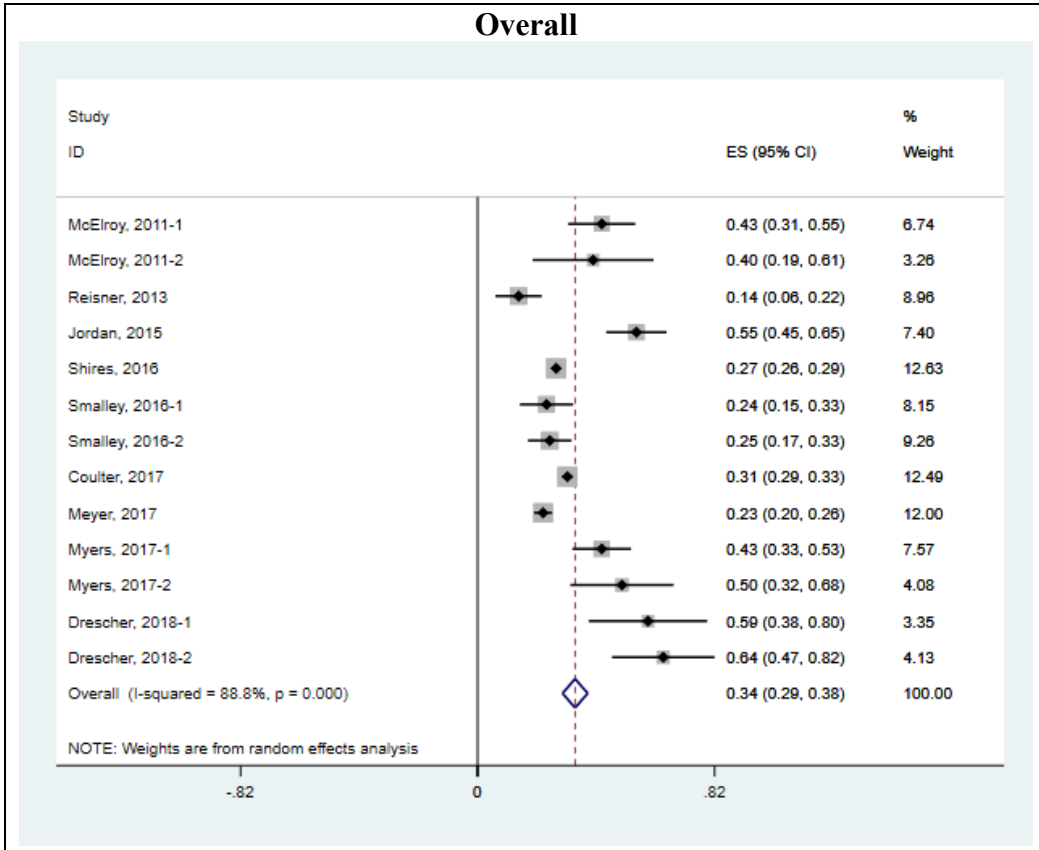
4f. Heterosexual men



Overall


Study ID
ES (95% CI)
% Weight
Rhodes, 2009 0.30 (0.29, 0.31) 3.45
Trocki, 2009 0.23 (0.21, 0.24) 3.45
Pizacani, 2009 0.20 (0.20, 0.21) 3.47
Conron, 2010 0.21 (0.20, 0.21) 3.46
Dilley, 2010 0.19 (0.19, 0.20) 3.47
Blosnich, 2011 0.20 (0.18, 0.22) 3.43
Hatzenbuehler, 2011 0.22 (0.22, 0.23) 3.46
Cochran, 2013 0.30 (0.28, 0.32) 3.43
Ott, 2013 0.25 (0.23, 0.26) 3.44
Garland-Forshee, 2014 0.19 (0.18, 0.19) 3.46
Kerr, 2014 0.18 (0.17, 0.18) 3.47
Fallin, 2015 0.16 (0.16, 0.16) 3.47
Blosnich, 2016 0.21 (0.16, 0.26) 3.23
Gonzales, 2016 0.19 (0.19, 0.20) 3.47
Homma, 2016-1 0.56 (0.55, 0.57) 3.46
Homma, 2016-2 0.47 (0.46, 0.48) 3.46
Homma, 2016-3 0.38 (0.37, 0.40) 3.46
Homma, 2016-4 0.34 (0.33, 0.35) 3.46
Homma, 2016-5 0.29 (0.28, 0.31) 3.46
Max, 2016 0.19 (0.19, 0.19) 3.47
Gonzales, 2017 0.20 (0.19, 0.20) 3.47
McCabe, 2017 0.26 (0.25, 0.27) 3.46
Mitchell, 2017 0.02 (0.01, 0.02) 3.47
Watson, 2017-1 0.27 (0.26, 0.28) 3.45
Watson, 2017-2 0.20 (0.18, 0.21) 3.45
Watson, 2017-3 0.17 (0.15, 0.18) 3.45
Watson, 2017-4 0.13 (0.12, 0.15) 3.45
Wheldon, 2018-1 0.28 (0.26, 0.30) 3.44
Wheldon, 2018-2 0.46 (0.44, 0.47) 3.45
Overall (I-squared = 99.9%, p = 0.000) 0.25 (0.21, 0.28) 100.00
NOTE: Weights are from random effects analysis
-.574
0
.574

4g. Transgender



APPENDIX A. Database Search Worksheet

Topic or Question: Tobacco use by sexual orientation
Limits: 1. Studies published 2007 June onwards 2. Differentiate heterosexual, gay/lesbian and bisexual men and women 3. US-based 4. Report any tobacco use quantitatively 5. In English
Purpose: Systematic review and meta-analysis

Databases: MEDLINE (PubMed), EMBASE, Biosis Previews (Web of Science), PsychInfo, the Proquest dissertation and thesis database

Date Searched: Feb 26th, 2018

Concept 1: Subject Terms

sexual minorit*	sexual and gender minorit*		
Bisexual*			
Homosexual*			
Heterosexual*			
Sexuality			

Concept 1: Key Words

Gay	Gays	Men who have sex with men	MSM	Men loving men
Lesbian	Lesbians	Women who have sex with women	WSW	Women loving women
sexual dissidents				
non-heterosexual				
queer				
lesbigay				
“LGB”	“GLB”			
“LGBT”	“GLBT”			
“LGBTQ”	“GLBTQ”			
“LGBTQI”	“GLBTQI”			

Concept 2: Subject Terms

tobacco			
tobacco product*			
nicotine			
smoking			

Smoker*			

Concept 2: Key Words

Cigarette	Cigarettes			
Cigar	Cigars	cigarillo		
snus	snuff	snuffs	smokeless	chewing tobacco
dissolvable tobacco products				
electronic nicotine delivery systems	ENDS	e-cigarette	electronic cigarette	e-cigs
hookah	waterpipe	pipe smoking		

Final search statement and number of results

In Pubmed (all fields search)
("sexual and gender minorities"[MeSH Terms] OR "bisexuality"[MeSH Terms] OR "homosexuality"[MeSH Terms] OR "heterosexuality"[MeSH Terms] OR "sexuality"[MeSH Terms] OR gay OR gays OR "Men who have sex with men" OR MSM OR lesbian OR lesbians OR "Women who have sex with women" OR WSW OR sexual dissidents OR sexual minorit* OR Bisexual* OR Homosexual* OR Sexualit* OR "non-heterosexual" OR queer OR lesbigay OR “LGB” OR “GLB” OR “LGBT” OR “GLBT” OR “LGBTQ” OR “GLBTQ” OR “LGBTQI”)
AND
("tobacco"[MeSH Terms] OR "tobacco products"[MeSH Terms] OR "nicotine"[MeSH Terms] OR "smoking"[MeSH Terms] OR "smokers"[MeSH Terms] OR Cigarette OR Cigarettes OR tobacco product* OR Tobacco* OR nicotine OR Cigar OR Cigars OR cigarillo OR snus OR snuff OR snuffs OR smokeless OR chewing tobacco OR dissolvable tobacco products OR smoking OR Smoker* OR "electronic nicotine delivery systems" OR ENDS OR e-cigarette OR electronic cigarette* OR e-cigs OR hookah OR waterpipe OR pipe smoking OR vape OR vaping)
Limit: Published since 05/30/2007; language is English
Counts: 788
Date searched: Feb 26, 2018

In Web of Science (Topic search)
(sexual and gender minorities OR bisexuality OR homosexuality OR heterosexuality OR sexuality OR gay OR "Men who have sex with men" OR MSM OR lesbian OR "Women who have sex with women" OR WSW OR sexual dissidents OR sexual minorit* OR Bisexual* OR Homosexual* OR Sexualit* OR non-heterosexual OR queer OR lesbigay OR LGB OR GLB OR LGBT OR GLBT OR LGBT OR GLBTQ OR LGBTQI OR LGBTQIA)
AND
(tobacco OR nicotine OR smoking OR smoker OR cigarette OR cigar OR cigarillo OR snus OR snuff OR smokeless OR e-cigarette OR e-cigs OR hookah OR waterpipe OR “water pipe” OR pipe smoking OR vape OR vaping)

Limits: Date since 05/30/2007, language is English, type is article
Counts: 699
Date searched: Feb 26, 2018

In EMBASE (all fields search)
sexual and gender minorities OR bisexuality OR homosexuality OR heterosexuality OR sexuality OR gay OR "Men who have sex with men" OR MSM OR lesbian OR "Women who have sex with women" OR WSW OR sexual dissidents OR sexual minorit* OR Bisexual* OR Homosexual* OR Sexualit* OR non-heterosexual OR queer OR lesbigay OR LGB OR GLB OR LGBT OR GLBT OR LGBT OR GLBTQ OR LGBTQI OR LGBTQIA
AND
tobacco OR nicotine OR smoking OR smoker OR cigarette OR cigar OR cigarillo OR snus OR snuff OR smokeless OR e-cigarette OR e-cigs OR hookah OR waterpipe OR "water pipe" OR pipe smoking OR vape OR vaping
Limits: Year since 05/30/2007, language is English, Type is article
Counts: 759
Date searched: Feb 26, 2018

In PsychInfo (all text search)
sexual and gender minorities OR bisexuality OR homosexuality OR heterosexuality OR sexuality OR gay OR "Men who have sex with men" OR MSM OR lesbian OR "Women who have sex with women" OR WSW OR sexual dissidents OR sexual minorit* OR Bisexual* OR Homosexual* OR Sexualit* OR non-heterosexual OR queer OR lesbigay OR LGB OR GLB OR LGBT OR GLBT OR LGBT OR GLBTQ OR LGBTQI OR LGBTQIA
AND
tobacco OR nicotine OR smoking OR smoker OR cigarette OR cigar OR cigarillo OR snus OR snuff OR smokeless OR e-cigarette OR e-cigs OR hookah OR waterpipe OR "water pipe" OR pipe smoking OR vape OR vaping
Limits: Date since 05/30/2007, language is English
Counts: 536
Date searched: Feb 26, 2018

APPENDIX B. Reference list for systematic review

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APPENDIX C. Reference list for meta-analysis

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CHAPTER 3: Sex and sexual orientation in relation to tobacco use among young adult college student in the US: A cross-sectional study

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ABSTRACT

Background: Sexual minority young adults represent a high-risk population for tobacco use. This study examined cigarette and alternative tobacco product (ATP) use prevalence across sexual orientation (heterosexual, gay/lesbian, and bisexual) among college-attending young adult men and women, respectively.

Methods: Baseline data from a two-year longitudinal study of 3,386 young adult college students aged 18-25 in Georgia were analyzed. Correlates examined included sociodemographics (age, sex, sexual orientation, race/ethnicity, college type, and parental education). Outcomes included past 30-day use of tobacco (cigarette, little cigars/cigarillos [LCCs], e-cigarettes, hookah, any tobacco product used, and number of tobacco products used, respectively). Two-group, multivariate multiple regression models were used to examine predictors of tobacco use among men and women, respectively.

Results: Among *men* (N=1,207), 34.7% used any tobacco product; 18.6% cigarettes; 12.3% LCCs; 16.8% e-cigarettes; and 14.7% hookah. Controlling for sociodemographics, gay sexual orientation (OR=1.62, p =0.012) was associated with higher odds of cigarette use; no other significant associations were found between sexual orientation and tobacco use. Among *women* (N=2,179), 25.3% used any tobacco product; 10.4% cigarettes; 10.6% LCCs; 7.6% e-cigarettes;

and 10.8% hookah. Being bisexual was associated with cigarette (p <0.001), LCC (p <0.001), and e-cigarette use (p =0.006). Lesbian sexual orientation was associated with cigarette (p =0.032) and LCC use (p <0.001). Being bisexual predicted any tobacco product used (p=0.002), as well as number of tobacco products used (p=0.004). Group comparisons showed that the effect of sexual minority status on LCC use was significantly different for men versus women. **Conclusion:** Sexual minority women, especially bisexual women, are at higher risk for using specific tobacco products compared to heterosexual women; homosexual men are at increased risk of cigarette use compared to heterosexual men. These nuances in tobacco use should inform interventions targeting sexual minorities.

BACKGROUND

Tobacco use is a significant public health problem in the United States. An emerging line of studies suggests that sexual minorities, defined for this study as lesbians, gays, and bisexuals, are at higher risk for tobacco use compared to their heterosexual counterparts, especially during young adulthood (Bandiera, 2013; J. Blosnich et al., 2013; Corliss et al., 2013; Emory et al., 2015; Johnson et al., 2016a; Marshal et al., 2008; Rath, Villanti, Rubenstein, & Vallone, 2013). Despite a relatively robust literature documenting higher risk of tobacco use among sexual minorities, these findings are more complex when considering specific sexual minority groups among the different sexes, as well as the more nuanced alternative tobacco products (ATPs).

First, findings about sexual minorities in the aggregate might not necessarily represent an accurate portrayal of tobacco use profiles among subgroups of this population. Recent work suggests that not all sexual minorities experience the same prevalence and risk of tobacco use (Corliss et al., 2013; Emory et al., 2015; Johnson et al., 2016a; Rath et al., 2013; Ward, Dahlhamer, Galinsky, & Joestl, 2014). In general, evidence across studies shows that bisexuals report a higher tobacco use rate than gay/lesbian and heterosexuals (Control & Prevention, 2014; Emory et al., 2015; Ward et al., 2014). Secondly, studies stratified by biological sex suggest higher rates of cigarette and ATP use among sexual minority versus heterosexual women, while these differences are not found among men (Emory et al., 2015; Hinds, Loukas, & Perry, 2017; Ward et al., 2014). Additionally, the increasingly prevalent use of ATPs, such as little cigars and cigarillos (LCCs), e-cigarettes, and hookah, further complicates our understanding of populations at high-risk for tobacco use (Bandiera, 2013; Emory et al., 2015; Hu, 2016; Jannat-Khah, Reynolds, Dill, & Joseph, 2017; Johnson et al., 2016a; Kasza et al., 2017; Y. O. Lee, Hebert, Nonnemaker, & Kim, 2014; Rath et al., 2013).

Young adulthood is a particularly vulnerable period for sexual minorities, especially college-attending sexual minorities. In transition to college, sexual minority individuals may experience unwelcoming environments and struggle with incivility or harassment (Kerr, Ding, & Chaya, 2014; Woodford, Krentzman, & Gattis, 2012). In addition, many sexual minorities might experience challenges in acknowledging, defining, accepting, and disclosing their sexual identity while transitioning to adulthood (Pollitt, Muraco, Grossman, & Russell, 2017; Russell, Toomey, Ryan, & Diaz, 2014; Tierney & Ward, 2017). As multiple stressors increasingly challenge an individual's coping capabilities, tobacco use may serve as an alternative coping strategy for sexual minority college students who experience "minority stress" (J. Blosnich et al., 2013; I. H. Meyer, 2003). Minority Stress Theory suggests that being a sexual minority leads to excess stress and, consequently, adverse health outcomes including tobacco use (Gamarel et al., 2016; I. H. Meyer, 2003).

To date, limited research has examined the use of various tobacco products among young adult men and women representing sexual orientation statuses. While examining sexual orientation group disparities in tobacco use, few quantitative analyses have considered the effect of biological sex or included ATPs (Baskerville et al., 2017b; Kasza et al., 2017). Two separate systematic reviews have examined the prevalence and etiology of smoking among sexual minorities thus far (J. Blosnich et al., 2013; J. G. Lee et al., 2009); however, neither of them simultaneously examined smoking by sex, sexual orientation, and specific tobacco products.

As a fundamental step toward addressing the gaps in the literature, this study examined the relationship of sexual orientation (distinguishing heterosexual, gay/lesbian, and bisexual sexual orientation) and past 30-day use of tobacco (cigarette, little cigars/cigarillos [LCCs], e-

cigarettes, hookah, any tobacco product used, and number of tobacco product used, respectively) among college young adult men and women, respectively.

METHODS

Participants and Procedures

We used baseline data from Project DECOY (Documenting Experiences with Cigarettes and Other Tobacco in Young Adults). The methods employed for sampling and recruitment for Project DECOY have been published elsewhere (Berg et al., 2016). Briefly, Project DECOY is a two-year longitudinal cohort study that includes 3,418 students (ages 18 to 25) from seven colleges and universities in Georgia. Schools were located in both rural and urban settings and included two public universities/colleges, two private universities, two community/technical colleges, and one historically black university. The registrars' offices from these campuses provided e-mail addresses for students aged 18 to 25. In three large campuses, 3,000 students were randomly selected; in the remaining four campuses, with fewer than 3,000 students, the census of students were emailed. The overall response rate was 22.9% (3,574/15,607), which ranged from 12.0% to 59.4% at different campuses. Participants were invited to participate in the study via email invitation. This email invitation included detailed information regarding the tasks involved in this study as well as a "confirm" hyperlink. Once participants clicked the "confirm" hyperlink, they were enrolled into the DECOY study. Participants received a $30 gift card for baseline assessment, and they could opt out at any time.

Our project was approved by the Emory University Institutional Review Boards (IRBs) as well as the IRBs of the participating colleges and universities. The current study used the

baseline data collected in Fall 2014. From this dataset, we excluded 32 (0.9% of 3,418) individuals who self-identified as "other" while answering sexual orientation or gender questions. The current study focused on the remaining 3,386 (99.1% of 3,418) participants.

Measures

Primary outcomes: Tobacco use. Analyses focused on six past 30-day tobacco use outcomes: cigarette use, LCC use, e-cigarette use, hookah use, any tobacco product use, and number of tobacco products used. Participants were asked: "During the past 30 days, on how many days did you: smoke cigarettes; smoke little cigars or cigarillos; use an e-cigarette; or use a hookah or waterpipe?" Responses were dichotomized into 0 (if days of use for any products = 0) or 1 (if days of use for any products ≥ 1) for each outcome. Given that the distribution of all ATP outcomes was approximately negative binomial, and only a few participants used ATPs in the past 30 days, we dichotomized them into "non-use" and "any use" in order to model them appropriately. For the cigarette outcome, there were a number of participants who used cigarettes frequently. Therefore, we conducted a sensitivity analysis to assess differences between categorizing cigarette use into three groups (i.e., no-use, used 1-25 days, and more than 25 days) and dichotomizing it (non-use vs. any use). Our results demonstrated that these two categorizations produced only minimal differences in the regression modeling results. For consistency and simplicity, we dichotomized the cigarette use outcome as well. We also constructed two additional outcome variables: 1) any vs. no tobacco product use in the past 30 days; and 2) the number of tobacco products used in the past 30 days (ranging from 0 to 4).

Primary predictor: Sexual orientation. Participants were asked in the survey, "Do you consider yourself to be: heterosexual or straight; gay, lesbian, or homosexual; bisexual; or

other?" Responses were recoded into dummy variables: heterosexual sexual orientation (1=yes, 0=no; reference group), gay/lesbian sexual orientation (1=yes, 0=no), and bisexual sexual orientation (1=yes, 0=no). Those who selected "other" (n=28, 0.8%) were excluded from the study.

Stratification variable: Sex. Participants were asked, "What is your gender?" The responses were dichotomized into "1" for men and "2" for women. Participants who selected "other" (n= 4, 0.1%) were excluded from this study.

Covariates: Sociodemographics. Participants were asked to report their age (continuous variable), race (White, Black, other [including American Indian or Alaskan Native, Asian, Native Hawaiian or Pacific Islander, and those with more than one race]), ethnicity (Hispanic vs. non-Hispanic), the school they attended (coded as public, private, technical, historically black), and highest educational level of either of their parents (coded as bachelor's degree or greater versus less education).

Statistical Analyses

Univariate analyses were conducted to examine the distribution of each variable. ANOVA and Chi-square tests were used to assess the bivariate relationships between independent variables and six dependent variables (all past 30-day): 1) cigarette use; 2) LCC use; 3) e-cigarette use; 4) hookah use; 5) any tobacco product used; and 6) number of tobacco products used.

To model the use of four types of tobacco products (past 30-day cigarette, LCC, e-cigarette, and hookah use), we used multivariate multiple regression in order to model all four outcomes simultaneously. We used biological sex as the grouping variable; the four types of

tobacco use behaviors as dependent variables; sexual orientation as the main predictor; and age, ethnicity, race, school type, and parental education as covariates. In this multivariate multiple regression, no equality constraints were imposed across groups. By modeling four types of tobacco use across men and women simultaneously, we took into account possible differences in variances across groups (Muthén & Muthén, 2010). We further tested whether men and women differ in the tobacco-sexual orientation associations. Specifically, we compared the parameter estimates of sexual orientation on each tobacco use outcome between men and women by imposing equality constraints across groups using the Wald Chi-square Test (Muthén & Muthén, 2010). All above analyses were conducted using Mplus 7.4 (Muthén & Muthén, 2010).

To model any tobacco use, we used binary logistic regression; to model the number of tobacco products used, we used Zero-inflated Poisson (ZIP) regression. These analyses were conducted using SAS 9.4. (SAS Institute, Inc., Cary, NC).

RESULTS

Participant Characteristics

Overall, 3.2% (n=109) identified as gay/lesbian, and 3.8% (n=129) of the respondents identified as bisexual. Among men (35.6%; n=1,207), 4.2% reported being gay, and 2.6% reported being bisexual. Among women (64.4%; n=2,179), 2.7% reported being lesbian, and 4.5% reported being bisexual.

Tobacco Use Among Men

Among men, 34.7% reported use of any tobacco products in the past 30 days; 18.6% cigarettes; 12.3% LCCs; 16.8% e-cigarettes; and 14.7% hookah (***Table 3.1***). The mean number of tobacco products used was 0.63 (SD=1.01). Bivariate analyses indicated that gay men had a higher rate of cigarette use than heterosexual men (31.4% vs. 17.8%, p =0.048; ***Table 3.2***).

In multivariable regression controlling for age, race, ethnicity, school type, and parental education (***Table 3.3***, upper panel), gay sexual orientation was significantly associated with higher odds of cigarette use among men (OR=1.62, 95% CI: 1.11-2.37). Being Black was associated with lower odds of LCC (OR=0.71, 95% CI: 0.51-0.99) and e-cigarette use (OR=0.58, 95% CI: 0.40-0.84). Sexual orientation did not predict "any" vs. "no tobacco product used" among men, nor did it predict number of tobacco products used (***Table 3.4***, upper panel).

Tobacco Use Among Women

Among women, 25.3% used any tobacco product in the past 30 days; 10.4% cigarettes; 10.6% LCCs; 7.6% e-cigarettes; and 10.8% hookah (***Table 3.1***). The mean number of tobacco products used was 0.39 (SD=0.78).

In bivariate analyses ***(Table 3.2***), compared to heterosexual women, both lesbians and bisexual women reported higher use rates of cigarettes (19% and 22.5% vs. 9.6%, p <0.001), LCCs (32.8% and 24.5% vs. 9.2%, p <0.001), hookah (12.1% and 18.4% vs. 10.5%, p =0.05). Bisexual women also reported higher e-cigarette use rate compared to heterosexual women and lesbians (15.3% vs. 7.29% vs. 5.2%, p =0.011). Additionally, bisexual women compared to lesbian and heterosexual women were more likely to report use of any tobacco products (49.0% vs. 39.7% and 23.8%, respectively) and also reported higher mean number of tobacco products used.

Among women, regression results (***Table 3.3***, lower panel) indicated that lesbian sexual orientation is associated with higher odds of using cigarettes (OR=1.61; 95% CI: 1.04-2.49) and LCCs (OR=2.22, 95% CI: 1.55-3.17). Compared to heterosexual women, women identifying as bisexual were more likely to use cigarettes (OR=1.84; 95% CI: 1.38-2.46), LCCs (OR=1.85, 95% CI: 1.32-2.59), and e-cigarettes (OR=1.57, 95% CI: 1.13-2.17). Black women were less likely to use cigarettes (OR=0.54, 95% CI: 0.43-0.69) and e-cigarettes (OR=0.63, 95% CI: 0.48-0.81). However, Black women reported higher odds of using LCCs (OR=1.69, 95% CI: 1.37-2.08) and hookah (OR=1.40, 95% CI: 1.14-1.73). Being bisexual predicted any tobacco product used (OR=3.05, CI: 1.99-4.67, p=0.002; ***Table 3.4***, lower panel), as well as number of tobacco products used (ZIP Beta=0.32, CI: 0.15-0.70, p=0.004).

Two-Group (Men vs. Women) Comparison Results

We also tested whether men and women differ in the tobacco-sexual orientation associations. The sexual orientation parameter estimates among the sample of men and women were compared using a two-group comparison technique using the Wald Chi-square Test. The two-group (men vs. women) parameter comparison results suggest that biological sex magnifies the association of sexual minority status with negative tobacco use outcomes (***Table 3.5***). Specifically, being a woman magnifies the effect of lesbian (p =0.005) and bisexual (p =0.015) identities in increasing LCC use. In terms of other types of tobacco use outcomes, no significant between-sex differences were found.

DISCUSSION

This study examined the association between sexual orientation and use of various tobacco products, with the goal of advancing the literature regarding how biological sex and sexual minority status (gay/lesbian sexual orientation and bisexual sexual orientation) are associated with cigarette and ATP use. Our results indicated that some sexual minority subgroups are at a higher risk for using specific tobacco products. However, sexual minority women subgroups reported greater tobacco use differences compared to sexual minority men.

Among young adult men, gay sexual orientation, but not bisexual orientation, was significantly correlated with cigarette use. This finding is consistent with prior research indicating gay men were significantly more likely to smoke cigarettes, while bisexual men were no different from heterosexual men (J. G. Lee et al., 2009; Tang et al., 2004). However, neither gay nor bisexual orientation was associated with LCC, e-cigarette, or hookah use. Evidence has been inconsistent for ATP use among sexual minority men. For example, Emory et al. (2015) reported bisexual men were more likely to use LCCs, while gay men were less likely to use them compared to heterosexual men (Emory et al., 2015). In contrast, Johnson and colleagues (2016) found no statistically significant difference between sexual minority men and straight men in cigar use. Instead, they found sexual minority men reported a higher rate of ever using e-cigarettes and hookah than heterosexual men (Johnson et al., 2016a). The differences between findings in these aforementioned studies and current findings are difficult to discern. However, it is possible that, in the current study, the smaller number of men in the sexual minority subgroups and the small number of ATP users among men limited our statistical power to detect potential associations between sexual orientation and ATP use.

In young adult women, lesbian sexual orientation was associated with cigarette and LCC use; bisexual sexual orientation was associated with cigarette, LCCs, and e-cigarette use. These

findings align with existing literature that sexual minority statuses among women are associated with the use of a range of tobacco products (Bandiera, 2013; Emory et al., 2015; Johnson et al., 2016a; Rath et al., 2013; Ward et al., 2014). This includes data drawn from a nationally representative sample of 17,087 U.S. adults, which showed that lesbians were more likely to use regular cigars and LCCs compared to heterosexual women, and bisexual women were more likely to use e-cigarettes and LCCs (Emory et al., 2015). Our results also echo previous findings (Bandiera, 2013; Emory et al., 2015; Ward et al., 2014) that bisexual women might be experiencing the greatest tobacco use disparities compared to other sexual minority groups or heterosexual men and women. From the perspective of Minority Stress Theory, it is plausible that bisexual women may experience unique stressors (e.g., exclusion from heterosexual and lesbian communities) that may lead to tobacco use (Lewis, Kholodkov, & Derlega, 2012).

Race was consistently found to be a significant correlate of multiple tobacco use outcomes among young adults, especially among women in our study. However, the sample size limitation restricted further exploration attempts on how race might interact with sexual orientation as well as biological sex in influencing tobacco use. Similarly, Blosnich et al (2011) reported a higher rate of LCCs and hookah use among Black sexual minorities compared to white sexual minorities (J. R. Blosnich, Jarrett, & Horn, 2011). Previous meta-analyses also suggest race is a statistically significant correlate of overall substance use among sexual minorities but do not specify tobacco use (Goldbach, Tanner-Smith, Bagwell, & Dunlap, 2014). However, more evidence is needed to understand the interaction of multiple identities (i.e., sexual orientation, biological sex, race, etc.) and tobacco use disparities. School type was also a significant correlate of tobacco use in our study. Among young adult men and women attending technical college, a two-year institution, the likelihood of using cigarettes and e-cigarettes in the

past 30 days was significantly higher than four-year institutions. One explanation could be that technical colleges typically represent a group of students with lower socioeconomic status (SES) compared with four-year education institutions (Radwin, Wine, Siegel, & Bryan, 2013) and lower SES is associated with an escalated use of tobacco (Novotny, Warner, Kendrick, & Remington, 1988).

Furthermore, results from the two-group comparison analysis suggest that the sexual orientation – LCC use association is statistically different between men and women, indicating being a woman magnifies the influence that being a sexual minority has on LCC use. However, for use of cigarettes, e-cigarettes, and hookah, the effect of sexual minority status did not differ between men and women. A few studies on tobacco use have documented such between-sex heterogeneity among sexual minorities. For example, Bandiera (2013) suggested that lesbian/gay and bisexual sexual orientation correlated with cigarette use among women but not among men (Bandiera, 2013). However, none compared this heterogeneity statistically (Bandiera, 2013; Control & Prevention, 2014; Emory et al., 2015; Hinds et al., 2017; Johnson et al., 2016a; Rath et al., 2013; Ward et al., 2014). Our findings suggest that between-sex differences might be mostly prominent in LCCs use rather than other types of tobacco use in sexual minority young adults. One study suggested that LCCs are more appealing to young adults for the variety of available sweet and fruit flavored LCCs are more palatable, and using LCCs can enhance mood (Sterling, Fryer, Nix, & Fagan, 2015). Bisexual women reported higher levels of depressive symptoms than gays and lesbians did, and lesbians reported higher levels of depressive symptoms than gays did (Baams, Grossman, & Russell, 2015; Bostwick, Hughes, & Everett, 2015). Based on Minority Stress Theory, it is possible that sexual minority women, especially

bisexual women, use LCCs more often to deal with symptoms of depression or stress more broadly.

Nonetheless, the causes for the between-sex difference across sexual minority groups remain largely unknown. Matthews et al. (2014) found neither childhood victimization, depression, nor anxiety explained differences in smoking prevalence among sexual minority women (Alicia K. Matthews et al., 2014). One possible explanation may be exposure to tobacco marketing (Smith, Thomson, Offen, & Malone, 2008; Stevens, Carlson, & Hinman, 2004; Washington, 2002). A 2018 study found that sexual minorities more frequently reported exposure to tobacco-related advertisements and anti-tobacco messages (Vera, 2018). Dilley et al (2008) suggested that sexual minority women were exposed to more tobacco marketing and also were more receptive to tobacco industry marketing than heterosexual women while sexual minority men were more exposed but no more receptive than heterosexual men (Dilley, Spigner, Boysun, Dent, & Pizacani, 2008). Similarly, Fallin et al (2015) also found higher tobacco advertising receptivity among sexual minority women, especially bisexual women (Fallin, Goodin, Lee, & Bennett, 2015). It is, therefore, possible that tobacco marketing may target not only sexual minority as a whole, but also specific sexual minority subgroups (Emory et al., 2015). Efforts to understand the drivers of tobacco use disparities among sexual minority women, especially bisexual women, are warranted.

The current results indicating tobacco product heterogeneity across sexual minorities emphasize the importance of understanding how newer forms of tobacco products may differentially appeal to these subpopulations. Although ATPs have become increasingly popular in the U.S.(Hu, 2016; Jamal, 2016; Lauterstein et al., 2014; Y. O. Lee et al., 2014), the majority of existing studies on tobacco use and sexual minority often do not examine the types of tobacco

products or just simply assess participants' cigarette smoking status (Austin et al., 2004; Corliss et al., 2013; J. G. Lee et al., 2009; Marshal et al., 2008; Alicia K. Matthews et al., 2014; Rosario, Schrimshaw, & Hunter, 2011; Ward et al., 2014), making it difficult to assess the actual tobacco-related risks among disadvantaged populations such as sexual minorities. Moreover, while the specific health risks of ATPs warrant additional research, it is important to note that no tobacco is safe to use and that the newer forms of tobacco products (i.e., ATPs) do have distinctive health risks (i.e. nicotine dependence potential and toxicity) (Nutt et al., 2014). Future research should consider ATPs in addition to cigarette use to address tobacco use disparities in sexual minorities accurately.

The current study findings add to the relatively sparse literature by providing evidence on the distinctive profiles in sexual minority use of tobacco products, as well as pinpointing most at-risk subgroups for tobacco use. Despite experiencing higher rates of tobacco use, public tobacco cessation services were underused by sexual minorities (P. A. Matthews et al.). Additionally, tobacco interventions that directly target sexual minorities are scarce (Baskerville et al., 2017b; Dickson-Spillmann, Sullivan, Zahno, & Schaub, 2014; Eliason, Dibble, Gordon, & Soliz, 2012; J. G. Lee et al., 2014; Walls & Wisneski, 2011). Recent systematic reviews suggest that sexual minority tailored tobacco interventions, including communication campaigns and individual and group counseling programs, appear to be effective (Baskerville et al., 2017b; I. Berger & Mooney-Somers, 2017). However, qualitative data suggest that sexual minority communities have specific needs regarding tobacco cessation, such that programs designed to facilitate quitting should be tailored to their needs (A. K. Matthews, Cesario, Ruiz, Ross, & King, 2017). More importantly, interventions are favored when customized for their specific community (e.g., lesbian or bisexual women) rather than sexual minorities as a whole or the general population (I.

Berger & Mooney-Somers, 2017). Thus, culturally-competent and inclusive messaging tailoring certain sexual minority subgroups and their patterns of tobacco use may be more effective in recruiting these subgroups. In particular, since we found that bisexual women may be more prone to tobacco use, especially LCC use, interventions might target reductions in LCC use to address the tobacco use disparities among bisexual women.

Limitations

Although this study has important findings, some limitations should be noted. Although this sample was comprised of diverse young adults in terms of race, ethnicity, and socioeconomic backgrounds; diverse college campus types (e.g., private, public, two-year, HBCU); and students in rural and urban settings, the sample was comprised of college students from Georgia, limiting the generalizability of our results to the broader young adult population. However, it is also important to note that estimated state prevalence of current tobacco use among Georgian young adults (18-24 years old) and Georgian adults in general are not significantly different from national estimates (CDC, 2016, 2018). We also had a relatively low overall response rate (22.9%), partly because we met our sampling quota target in short time intervals (ranging from one day at the private schools to seven days at the technical colleges). As such, our sample may not be representative of the entire college student population in Georgia. Our sample is largely reflective of the student populations of each school, with one exception: our study enrolled fewer male student participants (36%) than female participants (64%), which was disproportionate relative to the student enrollment at the colleges included in the study. However, given that tobacco use is less prevalent among women, having a larger proportion of women allowed us to examine tobacco use with more power. Additionally, the parent study was

not designed to address this research aim and thus did not aim to specifically target recruitment of sexual minority populations or assess relevant factors related to tobacco use among sexual minorities, limiting our ability to comprehensively examine the underlying factors for sexual minority tobacco disparities. Finally, the cross-sectional design of this study can only suggest associations rather than provide tests of causality. In terms of causality, no known theoretical basis has suggested sexual orientation itself causes or conveys risks for tobacco use. Instead, it is most likely that the social environment contributes to the tobacco use disparities among sexual minorities (Ilan H Meyer, 1995; I. H. Meyer, 2003; Ilan H Meyer & Dean, 1998; Pachankis, Westmaas, & Dougherty, 2011). To conclude, further research with larger samples of diverse young adults is needed to more comprehensively examine profiles of tobacco use, as well as the underlying mechanisms of use over time.

CONCLUSIONS

Among a sample of young adult college students, results indicated that among men, gay sexual orientation, but not bisexual sexual orientation, was significantly associated with cigarette use. Among women, lesbian sexual orientation was associated with cigarette and LCC use; bisexual sexual orientation was associated with cigarette, LCC, and e-cigarette use. Furthermore, the sexual orientation – LCC use association is statistically different between men and women, indicating being a woman magnifies the influence of being a sexual minority on LCC use.

Our findings provided evidence on the distinctive tobacco use patterns between heterosexual, gay/lesbian, and bisexual young adult college students, and documented that bisexual women might be experiencing the greatest tobacco use disparities compared to other young adult sexual minority groups or heterosexuals. Interventions might target reductions in LCC use to address

differences in tobacco use rates among sexual minority young adult women. Further studies are needed to understand the cause for differences in tobacco use prevalence among sexual minorities.

Table 3. 1 Sociodemographic characteristics and past 30-day tobacco use in men (n=1207) and women (n=2179)

Variables	Total sample M (SD) or N (%) N=3386	Men M (SD) or N (%) N=1207	Women M (SD) or N (%) N=2179
Sexual orientation (%)[a]			
Homosexual	109 (3.2)	51 (4.2)	58 (2.7)
Bisexual	129 (3.8)	31 (2.6)	98 (4.5)
Heterosexual	3120 (92.1)	1116 (92.5)	2004 (92.0)
Age (SD)	20.55 (1.97)	20.56 (2.03)	20.54 (1.93)
Race (%)[b]			
Black	827 (24.4)	156 (12.9)	671 (30.8)
White	2110 (62.3)	842 (69.8)	1268 (58.2)
Other	409 (12.1)	195 (16.2)	214 (9.8)
Ethnicity (%)[c]			
Non-Hispanic	3110 (91.8)	1113 (92.2)	1997 (91.6)
Hispanic	252 (7.4)	88 (7.3)	164 (7.5)
School type (%)			
Public university	924 (27.3)	411 (34.1)	513 (23.5)
Private college/university	1309 (38.7)	574 (47.6)	735 (33.7)
HBCU	410 (12.1)	49 (4.1)	361 (16.6)
Technical college	743 (21.9)	173 (14.3)	570 (26.2)
Parental education (%)[d]			
<Bachelor's degree	1625 (48.0)	438 (36.3)	1187 (54.5)
≥ Bachelor's degree	1717 (50.7)	753 (62.4)	964 (44.2)
Cigarettes (%)	450 (13.3)	224 (18.6)	226 (10.4)
vs. No	2936 (86.7)	983 (81.4)	1953 (89.6)
LCC (%)	379 (11.2)	149 (12.3)	230 (10.6)
vs. No	3007 (88.8)	1058 (87.7)	1949 (89.4)
E-cigarettes (%)	368 (10.9)	203 (16.8)	165 (7.6)
vs. No	3018 (89.1)	1004 (83.2)	2014 (92.4)
Hookah (%)	413 (12.2)	177 (14.7)	236 (10.8)
vs. No	2973 (87.8)	1030 (85.3)	1943 (89.2)
Any tobacco use (%)	970 (28.7)	419 (34.7)	551 (25.3)
vs. No	2416 (71.3)	788 (65.3)	1628 (74.7)
Number of tobacco products used (SD)	0.48 (0.87)	0.62 (1.01)	0.39 (0.78)

*****Participants indicated "Don't know" and "refused to answer": a) 0.8 (n=28); b) 1.2% (n=40); c) 0.7% (n=24); d) 1.3% (n=44).

Table 3.2 Bivariate analyses examining differences between participants identifying as heterosexual vs. homosexual vs. bisexual

	MEN				WOMEN			
Variables	**Heterosexual N=1116**	**Homosexual N=51**	**Bisexual N=31**	**p**	**Heterosexual N=2004**	**Homosexual N=58**	**Bisexual N=98**	**p**
Age (SD) [a]	20.56 (2.05)	20.80 (1.88)	20.03 (1.6)	.245	20.54 (1.92)	20.50 (2.06)	20.49 (2.00)	.953
Race (%) [b]								
Black	137 (12.4)	12 (23.5)	6 (19.4)	.107	602 (30.4)	27 (47.4)	37 (37.8)	**.022**
White	785 (71.2)	34 (66.7)	19 (61.3)		1175 (59.3)	26 (45.6)	56 (57.1)	
Other	181 (16.4)	5 (9.8)	6 (19.4)		204 (10.3)	4 (7.0)	5 (5.1)	
Ethnicity (%) [b]								
Non-Hispanic	1035 (93.1)	46 (90.2)	25 (83.3)	.100	1835 (92.4)	54 (93.1)	91 (93.8)	.852
Hispanic	77 (6.9)	5 (9.8)	5 (16.7)		152 (7.6)	4 (6.9)	6 (6.2)	
School type (%) [b]								
Public university	382 (34.2)	15 (29.4)	11 (35.5)	**.031**	473 (23.6)	15 (25.9)	20 (20.4)	.223
Private college/university	535 (47.9)	20 (39.2)	15 (48.4)		689 (34.4)	14 (24.1)	28 (28.6)	
HBCU	40 (3.6)	6 (11.8)	3 (9.7)		327 (16.3)	15 (25.9)	18 (18.4)	
Technical college	159 (14.3)	10 (19.6)	2 (6.4)		515 (25.7)	14 (24.1)	32 (32.7)	
Parental education (%) [b]								
<Bachelor's degree	397 (36.1)	24 (47.1)	12 (38.7)	.275	1086 (54.9)	35 (61.4)	57 (59.4)	.436
≥ Bachelor's degree	703 (63.9)	27 (52.9)	19 (61.3)		894 (45.1)	22 (38.6)	39 (40.6)	
Cigarettes (%) [b]	199 (17.8)	16 (31.4)	5 (16.1)	**.048**	192 (9.6)	11 (19.0)	22 (22.5)	**<.001**
vs. No	917 (82.2)	35 (68.6)	26 (83.9)		1812 (90.4)	47 (81.0)	76 (77.5)	
LCCs (%) [b]	140 (12.5)	6 (11.8)	2 (6.5)	.591	185 (9.2)	19 (32.8)	24 (24.5)	**<.001**
vs. No	976 (87.5)	45 (88.2)	29 (93.5)		1819 (90.8)	39 (67.2)	74 (75.5)	
E-cigarettes (%) [b]	189 (16.9)	9 (17.7)	4 (12.9)	.830	146 (7.29)	3 (5.2)	15 (15.3)	**.011**
vs. No	927 (83.1)	42 (82.3)	27 (87.1)		1858 (92.7)	55 (94.8)	83 (84.7)	
Hookah (%) [b]	164 (14.7)	7 (13.7)	4 (12.9)	.946	211 (10.5)	7 (12.1)	18 (18.4)	**.050**
vs. No	952 (85.3)	44 (86.3)	27 (87.1)		1793 (89.5)	51 (87.9)	80 (81.6)	
Any tobacco use (%) [b]	386 (34.6)	21 (41.2)	8 (25.8)	.362	477 (23.8)	23 (39.7))	48 (49.0)	**<.001**
vs. No	730 (65.4)	30 (58.8)	23 (74.2)		1527 (76.2)	35 (60.3)	50 (51.0)	
Number of tobacco products used (SD) [a]	0.62 (1.01)	0.74 (1.06)	0.48 (0.96)	.509	0.37 (0.75)	0.70 (0.96)	0.81 (0.97)	**<.001**

[a] Bivariate analysis was ANOVA

[b] Bivariate analysis was Chi-square

Table 3. 3 Multivariate multiple regression analyses predicting tobacco use behavior in the past 30 days among men (N=1207) and women (N=2179)

	Cigarettes				LCCs				E-cigarettes				Hookah			
Variables	**OR**	**95% CI**		**p**	**OR**	**95% CI**		**p**	**OR**	**95% CI**		**p**	**OR**	**95% CI**		**p**
MEN																
Sexual orientation (ref=heterosexual)																
Homosexual	1.62	1.11	2.37	**.012**	0.89	0.52	1.50	.650	1.05	0.69	1.59	.825	0.96	0.61	1.49	.847
Bisexual	1.02	0.60	1.75	.932	0.69	0.34	1.42	.316	0.85	0.47	1.52	.573	0.88	0.49	1.59	.677
Age	1.00	0.96	1.05	.960	0.94	0.89	0.99	**.030**	0.93	0.89	0.97	**.001**	0.98	0.94	1.03	.528
Hispanic	0.89	0.63	1.26	.516	0.69	0.44	1.08	.105	1.26	0.91	1.75	.160	1.23	0.87	1.72	.235
Race (ref=White)																
Black	0.71	0.51	0.99	**.041**	0.93	0.66	1.32	.686	0.58	0.40	0.84	**.004**	1.17	0.86	1.60	.323
Other	1.11	0.88	1.40	.370	0.93	0.71	1.24	.630	0.90	0.71	1.15	.415	1.29	1.01	1.66	**.042**
School type (ref=private)																
Public	0.99	0.81	1.20	.881	1.23	0.98	1.53	.067	1.05	0.86	1.29	.611	1.23	1.00	1.53	.056
HBCU	0.96	0.51	1.81	.900	2.27	1.34	3.85	**.002**	1.75	1.00	3.08	**.050**	1.38	0.83	2.30	.210
Technical	1.63	1.24	2.14	**<.001**	1.31	0.94	1.82	.106	1.76	1.33	2.31	**<.001**	1.02	0.74	1.40	.929
Parental education (ref=≥ Bachelor's)																
<Bachelor's	1.15	0.94	1.40	.166	1.01	0.81	1.26	.931	1.16	0.96	1.41	.134	1.13	0.91	1.39	.267
WOMEN																
Sexual orientation (ref=heterosexual)																
Homosexual	1.61	1.04	2.49	**.032**	2.22	1.55	3.17	**<.001**	0.89	0.50	1.58	.697	1.00	0.63	1.60	.993
Bisexual	1.84	1.38	2.46	**<.001**	1.85	1.32	2.59	**<.001**	1.57	1.13	2.17	**.006**	1.31	0.94	1.82	.111
Age	1.05	1.01	1.09	**.017**	0.97	0.92	1.01	.118	0.99	0.95	1.04	.682	0.99	0.95	1.03	.638
Hispanic	0.94	0.68	1.28	.685	0.72	0.47	1.09	.121	0.99	0.71	1.39	.960	1.15	0.87	1.52	.330
Race (ref=White)																
Black	0.54	0.43	0.69	**<.001**	1.69	1.37	2.08	**<.001**	0.63	0.48	0.81	**<.001**	1.40	1.14	1.73	**.002**
Other	0.77	0.57	1.04	.088	1.21	0.85	1.71	.286	0.88	0.63	1.23	.447	1.39	1.07	1.79	**.013**
School type (ref=private)																
Public	1.13	0.91	1.41	.253	1.49	1.17	1.92	**.002**	1.36	1.07	1.72	**.011**	1.45	1.18	1.78	**<.001**
HBCU	1.17	0.83	1.66	.374	1.82	1.35	2.44	**<.001**	1.46	1.01	2.11	**.044**	1.40	1.07	1.84	**.016**
Technical	1.74	1.42	2.14	**<.001**	1.45	1.13	1.88	**.004**	1.64	1.29	2.09	**<.001**	1.18	0.95	1.47	.132
Parental education (ref=≥ Bachelor's)																
<Bachelor's	0.86	0.72	1.02	.082	0.83	0.69	1.00	**.046**	0.88	0.73	1.06	.183	1.01	0.85	1.19	.948

Table 3.4 Binary Logistic Regression Analyses Examining Any Tobacco Use in the Past 30 Days and Zero-inflated Regression Analyses Predicting the Number of Tobacco Products Used in the Past 30 Days among Men (N=1207) and Women (N=2179)

	Any Tobacco Use				Number of Tobacco Products Used							
					(Count Portion)				(Zero-inflated Portion)			
Variables	**OR**	**95% CI**		**p**	**OR**	**95% CI**		**P**	**Beta**	**95% CI**		**p**
MEN												
Sexual orientation (ref=heterosexual)												
Homosexual	1.29	0.72	2.30	.120	1.06	0.66	1.70	.825	0.77	0.31	1.96	.588
Bisexual	0.67	0.29	1.52	.228	1.12	0.55	2.30	.754	1.76	0.59	5.26	.310
Age	0.95	0.90	1.01	.130	0.95	0.90	1.01	.105	1.02	0.92	1.12	.769
Hispanic	1.11	0.69	1.80	.666	0.93	0.61	1.43	.756	0.80	0.35	1.82	.588
Race (ref=White)												
Black	0.72	0.46	1.12	.077	0.93	0.62	1.40	.737	1.47	0.77	2.83	.243
Other	1.17	0.84	1.65	.096	0.97	0.72	1.31	.856	0.79	0.46	1.37	.404
School type (ref=private)												
Public	1.21	0.91	1.61	.103	1.05	0.83	1.33	.697	0.82	0.53	1.26	.360
HBCU	2.54	1.23	5.25	**.045**	1.10	0.55	2.20	.796	0.31	0.07	1.39	.125
Technical	1.63	1.09	2.44	.569	1.52	1.09	2.11	**.013**	1.80	0.45	1.41	.435
Parental education (ref=≥ Bachelor's)												
< Bachelor's	0.87	0.66	1.15	.326	0.85	0.67	1.09	.194	1.02	0.66	1.56	.946
WOMEN												
Sexual orientation (ref=heterosexual)												
Homosexual	1.92	1.10	3.35	.757	1.41	0.90	2.23	.136	0.63	0.24	1.61	.334
Bisexual	3.05	1.99	4.67	**.002**	1.31	0.96	1.80	.093	0.32	0.15	0.70	**.004**
Age	1.01	0.96	1.07	.701	0.98	0.92	1.04	.438	0.96	0.87	1.06	.419
Hispanic	0.95	0.62	1.46	.815	0.87	0.53	1.42	.573	0.89	0.40	1.95	.766
Race (ref=White)												
Black	1.25	0.94	1.66	.423	0.59	0.40	0.88	**.009**	0.36	0.15	0.88	**.025**
Other	1.22	0.83	1.77	.669	1.29	0.80	2.08	.292	0.62	0.32	1.22	.168
School type (ref=private)												
Public	2.03	1.51	2.73	.333	1.15	0.82	1.62	.407	0.51	0.32	0.83	**.006**
HBCU	2.50	1.68	3.72	**.016**	1.29	0.80	2.08	.292	0.46	0.17	1.23	.122
Technical	2.33	1.71	3.17	**.012**	1.12	0.81	1.56	.486	0.37	0.22	0.63	**<.001**
Parental education (ref=≥ Bachelor's)												
< Bachelor's	1.11	0.88	1.39	.391	1.26	1.00	1.58	**.050**	1.10	0.75	1.61	.624

Table 3. 5 Comparison of parameter estimates of tobacco use outcomes between men vs. women using Wald test

	Cigarettes			LCCs			E-cigarettes			Hookah		
	Value	**df**	**p**	**Value**	**df**	**p**	**Value**	**df**	**p**	**Value**	**df**	**p**
Sexual orientation (ref=heterosexual)												
Homosexual	0.001	1	.979	7.995	1	**.005**	0.198	1	.656	0.019	1	.889
Bisexual	3.589	1	.058	5.915	1	**.015**	3.285	1	.070	1.307	1	.253
Heterosexual (ref.)												
Age	2.496	1	.114	0.499	1	.480	3.983	1	**.046**	0.036	1	.850
Hispanic	0.045	1	.833	0.015	1	.902	1.028	1	.311	0.087	1	.769
Race (ref=White)												
Black	1.644	1	.200	8.277	1	**.004**	0.121	1	.728	0.893	1	.345
Other	3.609	1	.058	1.282	1	.258	0.015	1	.901	0.141	1	.707
School type (ref=private)												
Public	0.883	1	.347	1.329	1	.249	2.535	1	.111	1.135	1	.287
HBCU	0.288	1	.592	0.515	1	.473	0.283	1	.595	0.002	1	.964
Technical	0.151	1	.697	0.247	1	.619	0.130	1	.719	0.593	1	.441
Parental education (ref=≥ Bachelor's)												
<Bachelor's degree	4.779	1	**.029**	1.806	1	.179	4.006	1	**.045**	0.696	1	.404

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CHAPTER 4: Minority stress, depression and tobacco use among Chinese gay and bisexual men: Two-group structural equation model analyses

ABSTRACT

Background: Disproportionately high rates of cigarette smoking have been documented in sexual minorities compared to heterosexuals, with vast literature regarding such disparities in Western countries and less literature in Eastern countries like China. Minority Stress Theory hypothesizes that "minority stress" can exacerbate psychological stress, consequently leading to health risk behaviors. However, few studies have empirically applied this theory to tobacco use among sexual minority populations in China. This study examined mechanisms of tobacco use, particularly via minority stress and depression, among Chinese gay versus bisexual men.

Methods: Between September 2017 and November 2018, a convenience sample of 667 gay and bisexual men was recruited from local LGB organizations in four metropolitan cities (i.e., Beijing, Wuhan, Nanchang, and Changsha) in China. Measures included sexual orientation, sociodemographics (i.e., age, rural/urban, and employment), theory-based psychosocial stressors (i.e., everyday discrimination, outness, rejection anticipation, identity concealment internalized homophobia) and protective factors (i.e., resilience, social support), depressive symptoms, and past 30-day cigarette use. Subgroup-specific bivariate analyses and sequential logistic regression analyses, as well as examinations of measurement invariance and structural invariance, were used to inform the structural equation modeling (SEM) approach. Two-group SEM was used to test possible distinct mechanisms between theory-based stressors and protective factors, depressive symptoms, and cigarette smoking among gay men and bisexual men, respectively.

Results: Among the full sample, the proportion of cigarette use was 29.9%. Bisexual men reported a higher rate of cigarette use compared to gay men (39.9% vs. 27.3%). The final 2-

group SEM model fit were: $\chi 2=971.0$ (761), $p<.001$; RMSEA = .029; CFI = .921; TLI = .915; WRMR = 1.308. For both gay and bisexual men, higher rejection anticipation was associated with greater depressive symptoms (standardized $\beta = 0.32$, $p < .001$), and depressive symptomatology was not associated with cigarette use.

Conclusions: Rejection anticipation may contribute to higher depressive symptoms among both gay and bisexual men, but these factors may not increase risk of cigarette smoking. Further research is needed to replicate these findings in other samples and to identity other appropriate tobacco-related intervention targets among sexual minority men in China.

BACKGROUND

China has one of the highest burden of tobacco use in the world (WHO, 2017). Each year, around 1,000,000 people die prematurely from diseases related to tobacco use in China (Chen et al., 2015; S. S. Hu, 2016). Men represent a disproportionate number of China's smokers. According to the 2015 China Adult Tobacco Survey, on average, 51.4% Chinese adult (aged 15 and older) men were current cigarette smokers, while 2.7% of adult women smoke (China CDC, 2015a). While several Chinese metropolitan cities have passed increasingly progressive municipal-level tobacco control regulations, the prevalence of males who currently smoke cigarettes in these localities is still high, ranging from 32.7% to 44.5% (China CDC, 2015b).

Data from Western countries has extensively studied tobacco use among sexual minority populations – or lesbians, gays, and bisexuals (LGB). This literature has largely indicated high rates of cigarette use among sexual minorities compared to the general populations (Baskerville et al., 2017; Berger & Mooney-Somers, 2016; J. Blosnich, Lee, & Horn, 2013; Goldbach, Tanner-Smith, Bagwell, & Dunlap, 2014; J. G. Lee, Griffin, & Melvin, 2009; Schauer, Berg, & Bryant, 2013; Wheldon, Kaufman, Kasza, & Moser, 2018). While the literature regarding tobacco use among sexual minorities in Eastern countries like China is far more limited, some studies have similarly shown increased prevalence in this population. For example, a study of gay and bisexual men in Shanghai, China indicated a cigarette smoking prevalence of 66% (Berg et al., 2011; Yu et al., 2013), approximately 15% higher than the national average, and 22%-33% higher than the city-level prevalence (China CDC, 2015b).

According to a systematic review of correlates of tobacco disparities for sexual minorities by Blosnich et al. (2013), risk factors for tobacco use can be characterized into 1) common smoking risk factors (e.g., age, socioeconomic status) or 2) sexual minority-specific factors (J.

Blosnich et al., 2013). In regard to the latter, a range of sexual minority stressors may increase risk for tobacco use beyond those experienced by heterosexual individuals (Goldbach et al., 2014; Hatzenbuehler, 2009; Meyer, 1995). Minority Stress Theory (Meyer, 1995; 2003) is a framework for examining and understanding sexual minority-specific factors and mechanism of high-risk behaviors. Specifically, Minority Stress Theory views hostile social conditions as causes of stress for sexual minority groups (Ilan H Meyer, 1995; I. H. Meyer, 2003). Meyer (1995; 2003) suggested that minority stress can take the forms of distal minority stress, or external processes and experiences faced by sexual minorities, including discrimination experiences; and proximal stress, or internal processes and experiences such as outness, rejection anticipation, identity concealment, and internalized homophobia (Ilan H Meyer, 1995; I. H. Meyer, 2003). These stressors can exacerbate mental health problems and consequently lead to increased health risk behaviors (Fluharty, Taylor, Grabski, & Munafò, 2016; Ziedonis et al., 2008). Empirically, numerous studies have shown that these minority stressors are positively associated with psychological distress and health risk behaviors such as tobacco use (Frost, Lehavot, & Meyer, 2015; Gamarel et al., 2016; Goldbach et al., 2014; Hamilton & Mahalik, 2009; Lehavot, 2012; Wong, Schrager, Holloway, Meyer, & Kipke, 2014). For example, Burgess et al (2008) pointed out that distal stressors such as discrimination experience was associated with greater likelihood of depression, anxiety, greater perceived needs for mental healthcare, and more frequent use of mental health services (Burgess, Lee, Tran, & Van Ryn, 2008). Others focusing on proximal stressors like internalized homophobia or outness showed that these stressors were signification predictors of mental health problems (Newcomb & Mustanski, 2010; Poteat, Scheer, Digiovanni, & Mereish, 2013; Villarreal, Wiebe, Sauceda, & Simoni, 2012; Xu, Zheng, Xu, & Zheng, 2017). However, few studies have focused on minor frustrations and

annoyance such as everyday discrimination that could produce long-lasting feelings of rejection (Ilan H Meyer & Frost, 2013), and one main reason for sexual minorities to use substance including cigarettes was the feeling of rejection (Rosario, Schrimshaw, & Hunter, 2009). Conversely, individual coping such as resilience and coping resources such as social support were found to buffer the negative effects of minority stress on adverse health outcomes (Cohen & Wills, 1985; Cordero, 2011; Liu et al., 2011; Pollitt, Muraco, Grossman, & Russell, 2017; A. D. Sivadon, 2015).

To date, the majority of research examining tobacco use through the lens of Minority Stress Theory has been done in Western countries (Fish et al., 2019; la Roi, Meyer, & Frost, 2019; Wheldon et al., 2018). In China, the Minority Stress Theory has been almost exclusively applied to predicting physiological outcomes (Anshel & Si, 2008; Gnilka, Ashby, Matheny, Chung, & Chang, 2015; Ho, Chan, & Ho, 2004; Lau et al., 2015; Siu, Spector, Cooper, Lu, & Yu, 2002). Although few Chinese studies have explicitly examined the mechanism between minority stress and cigarette use, qualitative research has suggested that Chinese sexual minority men may use substances to relieve the stress of hostile social stigma, as well as familial and cultural pressures (He, Wong, Huang, Thompson, & Fu, 2007). Therefore, it is important to empirically examine specific pathways through which minority stressors might influence cigarette use among Chinese sexual minorities, particularly sexual minority men.

Particularly relevant to the current study, not all sexual minorities experience the same stressors or related health risks. In Western societies, evidence across studies indicates that bisexuals are at increased risk for mental health problems and substance use compared to monosexuals (i.e., gay/lesbians and heterosexuals) (Feinstein & Dyar, 2017; la Roi et al., 2019). Such intergroup differences between bisexuals and monosexuals can be explained by the unique

minority stressors that bisexuals experience. For instance, bisexually-identified individuals might often be assumed to be gay/lesbian or heterosexual depending on the sex of their partners (Feinstein & Dyar, 2017). Thus, bisexual people might anticipate others to dismiss their bisexual identity; this anticipation may contribute to depressive symptoms and mental distress (Brewster, Moradi, DeBlaere, & Velez, 2013; Feinstein & Dyar, 2017). Other research by Sweet and Welles (2012) indicates that bisexual men may experience significantly more adverse childhood experiences compared to gay men (Walters, 2013). Another study found outness was associated with increase substance use among bisexual women compared to lesbians (Feinstein, Dyar, & London, 2017). To date, it is unclear whether significant heterogeneity exist between bisexual men and monosexual men regarding their minority stress experiences and related health risks, particularly between bisexual men and gay men.

In contrast to the growing body of literature examining the heterogeneity of sexual minority stressors and subsequent psychological and health behavior risk among sexual minority subgroups in Western societies, very little is known about this topic in China. This study aimed to contribute to the literature addressing this gap and leveraged Minority Stress Theory. Specifically, this study examined the prevalence of cigarette smoking in a sample of Chinese gay versus bisexual men and potential mechanisms of tobacco use, particularly via minority stress and depression, among these subgroups. This research is critical, as the exploration of minority stressors and pathways among subgroups of sexual minority men may help advance our understanding of cigarette use behavior among high-risk populations in China and develop effective tobacco cessation interventions.

METHODS

Study Population and Data Collection

Between September 2017 and January 2018, baseline survey data of 755 self-identified gay and bisexual men from a three-year cohort study examining health risk behaviors among Chinese gay/bisexual men were collected using venue-based sampling from college campus-based LGB organizations in four metropolitan cities (i.e., Beijing, Wuhan, Nanchang, and Changsha) in China. After screening for eligibility (self-identified as gay/bisexual men and aged 16 years or older), participants were given a brief explanation of the survey's purpose by the research team members. If participants were willing to participate, they signed a consent form and were given a paper-copy anonymous questionnaire to complete in a quiet, private room. Participants were advised that they could withdraw from the survey study at any time. Each participant received a one-time compensation of 50 Chinese RMB (approximately $8 US dollars) for their time. For this study, we excluded 79 (10.5%) participants who reported "heterosexual/unsure/other" sexual orientation. Participants with "HIV-positive" status were also excluded as patients on medical therapies might have very different smoking patterns and might confound current study. The analytical sample size for this study was 676. This study was approved by the Institutional Review Board (IRB) at Wuhan University in China and was exempted by Emory IRB.

Measures

Primary outcome: Cigarette use. The World Health Organization's International Tobacco Control (ITC) Policy Evaluation Project (China Site) assesses use of various types of tobacco products, including cigarettes, little cigars or cigarillos, traditional pipe, chewing tobacco, e-cigarettes, and hookah (International Tobacco Control Policy Evaluation Project in

China (the ITC China Project), 2014). In our survey, all participants were asked, "During the past 30 days, on how many days did you smoke cigarettes? little cigars or cigarillos? traditional pipe? chewing tobacco? e-cigarettes? hookah?" Given that fewer than 10 participants reported on alternative tobacco use (i.e., little cigars or cigarillos, traditional pipe, chewing tobacco, e-cigarette, and hookah), this study only focused on the past 30-day cigarette use outcome, dichotomized as no use versus any use.

Primary stratification variable: Sexual orientation. Sexual orientation was assessed by asking, "Is your sexual orientation: heterosexual; gay or homosexual; bisexual; or unsure?" All responses were coded dichotomously (0 = gay and 1 = bisexual). Responses with "unsure" were excluded.

Sociodemographic characteristics. Participants were asked to provide sociodemographic information such as age, education (high school/below vs. college/above), place of origin (urban vs. rural), employment (dummy coded into student, employed, and unemployed), marital status (unmarried/divorced vs. married), monthly income (≤ 3000 RMB [73 USD] vs. > 3000 RMB), and health insurance (yes vs. no/unsure).

Psychosocial variables. Informed by Minority Stress Theory (Ilan H Meyer, 1995; I. H. Meyer, 2003), we measured distal minority stressors (everyday discrimination), proximal minority stressors (outness, rejection anticipation, identity concealment, and internalized homophobia), general stressors (adverse childhood experiences), stress-ameliorating factors (social support and resilience), and mental health (depressive symptoms). Depression was hypothesized as a mediator between minority stressors and cigarette use outcome. These measures are described in further detail below.

Everyday discrimination was assessed using the Everyday Discrimination Scale (Gonzales et al., 2016). This scale asks about the frequency of 9 types of hassles and prejudice events that sexual minority people encounters. This 9-items scale is rated on a 6-point Likert scale with 1 (happens daily) to 6 (never happened). All responses were reverse coded and averaged to create a mean score, with higher scores indicating severer everyday discrimination. The Cronbach's alpha coefficient was 0.94 for this study.

Outness was assessed by asking respondents "Have you ever 'come out' to anyone?" All responses were coded dichotomously (0 = No and 1 = Yes).

Rejection anticipation was assessed with a scale which was originally used to assess stigma of mental illness (Link, 1987). Later, this scale was modified and adapted by Forst et al. (2015) for assessing sexual minority's state of hypervigilance worrying about being rejected (Frost et al., 2015). This 6-item scale is rated on a 5-point Likert scale, ranging from 1 (applies very strongly) to 5 (does not apply at all). All responses were reverse coded and averaged to create a mean score, with higher scores indicating higher expectation of rejection. The Cronbach's alpha for this scale was 0.88.

Identity concealment was assessed using a subscale on nondisclosure developed and validated by Testa et al.(2015) (Testa, Habarth, Peta, Balsam, & Bockting, 2015). This 6-item scale asks about the intentions and behaviors of sexual minority individuals to avoid disclose their sexual minority identities. This scale is rated on a 5-point Likert scale, ranging from 1 (applies very strongly) to 5 (does not apply at all). All responses were reverse coded and averaged to create a mean score, with higher scores indicating greater identity concealment. The Cronbach's alpha for this scale was 0.91.

Internalized homophobia was assessed using the Internalized Homophobia Scale which was originally developed by Martin and Dean (1987) (Martin & Dean, 1987) and further modified and validated by Forst et al. (2009; 2015) (Frost et al., 2015; Frost & Meyer, 2009). This scale asks about the negative attitudes sexual minorities hold against their own sexual identities. This 8-item scale is rated on a 4-point Likert scale, ranging from 1 (never) to 4 (always). Responses were averaged to create a mean score, with higher scores indicating greater internal homophobia. The Cronbach's alpha for this scale was 0.89.

Adverse childhood experiences (ACEs) was assessed using a 10-item ACEs index developed by the US Centers for Disease Control and Prevention (Centers for Disease Control and Prevention, 2014; Felitti et al., 1998). This index asks about the physical and mental abuse and traumatised experiences of participants prior to 18 years old. Participants answered "yes" (= 1) or "no" (= 0) to each item and the total score of all responses was summed; higher scores indicate more adverse childhood experiences. The Cronbach's alpha for this index was 0.63.

Social support was assessed with the Multidimensional Scale of Perceived Social Support (Tonsing, Zimet, & Tse, 2012), which measures perceived support from family, friends, and significant others. This 12-item scale is rated on a 7-point Likert scale, ranging from 1 (very strongly disagree) to 7 (very strongly agree). The total score of this scale was calculated for each participant, with higher scores indicating more social support. The Cronbach's alpha of social support scale was 0.94.

Resilience was assessed with the 10-item Connor-Davidson Resilience scale (Campbell-Sills & Stein, 2007; Connor & Davidson, 2003). This scale is a measure of stress coping capabilities. It is rated on a 5-point Likert scale ranging from 1 (not true at all) to 5 (true nearly

all of the time). The responses are summed to derive a total score, with higher scores indicating more resilience. The Cronbach's alpha of this scale was 0.95.

Depressive symptoms were assessed with the Center for Epidemiological Studies Depression (CES-D) scale (Radloff, 1977). The CES-D is a 20-item scale designed to measure depressive symptoms experienced by the individual within the past week. Items were answered on a 4-point scale ranging from 0 (less than a day or never) to 3 (5–7 days). The total score of this depression scale was calculated for each participant, with higher scores indicating more depressive symptoms. The Cronbach's alpha of depression was 0.89.

Statistical Analysis

Univariate analyses were conducted to examine the distribution of each variable. ANOVA and Chi-square tests were conducted to assess the bivariate relationships between sociodemographic and psychosocial variables and the cigarette use outcome. We also examined the multi-collinearity between all variables. In consideration of study power, we excluded select sociodemographic variables (i.e., education, marriage, monthly income, and health insurance) from the subsequent modelling analyses, as these variables either were not associated with the outcome or showed considerable collinearity (data not shown).

Next, we conducted sequential logistic regressions to identify significant associations between predictors and cigarette use to inform the approach to the structural equation models (SEMs). Specifically, we assessed the effects of sexual orientation on cigarette use by building four models: (1) with only sexual orientation as predictor; (2) adding other sociodemographic predictors (i.e., age, place of origin, and employment); (3) adding psychosocial risk factors (i.e., everyday discrimination, outness, rejection anticipation, identity concealment, internalized

homophobia, and ACEs), and (4) adding psychosocial protective factors (i.e., social support and resilience**)**. We also ran correlation matrix to examine the group differences between gays and bisexuals.

For the two-group SEM, we specified the conceptual model for the SEM analysis presented in Figure 1, based on both Minority Stress Theory, preliminary screening analyses, and correlation matrix results. A two-phase modelling approach was used for the two-group SEM (Kline, 2015). First, we examined measurement invariance between gay and bisexual participants using confirmatory factor analysis (CFA), estimating two measurement models: (1) constraining all parameters to be equal, and (2) allowing parameters to differ between gay and bisexual groups. Chi-square between these two models was examined and indicated non-significant results and thus no group differences in the measurement models (Thompson, 2007). Second, we examined structural invariance between gay and bisexual participants by estimating two structural models: (1) constraining all path coefficients to be equal, and (2) allowing these coefficients to differ between gay and bisexual groups. Chi-square tests of these two models yielded non-significant results, indicating no group differences in the structural models.

Then, we examined the model fit and path-coefficients of the final 2-group SEM (gay vs. bisexual men). The model fit indices examined included: chi-square test, standardized root mean square residual (SRMR), comparative fit index (CFI), Tucker–Lewis fit index (TLI), and the root mean-square error of approximation (RMSEA). The indicators of goodness of fit were: $\chi 2$ $p < 0.05$; SRMR > 0.08; CFI > 0.90; TLI > 0.90; and RMSEA < 0.05 (L. t. Hu & Bentler, 1999). Modification indices (MI) were used to guide model re-specifications that were theoretically sound. The bootstrapping method was used to test 95% Confidence Interval (95% CI).

Standardized regression (β) coefficients, the standard errors, and p-values for β were reported in the final model.

Data were double-entered and cleaned using EpiData 3.1 (The EpiData Association, Odense, Denmark) software. Descriptive analysis and sequential regressions were conducted using SAS 9.4 (SAS Institute Inc.: Cary, NC, USA). Two-group SEM was conducted using MPlus 8.0 (Muthén & Muthén: Los Angeles, CA, USA).

RESULTS

Descriptive Statistics

Table 4.1 displays participants' characteristics and bivariate analyses examining differences between participants reporting current cigarette use versus non-use. Among the full sample, the proportion of cigarette use was 29.9%. The average age of the participants was roughly 27 years old, 76.3% reported holding college degree or above, 31.5% were current students, 58.6% were employed, 89.1% of them were unmarried or divorced, around half of them had monthly income over 3000 RMB, and the majority of them had health insurance.

Bivariate Analyses

In bivariate analysis, sexual orientation was significantly associated with cigarette use (*p* =.004). Bisexual men reported a higher rate of cigarette use compared to gay men (39.9% vs. 27.3%). In addition, lower education, unemployment, and lower income were associated with the outcome. In terms of psychosocial factors, only rejection anticipation was significantly associated with cigarette use. Given that marriage and health insurance either did not associated

with cigarette use, and education and monthly income correlated with employment, we excluded marriage, health insurance, education, and monthly income in the subsequent modelling.

Sequential Logistic Regression Models

Table 4.2 shows the results from four regression models. Model 1 result showed that compared to gay men, bisexual men were more likely to use cigarette (crude Odd Ratio [OR] = 1.76, 95% CI: 1.19 - 2.60). In model 2, bisexual men were still more likely to use cigarette compared to gay men (adjust OR = 1.79; 95% CI: 1.18 – 2.72). Compared to student, being unemployed was more likely to use cigarette (aOR = 3.96; 95% CI: 2.09 - 7.50). In model 3, only being unemployed (aOR: 3.69; 95% CI: 1.85 - 7.37) and rejection anticipation (aOR: 0.80; 95% CI: 0.65 - 1.00) were associated with cigarette use. In model 4, being unemployed was the only significant correlate of cigarette use (aOR: 3.78; 95% CI: 1.90 - 7.54). The majority of psychosocial factors were not associated with the outcome.

Two-Group SEM

The correlation matrix examining group differences between gays and bisexuals (***Table 4.3***) indicated that employment was the only significant correlate of cigarette use in both gay and bisexual subgroups. Among all psychosocial factors, group differences were only found regarding depressive symptoms and rejection anticipation. Thus, the two-group SEM included rejection anticipation, depressive symptoms, and cigarette use, predicted by student and employed (dummy variables of employment) (***Figure 4.1***).

Measurement model. We constructed unconstrained and constrained measurement CFA models. According to the model fit indices for the unconstrained model ($\chi 2$=1326.7 (576),

p<.001; RMSEA = .061; CFI = .908; TLI = .896; SRMR = .056) and factor-loading constrained model ($\chi2$=1358.2 (600), p<.001; RMSEA = .061; CFI = .907; TLI = .900; SRMR = .061), the chi-square difference test ($\chi2$= 31.5 [24]) was non-significant, indicating factor loading invariance. Thus, there was no significant difference between gay and bisexual men with regard to factor loadings. We also constrained both factor loadings and intercepts between two groups. The factor-loading and intercept constrained model showed following model fit statistics: $\chi2$=1407.2 (624), p<.001; RMSEA = .061; CFI = .904; TLI = .900; SRMR = .062. The chi-square difference test between this model and the unconstrained model was: $\chi2$= 49 (24), suggesting significant intercept differences between gay and bisexual subgroups. Based on the MI, we freed two items: the 4th item of the rejection anticipation scale (i.e., "I brace myself to be treated disrespectfully because I am gay/bisexual men") because gay participants reported higher values than bisexual participants did (M's=2.70 vs. 2.36, respectively), and 2) the 12th item of the depression scale (i.e., "I was happy"), as bisexual men reported higher scores than gay men did (M's=2.38 vs. 2.17, respectively). This process resulted in a partial measurement invariance CFA model and the model fit indices were: $\chi2$=1396.2 (623), p<.001; RMSEA = .061; CFI = .905; TLI = .900; SRMR = .062. The chi-square difference test became non-significant: $\chi2$= 31.9 (22). Therefore, we moved on to the structural analysis using this partially invariant measurement model.

Structural model. Unconstrained model (i.e., all path coefficients were free across the groups) and constrained model (i.e., all path coefficients were constrained to be equal across the groups) were constructed to examine the structural invariance between gay and bisexual participants. According to the model fit indices for the unconstrained model ($\chi2$=971.0 (761), p<.001; RMSEA = .029; CFI = .920; TLI = .916; WRMR = 1.312) and constrained model

($\chi2$=981.3 (770), p<.001; RMSEA = .028; CFI = .920; TLI = .916; WRMR = 1.397), the chi-square difference test ($\chi2$= 10.3 [9]) was non-significant, indicating structural invariance for gay and bisexual samples. Thus, the results from the constrained model showed that, for both gay and bisexual men (***Figure 4.2***), rejection anticipation was positively associated with greater depressive symptoms (standardized $\beta = 0.30$, $p < .001$) and negatively associated with being a current cigarette user (standardized $\beta = - 0.15$, $p < .001$). Being a student was positively associated with higher rejection anticipation (standardized $\beta = 0.17$, $p < .05$) and was negatively associated with cigarette use (standardized $\beta = - 0.33$, $p < .05$). Being a student was not associated with depressive symptoms. Depressive symptoms not associated with cigarette use.

DISCUSSION

This study examined cigarette smoking among sexual minority men in China through the lens of the Minority Stress Theory. To provide context for the findings, it is important to note that, compared to previous findings on the cigarette smoking prevalence (66%) among Chinese sexual minority men (Berg et al., 2011; Yu et al., 2013), or to the general Chinese male population (city-level rates ranging from 32.7% to 44.5% in 2013-2014) (China CDC, 2015b), the current sample of sexual minority men recruited from four major Chinese cities reported lower rates of cigarette use (29.9%). While it is difficult to deduce the reasons underlying the differences in these smoking rates, they may be partially due to the launch of public smoke-free legislation in major cities like Beijing since 2014. Thus, our results need to be interpreted within this context.

We did not find any significant associations of other minority stressors and stress-ameliorating factors to cigarette use in logistic regression models. Studies have reported similar

non-significant relationships between stress-ameliorating factors and smoking among sexual minorities (A. Sivadon, Matthews, & David, 2014). However, other research has documented significant relationships between minority stressors and tobacco use among sexual minority men (J. R. Blosnich & Horn, 2011; Choi, Steward, Miège, Hudes, & Gregorich, 2015; Pachankis, Hatzenbuehler, & Starks, 2014; Xu et al., 2017). Experience of discrimination is often deemed a key predictor for sexual minority substance use (Hatzenbuehler, 2017; Hatzenbuehler & Pachankis, 2016) and internalized homophobia was associated with greater psychological distress in a sample of Chinese gay/bisexual men (Feinstein et al., 2017; Xu et al., 2017). There might be some contextual factors – such as tobacco-free policy in our campus-based venues, peer influences, and social norms – confounding or buffering the effect of minority stressors on cigarette use in this study population. For example, structural discrimination was found to be a significant predictor of smoking among sexual minority subgroup (Shires & Jaffee, 2016). Peer violence and pressure could also lead to tobacco use among sexual minority youth (Rosario et al., 2014) Future studies should consider the contextual influencing factors to better understand the effects of minority stressors on cigarette use.

One major finding from this study was that rejection anticipation was associated with depressive symptoms in both gay and bisexual subgroups. Furthermore, the effect of rejection anticipation on depressive symptoms was no more pronounced for gay men than for bisexual men. The fact that this path was not moderated by sexual orientation suggests that perceiving rejection from others is associated with higher levels of depressive symptoms among sexual minority men, regardless whether being gay or bisexual men. This finding is consistent with the Minority Stress Theory. Meyer (2003) describes rejection anticipation as a status of remaining on guard to protect oneself from the possibility that one will be put in a rejecting situation. In other

words, rejection anticipation represents the anxiety and depressive symptoms associated with concerns that one might be rejected by the others. Empirically, this finding is consistent with other studies indicating that rejection anticipation is associated with the onset of depressive symptoms (Normansell & Wisco, 2017; Slavich, Thornton, Torres, Monroe, & Gotlib, 2009). Culturally, Chinese society highly values the sense of belonging to the "majority". In Chinese culture, being a majority represents righteousness and power, whereas minorities may be marginalized and/or ostracized (Li, 2006). Taken together, rejection anticipation is a critical construct for sexual minority stress that might predict important adverse health outcomes, especially in a collective culture like China. However, most studies that purport to be measuring minority stress only measure one aspect of it. Typically, studies only focus on discrimination events or internalized stigma (Frost et al., 2015; Frost & Meyer, 2009; Shao, Chang, & Chen, 2018). Given the sensitivity of rejection anticipation in predicting mental health problems, future research should consider integrating it when assessing sexual minority health disparities.

We found being a student was positively associated with rejection anticipation among Chinese sexual minority men. In the US, sexual minority students experience higher rates of parental or peer rejections compared to heterosexual counterparts (Ryan, Huebner, Diaz, & Sanchez, 2009). Moreover, 86.2% of sexual minority students in the US experienced verbal harassment and 44.1% of these students experienced physical harassment (Kosciw & Diaz, 2008). In the US, sexual minority students felt less safe at school compared to heterosexual students (Institute of Medicine, 2011). Depending on the school climate, sexual minority students might be placed in a hostile or protective environment. Currently, no known study has evaluated the impact of school environments or policies on the health of sexual minority students in China. Although we did not find significant associations between being a student and

depression, more studies are needed to evaluate the impact of school setting toward their feeling of rejection, mental illness, and health risk behaviors among Chinese sexual minority students.

We did not find significant inter-group differences in the mechanism through which minority stress affects cigarette use that depressive symptoms did not mediate the relationship between rejection anticipation and cigarette use among gay and bisexual men. Interestingly, our finding suggest that the "one-size-fits-all" tobacco cessation program might work for sexual minority men population rather than sexual minority women (Emory et al., 2015; Joseph GL Lee, Matthews, McCullen, & Melvin, 2014), for that the underlying pathways for cigarette use are not different between gay and bisexual men.

Limitations

Guided by Minority Stress Theory, this study is among the first to examine the minority stress - cigarette use pathway among a sample of Chinese gay and bisexual men. However, our study is not without limitations. First, the representativeness of our sample is limited as we collected data from convenience sample that was mainly comprised of urban, well-educated, and high-income gay/bisexual men, which might not be representative to all sexual minority men. Second, we collected data in LGB organizations located in or close to college campuses, thus our measurement of cigarette use outcome might be influenced by the smoke-free campus policies enforced since 2014 and thus might not reflect the actual cigarette use prevalence. Additionally, According to a Chinese qualitative study on bisexuality, bisexual identity is a fairly new concept for many Chinese, especially among young adults and students. Bisexual individuals might undergo long time exploration of sexual identity and might experience enormous confusion and social pressure (Dong Wang, 2013). It may be that some young participants or student

participants in our study might still explore their identities and assume themselves to be gay, bisexual, or heterosexual, depending on the sex of their partners (Feinstein & Dyar, 2017). Thus, the distinction between gay men and bisexual men might be biased because of high proportion of student participants in our study. Third, the cross-sectional nature of the data limits the capability of drawing the causal inference regarding our findings. Four, due to the page limitation of the survey instrument, we did not assess important influencing factors such as cultural aspects or peers or family influences. Last, data were collected based on self-report using pen-and-paper and thus might be prone to recall bias and social desirability.

CONCLUSIONS

Our findings make novel contributions to the existing literature by providing important evidence concerning the similarities and intergroup homogeneity between gay and bisexual men regarding the mechanism through which minority stress affects cigarette use. More specifically, this study of a sample of gay and bisexual men in China indicated that rejection anticipation may contribute to higher depressive symptoms among both gay and bisexual men. However, depression was not predictive of cigarette use in gay and bisexual men. This study adds to the literature by documenting the prevalence of cigarette use among gay and bisexual men in China and revealing the mechanisms under which minority stress (i.e., rejection anticipation) may lead to poorer mental health outcome. Although this study did not find direct relationship between depression and cigarette use nor distinctive inter-group differences, attending to the complexity of sexual orientation, sexual minority stress, and tobacco use remain an important area for producing more effective intervention among sexual minorities in China and beyond.

Table 4. 1Descriptive characteristics and bivariate analyses examining differences between past 30-day cigarette use (N=202) vs. non-use (N=474) in Chinese gay and bisexual men (N=676)

Variables	Total Sample M (SD) or N (%) N=676	Smoking Status		*p*
		Smoker M (SD) or N (%) N=202	Nonsmoker M (SD) or N (%) N=474	
Sexual Orientation (%)				
Gay	538 (79.6)	147 (72.8)	391 (82.5)	**.004**
Bisexual	138 (20.4)	55 (27.2)	83 (17.5)	
Sociodemographics				
Age (SD)	26.51 (8.41)	27.33 (9.35)	26.16 (7.95)	.102
Education (%)				
High school or below	160 (23.7%)	72 (35.6)	88 (18.6)	**<.001**
College or above	516 (76.3%)	130 (64.4)	386 (81.4)	
Rural/Urban (%)				
Urban	412 (61.0)	118 (58.4)	294 (62.0)	.379
Rural	264 (39.0)	84 (41.6)	180 (38.0)	
Employment (%)				
Student	213 (31.5)	40 (19.8)	173 (36.5)	**<.001**
Employed	396 (58.6)	131 (64.9)	265 (55.9)	
Unemployed	67 (9.9)	31 (15.3)	36 (7.6)	
Marital Status (%)				
Unmarried/divorced	602 (89.1)	181 (89.6)	421 (88.8)	.764
Married	74 (10.9)	21 (10.4)	53 (11.2)	
Monthly Income in RMB (%)				
≤ 3000 (73 USD)	352 (52.1)	93 (46.1)	259 (54.6)	**.040**
> 3000	324 (47.9)	109 (53.9)	215 (45.4)	
Health Insurance (%)				
Yes	565 (83.6)	161 (79.7)	404 (85.2)	.076
No/Unsure	111 (16.4)	41 (20.3)	70 (14.8)	
Psychosocial Factors				
Everyday Discrimination (SD)	2.06 (1.11)	2.10 (1.15)	2.05 (1.10)	.583
Outness (%)				
Yes/ever coming out	549 (81.2)	156 (77.2)	393 (82.9)	.083
Never	127 (18.8)	46 (22.8)	81 (17.1)	
Rejection Anticipation (SD)	2.44 (1.02)	2.29 (0.95)	2.49 (1.04)	**.013**
Identity Concealment (SD)	2.80 (1.09)	2.84 (1.07)	2.78 (1.09)	.527
Internal Homophobia (SD)	1.63 (0.68)	1.77 (0.71)	1.66 (0.67)	.058
ACEs (SD)	1.00 (1.38)	1.12 (1.33)	0.96 (1.39)	.183
Depressive symptoms (SD)	17.47 (10.59)	17.75 (10.74)	17.34 (10.54)	.643
Social Support (SD)	5.07 (1.02)	4.99 (1.09)	5.11 (0.99)	.190
Resilience (SD)	26.71 (8.45)	26.89 (8.45)	26.64 (8.38)	.724

Table 4. 2 Sequential logistic regressions identifying correlates of past 30-day cigarette use among gay and bisexual men in China (N=676)

	Model 1			Model 2			Model 3			Model 4		
Variables	**OR**	**CI**	***p***	**OR**	**CI**	***p***	**OR**	**CI**	***p***	**OR**	**CI**	***p***
Sexual Orientation												
Gay (ref)												
Bisexual	1.76	1.19-2.60	**.004**	1.79	1.18-2.72	**.048**	1.50	0.92-2.45	.151	1.45	0.89-2.35	.138
Sociodemographics												
Age				1.00	0.98-1.03	.760	1.01	0.98-1.04	.676	0.99	0.97-1.02	.653
Rural/Urban												
Urban (ref)												
Rural				1.24	0.86-1.78	.250	1.26	0.85-1.87	.317	1.23	0.83-1.81	.310
Employment												
Student (ref)												
Employed				2.17	1.38-3.40	.655	1.98	1.22-3.22	.719	2.06	1.27-3.34	.779
Unemployed				3.96	2.09-7.50	**<.001**	3.69	1.85-7.37	**.001**	3.78	1.90-7.54	**.001**
Psychosocial Risk Factors												
Everyday Discrimination							1.02	0.85-1.22	.844	1.03	0.85-1.25	.772
Outness												
Yes (ref)												
Never							0.98	0.59-1.63	.950	0.97	0.58-1.61	.899
Rejection Anticipation							0.80	0.65-1.00	**.048**	0.81	0.65-1.01	.057
Identity Concealment							1.03	0.84-1.27	.751	1.04	0.84-1.28	.744
Internal Homophobia							1.17	0.85-1.60	.342	1.15	0.84-1.28	.387
ACEs							1.14	0.99-1.30	.058	113	0.98-1.30	.088
Depressive symptoms							1.00	0.98-1.02	.642	1.00	0.98-1.02	.775
Psychosocial Protective Factors												
Social Support										0.97	0.78-1.20	.754
Resilience										1.01	0.98-1.04	.530

Table 4.3 Correlation matrix examining correlates of past 30-day cigarettes use among the full sample of Chinese sexual minority men, gays, and bisexuals, respectively

Variables	**Total sample** r coefficient, *p value* **N=676**	**Gay** r coefficient, *p value* **N=538**	**Bisexual** r coefficient, *p value* **N=138**
Sociodemographics			
Age	0.063	0.061	-0.005
	.102	*.161*	*.949*
Place of Origin	0.034	0.033	0.008
	.379	*.448*	*.920*
Employment	0.185	0.157	0.240
	<.001	***<.001***	***0.004***
Psychosocial Factors			
Everyday Discrimination	0.021	0.030	-0.032
	.583	*.481*	*.710*
Outness	0.067	0.023	0.068
	.084	*.591*	*.423*
Rejection Anticipation	-0.095	-0.102	-0.066
	.013	***.018***	*.444*
Identity Concealment	0.024	0.029	-0.015
	.526	*.497*	*.864*
Internal Homophobia	0.073	0.005	0.129
	.058	*.900*	*.129*
ACEs	0.054	0.054	0.082
	.183	*.232*	*.378*
Depressive symptoms	0.018	-0.032	0.199
	.643	*.459*	***.019***
Social support	-0.050	-0.046	-0.051
	.190	*.291*	*.550*
Resilience	0.013	0.024	-0.013
	.723	*.575*	*.882*

Figure 4. 1 Hypothesized conceptual model of rejection anticipation to cigarette use among gay and bisexual men in China

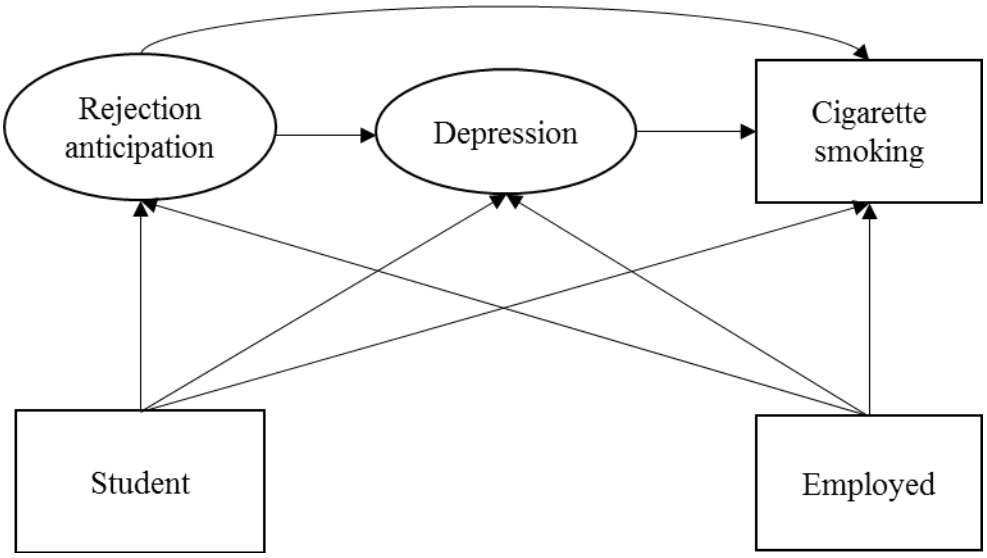
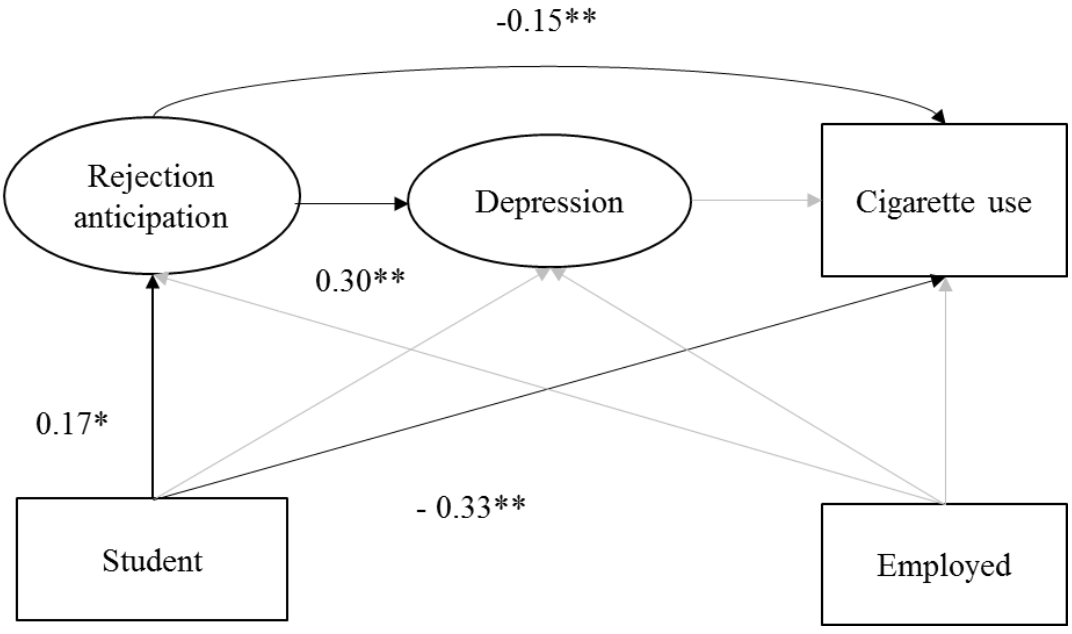


Figure 4. 2 Final structural equation model testing pathway between rejection anticipation, depressive symptoms, and cigarette smoking among Chinese gay men and bisexual men



* *P*< 0.05, ** *p*< 0.001

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CHAPTER 5: Summary and Conclusions

BACKGROUND

Tobacco use-related health disparity leads to substantial health risks for sexual minority populations in both US and China (Emory et al., 2016; Lee, Matthews, McCullen, & Melvin, 2014; US Department of Health and Human Services, 2014; Wheldon, Kaufman, Kasza, & Moser, 2018). Given the well-documented tobacco-related disparities among sexual minorities, there is an urgent need to address the tobacco use across sexual minorities, as this population has been underserved and understudied despite their disproportionate risk for tobacco-related outcomes. However, to date, no consensus has been reached in sexual minority demographic research, particularly which subgroup experiences the highest tobacco use disparity. Moreover, a lack of research on the correlates of tobacco use among this vulnerable population complicates developing effective interventions. Further, it is still unclear how sexual minority status may impact tobacco use, and specific pathways through which minority stressors might influence cigarette use among sexual minorities. Research in these areas is critical for expanding knowledge base and facilitating the development of effective tobacco cessation intervention for sexual minorities in both US and China.

SUMMARY OF FINDINGS

The three studies included in this dissertation highlight several key findings. Prominent among them are 1) there is indeed differential cigarette smoking rates among sexual minority subgroups across the sexes in the US; 2) young adults in the US representing sexual orientation subgroups have distinct profiles of cigarette and alternative tobacco product (ATP) use; and 3) the mechanisms regarding tobacco use among sexual minority men in China may not be accounted for by Minority Stress Theory. In subsequent sections, we will elaborate further on

these key findings, the context within which these findings may contribute to the existing literature, and how these findings may guide future research, policy, and practice.

We first conducted a systematic review and meta-analysis of existing literature regarding tobacco use among sexual minorities in the US. We found that bisexual women had the highest prevalence of current cigarette use among all subgroups, followed by bisexual men, transgender, lesbian, and gay men. Heterosexuals had the lowest prevalence. This is the first numerical estimate of the prevalence of tobacco use across sexual minority subgroups in the US. Because we were limited by the number of records on ATPs, the meta-analysis focused on current cigarette use among gay, bisexual men, heterosexual men, lesbian, bisexual women, heterosexual women, and transgender populations. This analysis indicated high current cigarette use among bisexual women. This review reminds us that sexual minority populations are extremely heterogeneous in terms of their tobacco use patterns, and a one-size-fits-all tobacco control approach may be insufficient to reduce tobacco-related health disparities among sexual minorities, especially among sexual minority women. It is therefore important to examine the intragroup difference, particularly how the intersection between sexual orientation and biological sex results in significant variations in tobacco use among sexual minorities.

Then, we examined the relationship of sex and sexual orientation to tobacco use among young adult college student in the US. We found that, among men, gay sexual orientation was associated with higher odds of cigarette use. Among women, being bisexual was associated with cigarette, little cigars and cigarillos (LCCs), and e-cigarette use. Lesbian sexual orientation was associated with cigarette and LCC use. Group comparisons showed that the effect of sexual minority status on LCC use was significantly different for men versus women. This study suggests that sexual minority women, especially bisexual women, are at higher risk for using

specific tobacco products compared to heterosexual women; gay men are at increased risk of cigarette use compared to heterosexual men. However, this study was a secondary study, precluding the examination of relevant theoretically-informed psychosocial risk factors related to tobacco use.

As empirical studies and our own analysis both show strong evidence that bisexual individuals experience increased risk of tobacco use compared to heterosexual individuals and often compared to gay/lesbians as well, our third analyses provided the opportunity to explore the unique minority stressors and pathways among subgroups of sexual minority men – with this analyses focusing on a Chinese population. Guided by Minority Stress Theory (I. H. Meyer, 2003), we examined the minority stress - cigarette use pathway among a sample of Chinese gay and bisexual men. One major finding from this study was that rejection anticipation was associated with depression in both gay and bisexual subgroups. We did not find significant inter-group differences in the mechanism through which minority stress affects cigarette use that depression did not mediate the relationship between rejection anticipation and cigarette use among gay and bisexual men. Importantly, our finding might suggest that the "one-size-fits-all" tobacco cessation program might work better for sexual minority men population rather than sexual minority women (Emory et al., 2015; Lee et al., 2014), for that the underlying pathways for cigarette use are not different between gay and bisexual men.

In summary, sexual minority populations in both countries are experiencing tobacco-related health disparity compared to heterosexuals, and there are critical intergroup distinctions between subgroups, especially in sexual minority women, that need to be taken into consideration when designing tobacco cessation interventions.

IMPLICATIONS

Although in recent years, sexual minority populations have seen fundamental surges both in their human rights and in public health attention in many Western countries (Ilan H Meyer, 2016; Sabharwal, Levine, D'Agostino, & Nguyen, 2018; Westwood, King, Almack, Yiu-Tung, & Bailey, 2015), in other parts of the world, such as China in Asia, sexual minorities are still facing huge societal and cultural pressure and severe health disparities (Badgett et al., 2017; Latypov et al., 2013; Mavraj, 2016).

Research focusing on sexual minority's health disparity should inform public health and policy decisions. An important unsettled scientific question concerns the intersection of sexual orientation and biological sex—that is, why are some bisexually-identified people experiencing an even more pronounced health disparities compared to other sexual minorities and heterosexuals (Emory et al., 2016; Feinstein & Dyar, 2017; Normansell & Wisco, 2017)? However, due to limited research, the answers to this question are still generally not well understood (Feinstein & Dyar, 2017).

Although the evidence of disproportionate prevalence of tobacco use among sexual minority populations seems robust (Bandiera, 2013; CDC, 2018; Corliss et al., 2013; Emory et al., 2015; Fallin, Goodin, Lee, & Bennett, 2015; Grinberg & Goodwin, 2016; Majeed, Sterling, Weaver, Pechacek, & Eriksen, 2017), our understanding of the origins of tobacco use disparities for this vulnerable population is still limited (Blosnich et al., 2013). My dissertation is a comprehensive examination of the determinants of tobacco use among LGB populations in the US and China. This dissertation research provides important and timely information regarding the use prevalence of tobacco – including alternative tobacco products (ATPs) – among subgroups of sexual minorities (by sex and by minority categorization, e.g., gay/lesbian, bisexual) and in relation to theory-informed psychosocial correlates of use.

This study was the first to provide a numerical prevalence estimates of current cigarette use among sexual minority in the US. It was also the first theory-driven study of sexual minority men's tobacco use in China. Specific public health implications of this dissertation include: First, this research extends the knowledge base regarding the demographic risk profiles of tobacco-related health disparities among sexual minorities and provided a better understanding of the pressing needs of sexual minority subgroups, particularly bisexual women and youth/youth adults. Second, findings provide evidence on the theory-based psychosocial factors to tobacco use among sexual minorities in China, that constructs suggested by Minority Stress, specifically rejection anticipation among sexual minority men was associated with depression but not smoking status, indicating the utility of this theoretical frameworks in explaining smoking disparities among sexual minority populations in China need to be further examined. Third, we found that the data on sexual minorities have expanded substantively in the past decade and we saw growing consistency of the assessment of sexuality, this improvement offers opportunity to assess accurately identify health disparity experienced by sexual minorities more accurately. However, more data on sexual minority in national or regional surveys is needed, as data on the use of alternative tobacco products (ATPs), on transgender populations and youth are still very limited.

STRENGTH AND LIMITATIONS

This dissertation adopted a Minority Stress perspective and an Intersectionality perspective to illustrate the distinct tobacco use profiles of sexual minorities. Research that takes account of this diversity is still scarce. This research also explored distinctive and shared minority stressors across sexual minority subgroup in order to understand the underlying reason

for the inter-group differences between subgroup. We applied advance statistical models such as two-group structural equation modeling (SEM) to reduce the error in the modeling processes and obtained more accurate estimates. However, this research is not without limitations.

Most of this dissertation research and evidence have relied on observational, cross-sectional data. Thus, our study could not draw casual inferences between correlates and tobacco use outcome. Another major limitation is that we only considered individual-level correlates. However, successful interventions should be comprehensive, go beyond the individual level, and acknowledge the facts that behaviors are contextualized and related to higher-level social forces (Glanz, Rimer, & Viswanath, 2015; Kawachi & Berkman, 2003; A. D. Roux, 2008; A. V. D. Roux, 2001). Although Minority Stress Theory focuses on individual-level causal pathway, it indicates a top-down connection between social environment, interpersonal ties, sexual minority stress, and health problems. In order to understand how social factors lead to sexual minority health disparity such as heightened tobacco use, future study should apply the socio-ecological model and consider including interpersonal and macro-level factors using multilevel analysis and/or longitudinal data.

DIRECTION FOR FUTURE RESEARCH

Prior studies on the correlates of tobacco use in sexual minorities have been dominated by cross-sectional designs over the past decade (Armstrong et al., 2016; Bandiera, 2013; John Blosnich et al., 2010; J. Blosnich et al., 2013; Emory et al., 2015; Goldbach et al., 2014; Jannat-Khah et al., 2017; Johnson et al., 2016; McElroy et al., 2011; Rath et al., 2013; Ward et al., 2014). Correlates identified by cross-sectional studies might not always be in the casual pathway. Further, from a life course perspective, the risk factors, either independent or clustered, may

cause accumulation of risk, or long-term risk (Kuh et al., 2003). As an early life course study showed, trajectories that generate short-term risks may be governed by different variables than the trajectories that produce long-term risks (Herrick, Stall, Goldhammer, Egan, & Mayer, 2014). Additionally, tobacco use usually initiates and develops throughout the adolescence and early young adulthood (Backinger et al., 2003; Breslau & Peterson, 1996; DeWit et al., 1997). Adolescence and young adulthood are also periods when sexual minorities negotiate the process of acknowledging, defining, and accepting their sexual identities. During this process, many LGB individuals experienced emotional or psychological distress during a series of stressful life events such as coming out, which might result in using tobacco as a stress coping strategy (Austin et al., 2004; Eisenberg & Wechsler, 2003; Rosario et al., 2011). However, these processes leading to increased tobacco use risk during this significant developmental period in sexual minorities remain unclear (J. Blosnich et al., 2013; Corliss et al., 2013; J. G. Lee et al., 2009; Matthews et al., 2014). Therefore, future studies should adopt a longitudinal research design accompanied with a life course perspective to understand the trajectory and long-term effects of tobacco use risk factors during sexual minorities' key transitioning periods.

CONCLUSIONS

Overall, this research made novel contributions to the existing intervention efforts, by providing a greater understanding of tobacco use patterns, the scope of ATP use, as well as the influence of intersecting sexual orientation and sex, which can aid in the development of interventions and policies to reduce tobacco disparities in sexual minorities. In a broader scope, our research adds to the knowledge base that across culture, sexual minorities are at sub-optimal health when societal hostility imposes great stressors on them (Bonvicini, 2017). These stressors

culminate and result in physiological problems and consequently lead to health disparities. Greater equality would reduce the health disparity experienced by all sexual minorities and thus is needed.

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