Evidence for Sex Convergence in Prevalence of Cannabis Use: A Systematic Review and Meta-Regression

CATH CHAPMAN, PH.D.,[a] TIM SLADE, PH.D.,[a] WENDY SWIFT, PH.D.,[a,*] KATHERINE KEYES, PH.D.,[b] ZOE TONKS, B.SC. (HONS),[a] & MAREE TEESSON, PH.D.[a]

[a]*National Health and Medical Research Council (NHMRC) Centre of Research Excellence in Mental Health and Substance Use, National Drug and Alcohol Research Centre, University of New South Wales, Randwick NSW, Australia*

[b]*Mailman School of Public Health, Columbia University, New York, New York*

ABSTRACT. Objective: Generally, cannabis use has been more prevalent in men than in women. However, emerging evidence suggests that the prevalence of cannabis use is converging among males and females from recent cohorts. This study aimed to systematically summarize published literature on birth cohort changes in male-to-female ratios in prevalence of cannabis use. **Method:** Twenty-two studies with a median sample size of 85,052 were identified for inclusion. Data were collected between 1979 and 2010, representing birth cohorts from 1936 to 1999. For quantitative synthesis, male-to-female ratios in prevalence of any cannabis use were calculated for all 5-year birth cohorts available, generating 348 separate ratios among birth cohorts from 1941 to 1995 in 30 countries. Random-effects meta-analyses generated pooled sex ratios, stratified by 5-year birth cohorts. **Results:** Of the 22 included studies, 10 reported some evidence of sex convergence in cannabis use among more recent cohorts. Quantitative synthesis found that the ratio of cannabis use prevalence in males and females decreased significantly from 2.0 among cohorts born in 1941 to 1.3 among those born in 1995. **Conclusions:** Findings support the narrowing sex gap in the prevalence of cannabis use. Results are concordant with a broader literature demonstrating sex convergence in prevalence of other substance use, particularly alcohol use and related harms. Both young women and men should be the target of prevention and early intervention efforts. Future research in more diverse global settings, especially in low- and middle-income countries, would enhance the international scope of the findings. (*J. Stud. Alcohol Drugs, 78,* 344–352, 2017)

RECENT REPORTS INDICATE that about 3.5% of the population worldwide has used cannabis in the past year, making it one of the most widely used psychoactive substances (Gowing et al., 2015). Although studies from some countries have shown declines in prevalence of cannabis use among more recent birth cohorts (ter Bogt et al., 2014), others have reported significant increases over the past decade, with recent estimates of past-year prevalence in the United States as high as 9.5% (Hasin et al., 2015). In other countries, patterns of use over time have been more complex, particularly among young people (Copeland et al., 2013). In Australia, for example, although overall prevalence of cannabis use among those aged 12–17 has been declining, those who are using cannabis are doing so in greater quantities (Roxburgh et al., 2010). Similarly, a recent analysis of data from France, Germany, and the United States determined that despite some variations in patterns of use across these three countries, cannabis use was beginning at an earlier age among more recent cohorts (Legleye et al., 2014). These findings are particularly concerning given mounting evidence that chronic or prolonged cannabis use at young ages is associated with adverse psychiatric and other sequelae (Copeland et al., 2013; Hall & Degenhardt, 2009; Silins et al., 2014; Volkow et al., 2014).

Within this context, the prevalence of cannabis use has typically been approximately two to three times higher in men than in women (Zilberman et al., 2004). However, there is emerging evidence to suggest that the gap between men and women in cannabis use may be closing. Degenhardt et al. (2008), using cross-sectional data from a large cross-national study, demonstrated that the relative odds of cannabis use among women compared with men were lower in older birth cohorts compared with younger birth cohorts in a number of countries. More recently, Hasin et al. (2015), using data from two cross-sectional national surveys a decade apart, determined that increases in cannabis use between 2001–2002 and 2012–2013 in the United States were greater among women than among men. In a multi-country study, Legleye et al. (2014) determined that sex ratios in cannabis use were decreasing across birth cohorts in the United States and in Germany but increasing in France.

Age-period-cohort (APC) modeling, a statistical approach specifically designed to isolate temporal changes in prevalence that are independently associated with being in a specific birth cohort from changes that are a result of being of a specific age and/or living through a historical period, affords a rigorous test of changes in prevalence over time. It is therefore well suited to address the question of whether co-

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*Correspondence may be sent to Wendy Swift at the NHMRC Centre of Research Excellence in Mental Health and Substance Use, National Drug and Alcohol Research Centre, University of New South Wales, 22-32 King Street, Randwick NSW 2031, Australia, or via email at: w.swift@unsw.edu.au.

hort changes in prevalence of cannabis use have been similar for males and females. However, although two published APC studies have reported evidence of sex convergence in cannabis use (Johnson & Gerstein, 2000; Kerr et al., 2007), two have not (Miech & Koester, 2012; Piontek et al., 2012), with one study instead finding that variations in cannabis use over time are most likely explained by an age effect—that is, that both men and women mature out of cannabis use as they age (Piontek et al., 2012).

Understanding sex-specific birth cohort trends in the epidemiology of cannabis and other substance use is vital because they may point to key environmental and social mechanisms associated with population shifts in substance use patterns (Kuhn, 2015; Legleye et al., 2014). Furthermore, several studies have suggested that women who use cannabis are more vulnerable than men to the development of cannabis use disorder, particularly during adolescence (Kuhn, 2015) and that, following first use, they progress more quickly than men through the cannabis-related problems cycle (Lewis et al., 2014). Substantial changes over time in the sex distribution of cannabis use may require a rethink of effective prevention, public health, and intervention strategies to combat the harms and costs associated with cannabis use. A recent review of international evidence for sex convergence with respect to alcohol use concluded that male and female rates of alcohol use and related harms were converging among more recent cohorts (Slade et al., 2016). To the authors' knowledge, no systematic review has been carried out examining and synthesizing evidence for the closing male–female gap in cannabis use.

The aims of the current study, therefore, were (a) to carry out a systematic review of evidence for the closing male–female gap in prevalence of cannabis use, and (b) to use meta-analysis to provide a pooled numerical summary of the male-to-female ratio in prevalence of cannabis use across 5-year birth cohorts dating back to the mid-20th century, thus enumerating the magnitude of any observed male–female convergence in cannabis use over time.

Method

The current systematic review followed guidelines for the conducting and reporting of meta-analyses of observational studies in epidemiology (MOOSE) (Stroup et al., 2000) and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Liberati et al., 2009; Shamseer et al., 2015). EppiReviewer Version 4 was used for the management of screening, coding, and data extraction (Thomas et al., 2010).

Study inclusion criteria

Full electronic search strategies, including search terms, are contained in Supplemental Tables A–C. (The supplemental tables are provided as an online-only compendium that accompanies the electronic version of this article.) We aimed to identify studies that reported on the following indicators of cannabis use: any cannabis use, frequent or regular use, and stages in the cannabis use and related problems cycle (e.g., onset of use, transition from use to disorder). We included studies published between January 1980 and June 2014, inclusive, that (a) measured at least one of the above indicators of cannabis use, (b) reported on a regionally or nationally representative population sample, (c) explicitly measured a cohort effect or presented estimates across at least two birth cohorts, and (d) presented estimates separately for males and females or carried out explicit comparisons between males and females (this included Sex × Time or Sex × Cohort interactions).

We excluded studies that only sampled targeted groups within the population (e.g., people seeking treatment). The decision to focus only on representative population samples (i.e., those that were sampled and/or weighted to match the age and sex distribution of the population from which they were drawn) was made to characterize overall changes in population prevalence estimates at regional and national levels and to capture the range of cannabis use in general populations. Non-English texts were not included in the review.

Search strategy

We searched three commonly indexed databases (Medline, EMBASE, PsycINFO) using three separate search strategies. Full search strings are presented in Supplemental Tables A–C. Search Strategy 1 aimed to identify studies that explicitly derived parameter estimates that reflect changes over time in indicators of cannabis use. Search Strategy 2 aimed to identify studies that focused on sex differences in cannabis use but did not explicitly conduct APC analyses. Search Strategy 3 aimed to identify studies that reported estimates by sex and birth cohorts or by sex and age groups (as a proxy for birth cohorts) but did not explicitly conduct APC analysis or examine sex convergence. This search was restricted to gold standard epidemiological studies based on guidelines developed for the World Health Organization 2010 Global Burden of Disease study protocols (Whiteford et al., 2013).

The initial search of the three databases was undertaken in January 2013 and updated at the end of June 2014. The electronic search strategy was supplemented by hand-searching literature reviews and reference lists of key articles. All article abstracts were screened independently by one of the authors, and the same authors independently assessed full-text articles for inclusion. Approximately 20% of abstracts and full texts were independently screened by a second reviewer, and all extracted data for included studies were independently checked by a second reviewer.

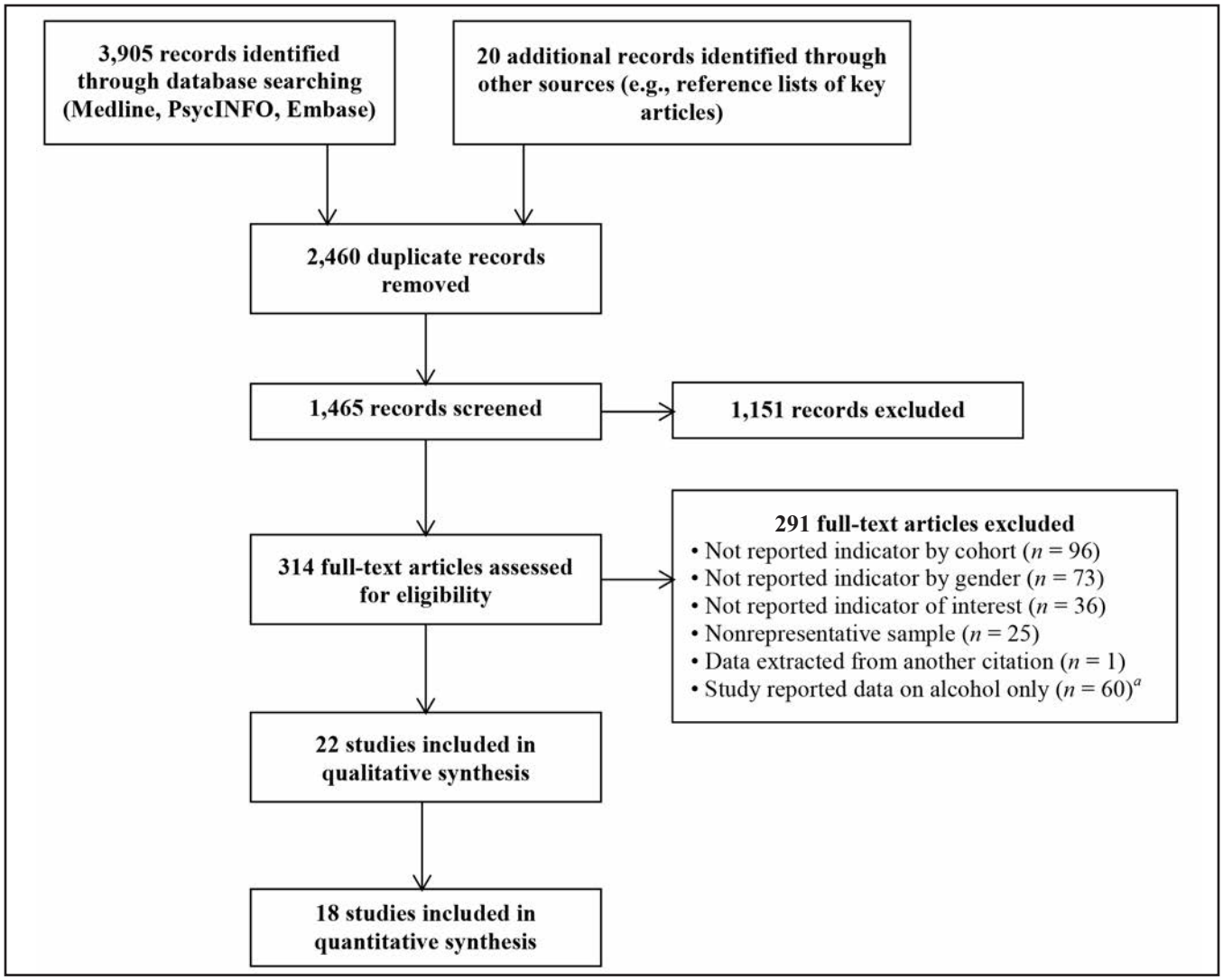

FIGURE 1. Flowchart of systematic review procedure for identifying citations reporting indicators of alcohol or cannabis use and related harms by sex and cohort. [a]Alcohol indicators were analyzed separately and are reported elsewhere (Slade et al., 2016).

Figure 1 shows the number of articles obtained using the search strategy and the number of records excluded, with reasons. The present study had a parallel aim of examining evidence for the closing male–female gap in indicators of alcohol use, and the screening protocol was designed to screen records for both alcohol and cannabis, which were reported together in many cases (Slade et al., 2016). The electronic search strategy identified 1,445 unique records, and an additional 20 records (approximately 1%) were retrieved by examining literature reviews and reference lists of key articles. After we screened the abstracts, 314 full text articles were retrieved and examined. A total of 22 articles met the cannabis-related inclusion criteria. Quantitative synthesis was conducted on 18 studies. Table 1 provides summary characteristics of included studies. (Supplemental Table D provides detailed characteristics of included studies.)

Data extraction

Data were extracted in the following domains: study design, population, country, survey name, survey year, sample age, sample size, birth cohorts covered, indicators reported including indicator definitions, definition time frame, and whether the authors reported evidence of sex convergence on any indicators of interest.

Statistical analysis

In addition to the extracted qualitative data described above, quantitative data on the prevalence of cannabis use for each available birth cohort for males and females were also extracted and summarized using random-effects meta-analysis. We calculated the male-to-female ratio in the

Table 1. Summary characteristics of included studies

Characteristic	Cannabis use (n = 22)	
	n	%
Design		
Repeated cross-sectional	15	68.2
Single cross-sectional	7	31.8
World region[a]		
North America	7	31.8
Europe	8	36.4
Oceania	1	4.5
>1 world region	6	27.3
Sample age[a]		
Adolescent & young adult (11–26 years)	8	36.4
Adult (≥18 years)	3	13.6
Adolescent and adult (≥12 years)	11	50.0
Sample size[a]		
1,000–9,999	4	18.2
10,000–19,999	2	9.1
20,000–49,999	2	9.1
50,000–99,999	7	31.8
≥100,000	6	27.3
Time frame[b]		
Past month	1	4.5
Past 12 months	5	22.7
Lifetime	12	54.5
Multiple	4	18.2

[a]Summary groupings are presented here. However, estimates included in meta-analysis coded country, sample age, and size specific to each estimate. Sample size and age were not reported by all studies. [b]For some studies, assessment time frame varied by survey year, country, or indicator measured. Estimates included in meta-analysis coded time frame specific to each estimate. Assessment time frame was not reported by all studies.

prevalence of cannabis use for each birth cohort in each study that had available data. All sex ratios were logarithmically transformed and all meta-analyses were carried out on these logarithmically transformed values, with back-transformation for reporting purposes. Log sex ratios were considered equivalent to log risk ratios, and standard errors were calculated accordingly (Katz et al., 1978). Pooled (log) sex ratios with 95% confidence intervals [CIs] were calculated separately for each birth cohort with the Stata (Version 12.1) metan program (Harris et al., 2008). Heterogeneity across all estimates was assessed by the I-squared index. Random-effects meta-analyses were carried out and statistical heterogeneity was handled using the Knapp–Hartung approach, which performs better than the standard DerSimonian–Laird approach, particularly when there are substantial differences between individual estimates (Cornell, 2014). Random-effects meta-regression analyses, using the Stata metareg command (Harbord & Higgins, 2008), were carried out to determine how much of this heterogeneity in sex ratios was explained by birth cohort, controlling for important methodological characteristics. These characteristics included age at the time of data collection (<26, 26–49, or >49), world region (North America, Europe, or Oceania), study design (repeated cross-sectional or single cross-sectional), and indicator time frame (lifetime, past 12 month, past month, or various). Formal tests of publication bias were not applicable in the context of the current analysis.

Results

Summary of characteristics of included studies

We identified 22 citations that met inclusion criteria (Figure 1, Table 1, Supplemental Table D). Data used in the studies were collected between 1979 and 2010 representing birth cohorts from 1936 to 1999. Half of the studies used data collected over a time span of 10 years or more (n = 11), two of which used data collected over 20 years or more. Study sample sizes ranged from 1,057 to 776,242 (*Mdn* = 85,052), and 59.1% had a sample size of >50,000; the combined total sample size was 2,735,973. The majority of studies were repeated cross-sectional studies (n = 15), four of which conducted APC analyses. Data were reported on eight different indicators of cannabis use: prevalence of any cannabis use (any use on one or more occasions; n = 17), any use on one or more occasions before age 21 (n = 1), prevalence of frequent use (n = 2), cumulative incidence of use (n = 3), incidence of use (n = 1), frequency of use (n = 1), rapid transition from opportunity to use (n = 1), and prevalence of use given opportunity (n = 1). Six studies reported more than one indicator, and the most commonly used assessment time frame was lifetime (n = 12).

Summary of results from included studies

Just under half of included studies (n = 10) found evidence of sex convergence in more recent cohorts on at least one indicator of cannabis use (Supplemental Table D). The majority of these (n = 7) reported that convergence was driven by greater and/or more consistent increases across birth cohorts in prevalence of cannabis use among females compared with males. The remaining three studies reported that decreases in the prevalence of cannabis use among males drove convergence among more recent cohorts. Eleven studies found no evidence for sex convergence among more recent cohorts, reporting similar trends among males and females, and one study reported that greater increases in frequent use among males drove divergence in more recent cohorts.

Quantitative synthesis

Individual study estimates. Of the 22 included citations, 18 provided data on prevalence of any cannabis use separately for males and females across at least two separate birth cohorts, and we focused quantitative analyses on these studies. Collectively, these citations spanned birth cohorts starting in 1941 and ending in 1995 and provided 348 individual sex ratios from 30 countries (65% from the

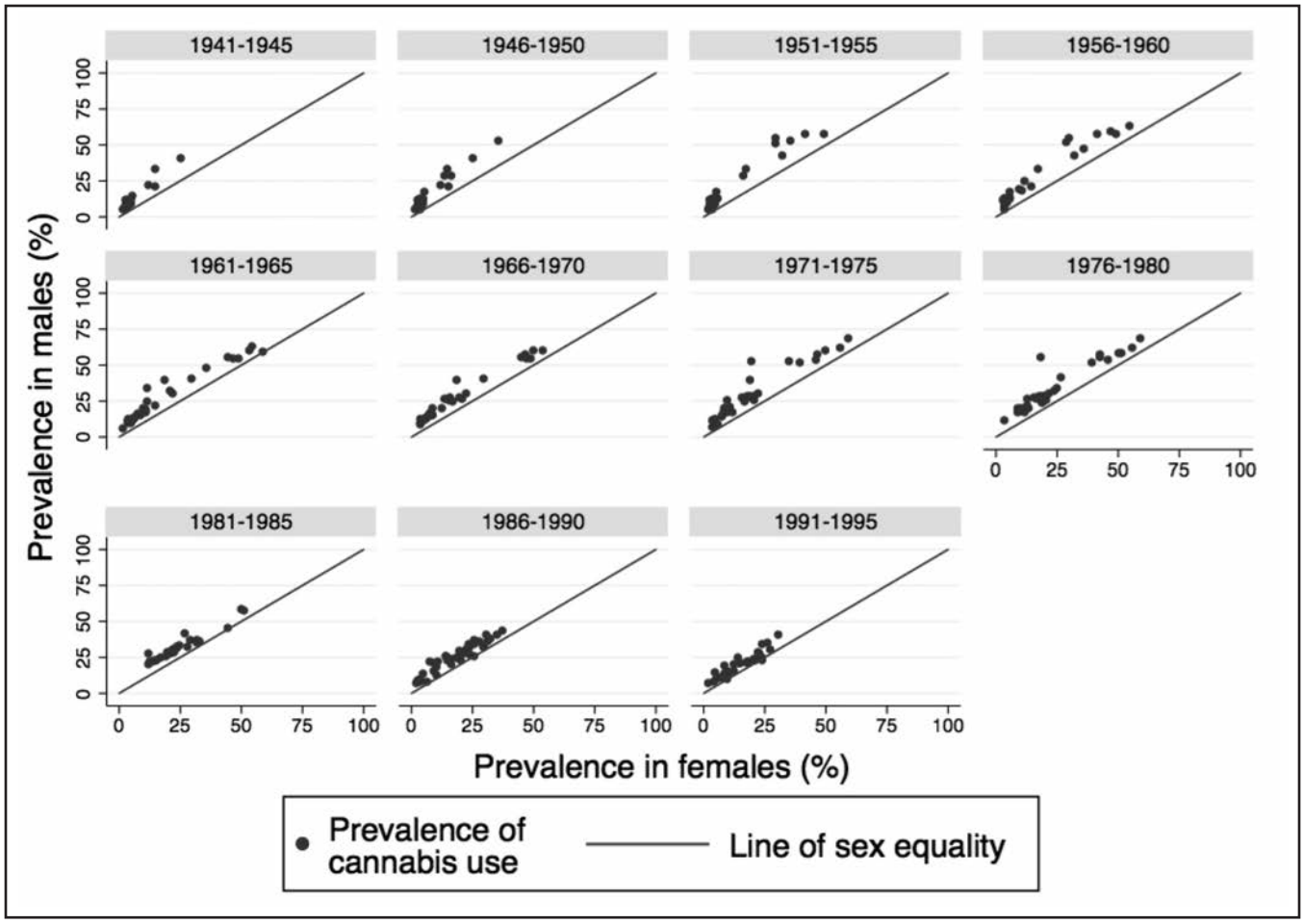

FIGURE 2. Cannabis use (%) in females (*x*-axis) and males (*y*-axis) by 5-year birth cohort. Each dot represents a single prevalence estimate.

United States). Individual female (*x*-axis) and male (*y*-axis) prevalence estimates, by birth cohort, are graphed in Figure 2. In earlier birth cohorts, males clearly surpassed females in the prevalence of cannabis use. However, in more recent birth cohorts, particularly from 1981 onward, the estimates are closer to the line of equality, indicating a narrowing of the male–female gap.

Pooled results from meta-analyses and meta-regression. The pooled cannabis use sex ratio from random-effects meta-analyses within each birth cohort was 2.0 (95% CI [1.8, 2.3]) in the earliest cohort (1941–1945) and declined over time to a low of 1.3 (95% CI [1.2, 1.4]) in cohorts born between 1991 and 1995 (Table 2). Random-effects meta-regression analyses indicated that the cannabis use sex ratio declined linearly across birth cohorts. When birth cohort was entered into the meta-regression as a continuous variable, each successive 5-year birth cohort was associated with a 4.8% (95% CI [3.9%, 5.6%]; t = -10.34, $p < .001$) decrease in the sex ratio. This effect remained once we controlled for methodological characteristics. With these characteristics included in the model, the sex ratio decreased linearly by 5.6% (95% CI [4.4%, 6.8%]; t = -8.73, $p < .001$) with each successive 5-year birth cohort. Given that the spread of countries was greater in more recent compared with earlier cohorts, we conducted a sensitivity analysis in which we grouped estimates based on whether they came from studies based in the United States or in other countries and found a significant cohort effect in both.

Discussion

The current study summarized English-language published literature on sex convergence in indicators of cannabis use. We derived male-to-female ratios of cannabis use and used meta-analysis to numerically summarize the overall relationship of male-to-female cannabis use prevalence. To our knowledge, this is the first study to do so. Just under half of the included studies found some evidence of sex convergence in cannabis use prevalence rates among more recent birth cohorts. The quantitative synthesis found that the cannabis use sex ratio has decreased linearly from 2.0 to 1.3 among cohorts born in the 50 years between 1941 and 1995

Table 2. Random-effects meta-analysis pooled gender ratios for prevalence of any cannabis use within 5-year birth cohorts

Birth cohort	*n* of individual gender ratio estimates	*n* of citations[a]	*n* of countries	Random-effects pooled gender ratio [95% CI]
1941–1945	16	5	2	2.0 [1.8, 2.3]
1946–1950	24	6	3	2.0 [1.8, 2.3]
1951–1955	29	6	3	1.9 [1.7, 2.2]
1956–1960	32	8	3	1.9 [1.7, 2.1]
1961–1965	35	9	4	1.8 [1.6, 1.9]
1966–1970	35	10	5	1.7 [1.5, 1.8]
1971–1975	38	14	9	1.6 [1.5, 1.8]
1976–1980	33	12	7	1.4 [1.3, 1.5]
1981–1985	28	13	9	1.3 [1.2, 1.4]
1986–1990	43	8	29	1.3 [1.2, 1.4]
1991–1995	35	6	28	1.3 [1.2, 1.4]

Notes: CI = confidence interval. [a]Represents the number of citations from which the individual estimates were extracted. Some citations reported results from separate repeated cross-sectional surveys, or separate surveys conducted in a number of different countries.

and remained significant after adjusting for methodological characteristics.

Although the sex ratio provides information on the relative prevalence of cannabis use in males versus females, it does not include information on the base rate of prevalence and therefore does not empirically determine whether observed changes in the sex ratio are being driven by increases or decreases in male or female prevalence or whether a more complex pattern of changes over time exists. However, the summary of the results from the included studies indicated that the majority of studies that found evidence of sex convergence reported greater increases in prevalence of cannabis use among females compared with males from more recent cohorts (Colell et al., 2013; Degenhardt et al., 2008; Johnson & Gerstein, 2000; Maxwell, 2001, 2003, 2008; Reid et al., 2000), and this is further supported by recently published estimates from the United States showing that although prevalence of cannabis increased among both males and females between 2001–2002 and 2012–2013, the increase was greater for females (Hasin et al., 2015).

Although the current study did not test specific hypotheses for why the male–female gap in substance use may be closing, speculative explanations can be proposed. Certainly, research has demonstrated that social norms and attitudes with respect to cannabis use are strong determinants of use and that, importantly, these attitudes tend to cluster in birth cohorts (Keyes et al., 2011b). For example, a recent analysis from the United States (Pacek et al., 2015) determined that decreased rates of perceived risk of regular cannabis use in the decade after 2002 occurred alongside increases in cannabis use and that this decrease in perceived risk was greatest among young people. Although they found higher overall rates of perceived risk among females compared with males, they did not examine sex-specific changes over time. It is possible that greater changes in perceived risk or other social norms associated with cannabis use among recent cohorts of females are associated with increased use among this group. Relatedly, there have been substantial changes in cannabis-related legislation in many countries over the last decade and a number of analyses focusing on the relationship between these changes and changes in cannabis use among recently born cohorts. In a large cross-national study, Shi et al. (2015), using samples of adolescents born after 1984, determined not only that cannabis liberalization was associated with higher levels of regular cannabis use among adolescents but also that the relationship between cannabis control policies and cannabis use was greater in females.

Within this context, it is worth noting that the parallel review conducted by our team on sex convergence in alcohol use and related harms also found evidence of a closing male–female gap among more recent cohorts (Slade et al., 2016), and the findings support those of an earlier narrative review by one of our team, which also found evidence of a narrowing male–female gap (Keyes et al., 2011a) in alcohol use and related harms in many countries. The authors suggested that these changes could be linked to geographic and temporal changes in sex-based social roles and improvements in economic conditions for women, particularly post–World War II. In support of this hypothesis, a large multi-country epidemiological study demonstrated that the narrowing sex differences in the prevalence of substance use disorders across birth cohorts were most pronounced in those countries in which female and male roles were converging over time (Seedat et al., 2009). It is possible that the findings of the current study with respect to cannabis may reflect broader sex-specific social and economic changes associated with increased rates of use of both licit and illicit substances among women (Degenhardt et al., 2008; Wilsnack, 2012).

Regardless of the explanations for these shifts, given evidence that cannabis use in women is associated with a faster progression to cannabis use disorder (Lewis et al., 2014) as well as greater risk for comorbid anxiety and depression during adolescence (Kloos et al., 2009), the findings raise concerns about the potential for increased cannabis-related harms among young women. Further, given that recent reviews have suggested that greater female vulnerability to cannabis use disorder may be linked to important biological differences such as neuronal maturation over adolescence, sex-specific responses to cannabinoid compounds, and hormone and cannabinoid receptor interactions (Kuhn, 2015; Rubino & Parolaro, 2015), increased cannabis use among adolescent females is of particular concern.

A number of limitations of the current study require discussion. First, despite the large sample sizes in the included studies, the relatively small number of individual studies precluded quantitative analyses among subgroups or across different world regions. Although data from 30 countries were included, the majority of estimates (65%) came from the United States, including three of the four APC studies. This

is particularly relevant for earlier birth cohorts, in which we had estimates from only two or three countries, as opposed to more recent birth cohorts, in which we had estimates from a much larger number of countries. Similarly, coverage of the literature may not be complete, because available resources did not permit translation of non-English texts for the review. The preponderance of estimates from one or two regions of the world means that we need to be circumspect when drawing conclusions regarding the change over time in different countries, and this need for caution is underscored by the somewhat equivocal results from the qualitative analysis. However, the results of the sensitivity analysis demonstrated that, in more recent cohorts, the pooled sex ratios were close to one, based on both U.S. and non-U.S. estimates. Several cross-national studies have found differences across countries or world regions with respect to sex convergence in cannabis use (Degenhardt et al., 2008; Kuntsche et al., 2009), with one study suggesting that regional differences in wealth, particularly the change in country wealth over time, may account for these patterns (ter Bogt et al., 2014), and another suggesting that male-to-female differences in the prevalence of any cannabis use are smaller in countries in which overall prevalence of cannabis use is higher (Sznitman et al., 2015). Although future research may shed light on country-level differences in sex convergence of cannabis use, the present results should be interpreted within the context of a preponderance of data from high-income countries and the exclusion of non-English texts from the review.

Second, we restricted our search to published studies and did not include an assessment of the grey literature. This may have increased the chances of publication bias, and the pooling of estimates within birth cohorts across studies meant that we were not able to use traditional publication bias assessments (e.g., Begg & Mazumdar, 1994). However, our conclusions were informed most by large, nationally representative surveys, often conducted repeatedly over 5 or more years, several of which were strengthened by APC analyses. It is unlikely that these studies would be available only in the grey literature.

Third, availability of data dictated that the quantitative analysis focus on prevalence of any cannabis use rather than regular use, or development of disorder. Although there is evidence to suggest that chronic cannabis use is associated with a range of negative outcomes (Hall & Degenhardt, 2014), especially in adolescence (Copeland et al., 2013), and that increases in any cannabis use at a population level may lead to increases in risk of disorder (Hasin et al., 2015), future research can help determine whether sex-specific changes are also occurring in other patterns of cannabis use and related harms (e.g., regular or frequent use, abuse and dependence). Last, given that many of the cohorts that have seen the greatest sex convergence in cannabis use are now only in their 20s or 30s, it is not possible to comment on the impacts of these changes over the life span as these cohorts age. Given the specific harms associated with cannabis use during pregnancy and breastfeeding (Metz & Stickrath, 2015), increases in use among women herald further potential for increased harms as younger cohorts of women approach child-bearing age. Continued epidemiological research is warranted to address the impact of sex convergence in cannabis use as young cohorts of men and women age.

These limitations notwithstanding, the results have implications for understanding sex-specific changes in the prevalence of cannabis use and the risk of related harms in the population. Substance use and substance use disorders have long been viewed as a male phenomenon. Although cannabis use typically remains more prevalent among young men than young women, the present study indicates that this pattern is shifting among recent cohorts. The reasons for sex convergence in cannabis use are speculative, but the findings suggest that young women as well as young men should be the target of educational, prevention, and early intervention efforts with respect to cannabis use. Further, given that sex convergence in cannabis use appears to be a relatively recent phenomenon, the study highlights the importance of continued population-level monitoring of young cohorts of male and female cannabis users as they age into their 30s, 40s, and beyond, in order to assess the impact of these changes on longer term harms, including development of mental and other substance use disorders. Last, continued research in more diverse global settings, especially in low- and middle-income countries, may facilitate systematic comparisons with respect to sex-specific changes in prevalence of cannabis use across countries with a range of legal, policy, and sociocultural contexts.

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