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ORIGINAL ARTICLE

Do Sex Differences and Risk Perception Affect Cannabis Exposure? Results from a Sample of Current Cannabis Users from the European Web Survey on Drugs

Valentina Lorenzetti[1] · **Eugene McTavish**[1] · **João Matias**[2]

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Abstract
The rates of cannabis use have been narrowing between sexes over the past decade, and there are sex differences in the perception of cannabis use-related risks, yet it remains unexamined whether sex and risk perception interact to predict cannabis consumption levels. We aimed to examine for the first time how sex, risk perception, and their interaction affect cannabis consumption, accounting for age, alcohol use, mode of administration, education, employment status, and country via general linear mixed models. We conducted the European Web Survey on Drugs in 16 countries from 2016 to 2018. People who used cannabis at the time of the study included 6500 males and 2921 females, with a median age of 22 years. There was no risk perception-by-sex interaction effect on cannabis consumption. Greater past-month cannabis dosage in grams and frequency (days used/past month) were reported by males and by persons who reported having a perception of no risk and of a slight risk versus a moderate-to-high-risk perception. The findings may inform discussions on public health messaging aimed at alleviating cannabis-related harms in males and females who use cannabis.

Keywords Cannabis · Risk perception · Sex · Sex differences · Cannabis dosage · Cannabis use frequency · Males · Females

Cannabis products are undergoing significant and rapid changes in their legal status and patterns of use while becoming increasingly accessible (ESPAD Group, 2020; European Monitoring Centre for Drugs and Drug Addiction, 2022; Han et al., 2021; Jolene Okaneku et al., 2015b). One of such changes is the narrowing gap in the rates of cannabis use between males and females (Brown et al., 2017; Colell et al., 2013), which has decreased in the USA from a 7.6% difference in 1999 to a 2.9% difference in 2013 (Johnson et al., 2015; Substance Abuse and Mental Health Services Administration, 2014). While males

✉ Valentina Lorenzetti
valentina.lorenzetti@gmail.com

[1] Neuroscience of Addiction and Mental Health Program, Healthy Brain and Mind Research Centre, School of Behavioural and Health Sciences, Faculty of Health Sciences, Australian Catholic University, Brunswick East, VIC, Australia

[2] European Monitoring Centre for Drugs and Drug Addiction, Lisbon, Portugal

comprise around 2/3 of all those who used cannabis in the past year globally (Greaves & Hemsing, 2020; UNODC, 2022), the number of females who use cannabis has been increasing internationally (Brown et al., 2017; Colell et al., 2013; Miller et al., 2017; UNODC, 2022). Specifically, data from the annual US National Survey on Drug Use and Health (NSDUH) show that the proportion of females who use cannabis has risen from 6.29% in 2002 to 9.27% in 2014 for past month use and from 12.37 to 15.93% for past year use (Brown et al., 2017). These trends highlight the narrowing gap in cannabis consumption between sexes. Yet, little is known about sex differences in contemporary cannabis consumption. This knowledge gap limits the development of preventative and harm-reduction interventions targeting males and females who consume cannabis.

Sex differences are apparent in distinct aspects of cannabis consumption, including the quantity and frequency of cannabis use. For example, males have been reported to consume greater quantities of cannabis, e.g. grams per week, grams past 90 days, ad joints per day (Cuttler et al., 2016; Herrmann et al., 2015; Khan et al., 2013), are more likely to be chronic users (Preston, 2006), and consume cannabis more often than females (e.g. use days, occasions of use/day, greater proportion of daily users) (Cuttler et al., 2016; Greaves & Hemsing, 2020; Herrmann et al., 2015). However, the mechanisms that drive sex differences in cannabis consumption remain unclear. Importantly, sex differences in cannabis consumption have been ascribed to distinct psychosocial mechanisms (e.g. decrease in stigma toward cannabis use in women, different motivations for using cannabis (Cuttler et al., 2016), confidence in the knowledge on the effects of cannabis (Park et al., 2022)), including a different perception of health risks from cannabis use (Cooper & Craft, 2018; Janz & Becker, 1984; Schuermeyer et al., 2014; Spigner et al., 1993). Indeed, lower risk perception is shown to predict cannabis use cross-sectionally and over time (Pacek et al., 2015; Salloum et al., 2018; Schuermeyer et al., 2014; Wen et al., 2019); and males tend to perceive a lower risk from cannabis use than females (Compton et al., 2005; Galván et al., 2015; Herrmann et al., 2015; J. Okaneku et al., 2015a; Pacek et al., 2015; Park et al., 2022; Schuermeyer et al., 2014; Spigner et al., 1993; Thornton et al., 2013).

Overall, emerging evidence, as outlined in the above section, shows that both sex and risk perception affect cannabis consumption. However, to our knowledge, no study to date has examined sex differences in cannabis consumption residualising/accounting for risk perception or has concurrently examined if the interaction of sex and risk perception predicts cannabis consumption levels. The current manuscript aims to fill this knowledge gap. Furthermore, methodological limitations prevent an accurate understanding of the role of sex and risk perception on cannabis consumption. First, most studies used metrics of cannabis use that lack precision on consumption levels, e.g. dichotomous variables confirming cannabis use vs. non-use (Pacek et al., 2015) or nominal variables on distinct levels of cannabis consumption (Cuttler et al., 2016). Thus, it is unclear how risk perception and sex affect more accurate metrics of cannabis consumption (e.g. dosage, frequency), known to be potentially associated with adverse mental health and brain outcomes (EMCDDA, 2015; Lowe et al., 2019; Yücel et al., 2008).

Second, it is unexplored how the evidence to date on cannabis consumption generalises to multiple countries, as the evidence to date is largely based on single countries (e.g. USA, Spain, and Australia) (Brown et al., 2017; Colell et al., 2013). Finally, the role of psychosocial mechanisms known to be associated with cannabis consumption is unclear, as these have been inconsistently accounted for (e.g. age, employment status, highest education level, and other substance use) (Johnson et al., 2015; Khan et al., 2013; Pacek et al., 2015; Preston, 2006). For example, cannabis use has been shown to vary with age (Terry-McElrath et al., 2017) and has been associated with lower educational achievement (Fergusson

et al., 2003; Horwood et al., 2010; Lorenzetti et al., 2020; Lynskey & Hall, 2000), employment status, e.g. job loss (Cassandra A Okechukwu et al., 2019a), and other substance use (Chan et al., 2021).

Overall, methodological issues limit the understanding of how risk perception, sex, and their interactions affect contemporary cannabis consumption. New evidence is necessary to inform effective preventative interventions and public health harm-reduction messaging toward people who use cannabis and who experience harm, which comprises males and increasingly females. Furthermore, females compared to males have been shown to transition faster from recreational use to dependence, report greater subjective intoxication from cannabis exposure, have greater withdrawal symptoms and severity of CUD, and have stronger negative effect of cannabis use on mental quality of life scores (Greaves & Hemsing, 2020). Understanding sex differences in cannabis consumption is timely. Indeed, even if not all people who consume cannabis experience harm in relation to their cannabis consumption, those who can experience problems from use represent a substantial amount of people, e.g. 10% of 193 million people who use cannabis globally in 2018 alone (Connor et al., 2021).

Our primary aim was to fill the current knowledge gap in cannabis research regarding the sex-by-risk perception of cannabis consumption while addressing the methodological limitations of the literature outlined above. Furthermore, this work aims to address recent calls to acknowledge sex differences in substance use research as per the European Monitoring Centre for Drugs and Drug Addiction (e.g. www.emcdda.europa.eu/topics/gender-and-drugs_en) and the National Institute of Health, to account for sex differences in health research (Arnegard et al., 2020), and recent reports by the United Nations Office for Drugs and Crime that highlight ongoing sex treatment gap and disparities in drug use and treatment (e.g. www.unodc.org/unodc/frontpage/2022/June/unodc-world-drug-report-2022-highlights-trends-on-cannabis-post-legalization%2D%2Denvironmental-impacts-of-illicit-drugs%2D%2Dand-drug-use-among-women-and-youth.html). We hereby examine for the first time how sex, perception of health risks from regular cannabis use, and their interaction affect cannabis grams and frequency in a sample of people who use cannabis currently from 16 distinct European countries, beyond the influence of socio-demographic and substance use confounders (i.e. age, alcohol use, mode of cannabis administration, highest education, employment, and country). We hypothesised that males compared to females would have a lower risk perception and greater cannabis consumption (i.e. grams/month and use days/month).

Methods

Recruitment

The European Monitoring Centre for Drugs and Drug Addiction coordinates the European Web Survey on Drugs project (Matias et al., 2019), which had its first round in 2016 in which Croatia, Czechia, France, the Netherlands, Switzerland, and the UK participated. In the second round in 2017 and 2018, Austria, Belgium, Cyprus, Estonia, Finland, Italy, Latvia, Lithuania, Luxembourg, and Poland participated. Overall, around 84,000 people participated in the two rounds.

Recruitment strategies were previously described (Matias, 2022). Specifically, they were devised by each national partner based on their networks and experience, and the

lessons learned were shared among the participating countries. The recruitment strategies varied substantially and included dedicated web pages, flyers distributed in clubs and bars, general promotion through a variety of channels (e.g. student health insurance websites, magazines, universities, social and counselling service websites, and web pages targeting people who use specific drugs), advertising in drop-in and outreach centre premises, advertising on the darknet (Karden & Strizek, 2022), offering participants the incentive of entry in a lottery, and using paid ads on social media sites.

Inclusion and Exclusion Criteria

Participants were screened against key inclusion criteria: (i) male and female sex; (ii) age 18 to 80 years; and (iii) self-reported consumption of cannabis in the past year *and* in the past month. Exclusion criteria were (i) past-year consumption of illicit substances other than cannabis such as amphetamines, cocaine, 3,4-methylenedioxymethamphetamine, crack, heroin, gamma hydroxybutyrate, ketamine, lysergic acid diethylamide, hallucinogens, cathinone, and synthetic cannabinoids; (ii) missing/invalid information regarding substance consumption; and (iii) outliers for the cannabis grams or frequency or both, defined as 3 or more standard deviations from the mean according to the liberal standardised/automated outlier removal method (Grafarend, 2006; Pukelsheim, 1992).

Socio-demographic and Alcohol Consumption Measures

Assessment of socio-demographic and cannabis use data was conducted via online questionnaires. People were asked about their age in years, sex, and country of residence.

The highest education level was measured by the level of formal schooling completed: primary, lower-secondary, upper-secondary, or tertiary education. *Average monthly personal income* was measured in euros in a subsample (see Table 1) and via selecting one of six pay brackets defined according to typical income in each country: lowest, second-lowest, mid-lower, mid-higher, second highest, and highest (Vuolo & Matias, 2020). *Employment status* was measured by selecting one of the following categories that best described their present situation: employed full-time; employed part-time; self-employed full-time; self-employed part-time; full-time student; unemployed; and other (e.g. retired and homemaker). *The presence or absence of alcohol consumption over the past month* was also measured.

Assessment of Cannabis Consumption

We measured cannabis consumption parameters, including how much cannabis people used in the past month (i.e. cannabis dosage in grams), how often they used cannabis in the past month (i.e. number of days), the type of cannabis used (i.e. dry herb or resin or both), and the method used to consume cannabis (i.e. joints, dry pipes, water pipes; as well as vapes, food/edibles, and beverages/drinks for a subsample to the 2018 wave of data collection, due to the recent trends in diversification of cannabis products).

Cannabis dosage was measured as the number of cumulative cannabis grams used in the past month. It was measured by multiplying the number of grams contained in a typical joint/dry pipe/water pipe, by the number of joints/dry pipes/water pipes consumed on a

Table 1 Summary of sample socio-demographic, cannabis-use characteristics by sex, in median (range) or percentage

	Males	Females	U/x^2	*df*	*p*
N	6500	2921	–	–	–
Age (years)	22 (18–74)	21 (18–69)	8190.25	–	**< 0.001**
Cannabis dosage (g)	7.01 (0.01–74.06)	4.27 (0.03–5.33)	241.62	–	**< 0.001**
Cannabis frequency (days/month)	20 (1–30)	15 (1–30)	499.00	–	**< 0.001**
Perceived harm risk from cannabis use					
No risk	23.0%	20.1%	88.13	3	**< 0.001**
Slight risk	50.2%	45.7%			
Moderate risk	22.9%	26.2%			
Great risk	4.0%	8.0%			
Alcohol use, past month					
Yes	83.5%	84.7%	2.06	1	.151
No	16.5%	15.3%			
Mode of cannabis administration					
Joint	83.9%	86.1%	15.21	–	**0.015**
Chillum	4.7%	6.9%			
Waterpipe	4.6%	3.5%			
Joint/chillum	3.4%	1.4%			
Joint/waterpipe	1.4%	1.6%			
Chillum/waterpipe	1.7%	0.2%			
Joint/chillum/waterpipe	0.2%	0.2%			
An additional mode of cannabis administration[a]					
Food/edible	12.6%	40.3%	28.40	–	**< 0.001**
Beverage/drink	2.0%	4.2%			
Vape	85.3%	55.6%			
Highest education					
Primary	9.6%	11.6%	8.54	3	**0.036**
Lower secondary	25.8%	23.9%			
Upper secondary	43.0%	42.1%			
Tertiary	21.7%	22.4%			
Average income (€/month)[a]					
Lowest	32.0%	41.7%	192.05	5	**< 0.001**
Second-lowest	17.4%	24.5%			
Mid-lower	20.7%	15.7%			
Mid-higher	13.6%	10.0%			
Second-highest	7.4%	4.3%			
Highest	8.7%	3.9%			
Employment status					
Employed full-time	42.8%	28.1%	243.41	6	**< 0.001**
Employed part-time	6.3%	9.5%			
Self-employed full-time	6.9%	2.9%			
Self-employed part-time	2.1%	1.2%			
Full-time student	34.5%	48.5%			
Unemployed	5.4%	6.3%			
Other	2.1%	3.6%			

Table 1 (continued)

Bold values denote statistical significance at the $p < 0.05$ level. Scalar variables reported via median and range; categorical variables reported via frequencies; country of residence comparison performed via Fisher's exact test (FET; using Monte Carlo simulation with 10,000 sample tables)

N/A, not applicable; *U*, Mann–Whitney *U* test statistic; χ^2, Chi-square test statistic; *N*, number of participants; €, euro; *df*, numerator, denominator degrees of freedom

[a]Data from subsamples were available for additional mode of administration for 365 people (293 males, 72 females) and average income (€/mo) for 5410 people (3813 males and 1597 females)

typical cannabis consumption day, and by the number of cannabis consumption days in the past month.

Assessment of Perception of Risk Associated with Regular Cannabis Use

In people who use cannabis, the perceived risk associated with regular cannabis use was measured with the item: 'People risk harming themselves if they smoke marijuana or hashish regularly', whereby answer options were 'no risk', 'slight risk', 'moderate risk', or 'great risk'.

Statistical Analyses

Sex differences were examined for socio-demographic, cannabis consumption, and risk perception variables. We conducted a series of Mann–Whitney *U* tests for scalar data (i.e. age, cannabis grams/past month, cannabis use days/past month). We also ran Chi-squared tests for categorical data: presence of alcohol use in the past year, perceived risk associated with regular cannabis use, country of residence for the 16 countries, highest education achieved, and employment status.

To examine the primary aim—how sex, risk perception, and risk perception-by-sex perception affect cannabis use dosage and frequency—we ran two general linear mixed models, using sex (male, female), perceived risk (none, slight, moderate, great), and risk perception-by-sex as fixed factors. The outcome variables were cannabis grams/past month and consumption days/past month. Covariates included age, presence of alcohol use in the past month, mode of cannabis administration, highest education achieved, employment status, and country of residence.

Post hoc Mann–Whitney *U* tests were run to confirm the nature of the emerging significant effects in the main models, which were residualised against the impact of all covariates. Post hoc analyses were also run to explore the effects of country on cannabis dosage and frequency, which were also residualised against the impact of all covariates using Kruskal–Wallis tests.

All statistical analyses were performed using IBM SPSS Statistics version 28.0.

Results

Socio-demographic Data and Alcohol Use

Participants were 9421 people who used cannabis at the time when the study was conducted, with a median age of 22 years (range, 18–74 years). Of these, 6500 were males and

2921 were females from the 16 European countries surveyed. As shown in Table 1, males and females differed in all socio-demographic data, substance use data, and their perception of the risk associated with regular cannabis use. Females were significantly younger than males. There were sex differences in the country of residence of participants who used cannabis (Supplementary Fig. 1, FET = 228.215, $p < 0.001$; 95% confidence interval (CI) [< 0.001, < 0.001]). Specifically, there was a greater proportion of males than females in several countries: Italy, Finland, Latvia, Austria, Luxemburg, Cyprus, and the United Kingdom. Other countries comprised a larger proportion of cannabis-using females than males: Poland, Belgium, Croatia, Lithuania, France, the Netherlands, Switzerland, Czechia, and Estonia.

Males and females who used cannabis had similar completions of upper-secondary/tertiary education and unemployment status. A greater proportion of cannabis-using males compared to females who completed lower secondary school were employed/self-employed full-time or self-employed part-time. Instead, a larger proportion of females compared to males completed their highest education primary schooling, worked part-time, studied full-time, or had 'other' roles (e.g. 'retiree' or 'homemaker'). The presence of alcohol use in the past month was non-significant between the sexes.

Risk Perception

As shown in Table 1, there were sex differences in the perception of health risks from regular cannabis use ($p < 0.001$). A greater proportion of males compared to females perceived no health risk (23.0% vs. 20.1%, respectively) or a slight risk with regular cannabis use (50.2% vs. 45.7%, respectively). Instead, a greater proportion of females compared to males perceived moderate risk (26.2 vs. 22.9%, respectively) or high risk (8.0 vs. 4.0%, respectively).

Cannabis Consumption

Males consumed more cannabis grams in the past month and on more days over the past month. Sex differences also emerged in modes of cannabis administration ($p = 0.015$, see Table 1, with post hoc results ranging from $p = 0.015$ to $p = 0.018$). A greater proportion of males than females administered cannabis using only waterpipes, as well as both chillums (i.e. a stone pipe commonly used in Europe) *and* joints or waterpipes. Meanwhile, a greater proportion of females than males administered cannabis using only joints or only chillums. A similar proportion of males and females used both joints *and* waterpipes, and joints, chillums, *and* waterpipes. We also noted sex differences in novel modes of cannabis administration, whereby vapes were used by a larger proportion of males and edible cannabis solids/beverages were reportedly used by a greater number of females.

Effect of Risk Perception, Sex, and Risk Perception-by-Sex on Cannabis Consumption

Table 2 overviews the effects of risk perception, sex, and risk perception-by-sex on the number of cannabis grams consumed in the past month and on the number of cannabis consumption days in the past month (Fig. 1).

Cannabis Grams in the Past Month

There was a significant effect of sex ($p < 0.01$), a trend-level effect of risk perception on the number of *cannabis grams* used in the past month ($p = 0.076$), and no effect of risk perception by sex, accounting for age, alcohol use, mode of administration, highest education, employment status, and country of residence (Table 2).

Post hoc analyses showed that more cannabis grams were used in the past month by males than females, older participants ($r = -0.051$, $p = 0.047$), and those who did not report using alcohol. Other covariates significantly affected the model, namely the mode of cannabis administration, the level of highest education achieved, employment status, and country of residence (see Table 2; Supplementary Materials for post hoc analysis results). Exploratory analyses revealed no interaction between sex and the other significant covariates.

Cannabis Use Days in the Past Month

There was a significant effect of risk perception ($p < 0.001$) and a trend-level effect of sex on the number of cannabis use days in the past month ($p = 0.057$), accounting for age, alcohol use, mode of cannabis administration, highest education, employment, and country of residence (Table 2; Fig. 1). Risk perception by sex did not affect cannabis use frequency.

Post hoc analyses revealed a dose–response relationship between risk perception and frequency of use. Specifically, people who use cannabis who perceive no risk or a slight risk with regular cannabis use consume cannabis on more days in the past month than those who perceive a moderate risk ($p < 0.001$, $d = 0.30$), and more than those who perceived a great risk ($p < 0.001$, $d = 0.49$), with small-to-medium-effect sizes. Similarly, participants who use cannabis and who perceive a slight risk with regular cannabis use consume cannabis on more days in the past month than those who perceive a moderate risk ($p = 0.002$, $d = 0.18$) or a great risk ($p < 0.001$, $d = 0.27$), with small effect sizes. Furthermore, people who use cannabis and perceive a moderate risk with regular cannabis use reported consuming cannabis on more days than those who perceive a great risk ($p = 0.021$, $d = 0.23$).

Table 2 Overview of effects of sex, risk perception, and risk perception-by-sex on cannabis dosage and frequency, controlling for age, country, highest education, income, employment, and alcohol use

	Cannabis grams/past month			Cannabis use days/past month		
	F	*df*	*p*	*F*	*df*	*p*
Sex	7.17	1, 1477	**< 0.01**	3.63	1, 1477	0.057
Risk perception	2.29	3, 1477	0.076	10.53	3, 1477	**< 0.001**
Risk perception-by-sex	0.882	3, 1477	0.45	0.48	3, 1477	0.697
Age (years)	4.70	1, 1477	**< 0.05**	3.95	1, 1477	**< 0.05**
Alcohol use, past month	15.01	1, 1477	**< 0.001**	13.92	1, 1477	**< 0.001**
Mode of administration	2.24	6, 1477	**< 0.05**	0.94	6, 1477	0.462
Highest education	4.61	3, 1477	**< 0.01**	4.12	3, 1477	**< 0.01**
Employment status	3.43	7, 1477	**< 0.01**	5.75	7, 1477	**< 0.001**
Country of residence	2.78	14, 1477	**< 0.001**	7.37	14, 1477	**< 0.001**

Bold values denote statistical significance at the $p < 0.05$ level

df, numerator, denominator degrees of freedom

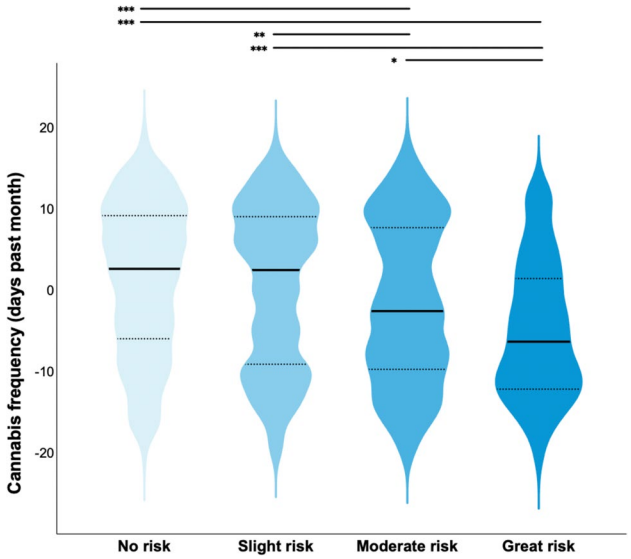

Fig. 1 Significant effect of risk perception on cannabis consumption days over the past month, controlling for age, country, highest education, employment, mode of administration, and alcohol use. Horizontal lines show post hoc results: cannabis users who perceive no risk or a slight risk with regular cannabis use consume cannabis on more days in the past month than those who perceive a moderate risk or a great risk. Furthermore, cannabis users who perceive a moderate risk with regular cannabis use reported consuming cannabis on more days than those who perceive a great risk. Violin plots show the median values (*solid horizontal lines*) and quartiles (25–75%, *dotted horizontal lines*) for cannabis use *days past month. Lighter-to-darker* shades represent low-to-great levels of perceived risk with regular cannabis use. *$p < 0.05$; **$p < 0.01$

Post hoc analyses revealed that cannabis was consumed more often in males than females who use cannabis ($p = 0.017$, $d = 0.12$), younger people ($r = 0.057$, $p = 0.028$), and those who did not use alcohol in the past month compared to those who did ($p < 0.01$, $d = 0.18$). There were also significant effects of highest education, employment status, and country of residence on cannabis use frequency, with details of post hoc analyses in Supplementary Materials (Supplementary Tables 1 to 3). No other covariates affected the model, and exploratory analyses revealed no interaction between sex and the other significant covariates.

Discussion

This is the first study to examine how risk perception, sex, and their interaction affect cannabis dosage and frequency in a large multi-country sample of 9421 people who use cannabis, comprehensively accounting for confounders (i.e. age, country of residence, highest education, income, employment status, and alcohol use). Sex differences were apparent in the perception of health risks from regular cannabis use. A greater proportion of males compared to females perceived no health risk or a slight risk with regular cannabis use. Meanwhile, a greater proportion of females compared to males perceived moderate risk or high risk. Cannabis was used more often and in greater quantity by

those who perceived no risk with regular cannabis use compared to people who perceived lesser degrees of risk. There was no significant risk perception-by-sex effect on cannabis consumption after accounting for confounding variables. Confounding variables predicted cannabis consumption: age and country predicted cannabis dosage and frequency, and the highest level of education achieved predicted cannabis dosage. Our findings suggest that risk perception and additional socio-demographic variables may drive heavier forms of cannabis use.

We found that risk perception by sex did not significantly affect cannabis consumption, accounting for age, country of residence, highest education, income, employment status, and alcohol use. Instead, risk perception alone (not its interaction with sex) consistently predicted cannabis dosage and frequency. Specifically, people who use cannabis and who perceived no health risks or a slight health risk with regular cannabis use consumed the greatest amount of cannabis grams and cannabis using days over the past month, compared to higher risk perception groups, with small-to-moderate effect sizes (d = 0.3–0.5). The findings are consistent with previous evidence that perceived risk predicts people's engagement in health-related behaviours, including cannabis consumption (Janz & Becker, 1984). Our findings are also in line with previous work showing that lower perceived risk predicts a greater level of cannabis consumption metrics, such as occasions used in the past month (Park et al., 2022), the presence of daily cannabis use (Pacek et al., 2015), and the presence of cannabis use in the past year (Kilmer et al., 2007; Lopez-Quintero & Neumark, 2010; Pacek et al., 2015). Therefore, our results suggest that risk perception may predict cannabis consumption across multiple countries.

Our study confirms previous findings that risk perception predicts cannabis use and extends them in several ways. First, we used a more precise metric of cannabis consumption levels (e.g. grams and consumption days) than previous studies (e.g. dichotomous and nominal variables measured via interval scales). Second, we examined a large multi-country sample across 16 distinct countries, while previous work has focused on individual countries (e.g. USA, Spain) (Pacek et al., 2015; Park et al., 2022). Third, we included adults across a wide age range measured via scalar metrics to enable a more accurate measure of age (18-to-74 years), while previous samples examined specific ages (e.g. youth undergraduates (Park et al., 2022)) or measured age using interval scales (12–17; 18–25; 26–49; 50+) (Pacek et al., 2015). As low-risk perception predicts the heaviest levels of cannabis consumption, preventative interventions aimed at reducing heavier forms of cannabis use could focus on public health messaging to raise awareness about the health risks (e.g. dependence, mental health) of heavier patterns of consumption (EMCDDA, 2015; Lowe et al., 2019; Yücel et al., 2008). However, public health messaging that is fear-based might not be effective, and the results reported herein should be carefully considered by public experts to inform debates on how to minimise risks associated with cannabis consumption, Also, not all people who consume cannabis in a heavy/chronic fashion do experience harms from their use. As this study failed to examine psychosocial harms in participants who use cannabis, future work should incorporate an assessment of such harms in order to identify how risk perception, sex, and their interaction affect the most vulnerable people who use cannabis.

We also found that males reported greater cannabis dosage and frequency than females, accounting for confounders. This result is in line with our hypotheses and previous evidence (Greaves & Hemsing, 2020). In addition, a greater proportion of males than females perceived low risk, while a greater proportion of females perceived high and moderate risk. Different risk perceptions between sexes have been previously shown in youth, college students, and adults across Europe (Andersson, 2009; Chomynova, 2009; Dzúrová, 2016),

the USA (Pacek et al., 2015; Park et al., 2022; Schuermeyer et al., 2014), and Australia (Thornton et al., 2013).

The mechanisms underlying sex differences in cannabis consumption and risk perception are unclear. The level of awareness of the health risks of cannabis use and confidence knowledge may play a relevant role (Pacek et al., 2015), and future work may further explore this notion. It is also possible that sex differences in drug consumption and risk perception are not specific to cannabis and extend to other health risk behaviours (Courtenay et al., 2002), e.g. presence and severity of use of substances other than cannabis (e.g. tobacco (Thornton et al., 2013)). Furthermore, sex differences in neurobiological pathways implicated in addictive behaviour may partly contribute to explaining greater cannabis consumption levels in males (Rossetti et al., 2022; Rossetti et al., 2021), as well as in the endocannabinoid system and responsiveness to THC (Fattore & Fratta, 2010; Levine et al., 2021). Multidisciplinary research is required to unpack the relative contribution of complex biopsychosocial factors implicated in cannabis use behaviour.

Our results showed that additional sociodemographic characteristics also play a role in predicting cannabis consumption levels (e.g. age, alcohol use, highest education achieved, employment, and country). First, older age predicted greater cannabis dosage and fewer cannabis use days. While the findings are preliminary, they suggest that different parameters of cannabis consumption can change with age and that health messaging campaigns about the risk of cannabis consumption may target different cannabis use parameters based on the age of the target population, e.g. amount of use in older users, and frequency of use in younger users. Understanding the role of age in cannabis consumption is relevant, as younger cannabis users can experience greater harm, such as a greater risk of cannabis addiction (Lawn et al., 2022). Second, the lack of alcohol use vs. alcohol use in the past month was associated with the consumption of greater cannabis quantities and frequency of cannabis. Interestingly, recent reports show that a portion of persons who use cannabis substitute cannabis for alcohol (while another portion co-use cannabis and alcohol) (Gunn et al., 2022) and that lower alcohol sales occur in jurisdictions that allow medical cannabis sales (Baggio et al., 2020). Thus, our study might have included a self-selected sample of both people who use cannabis in a heavy/chronic fashion and who prefer cannabis to alcohol—a pattern of substance use that may correspond to therapeutic use or to a means of managing health-related issues, e.g. pain management, mental health—and those who use cannabis in a lighter fashion who co-use both substances. Importantly, our web survey did not have a specific module on alcohol, so it might have been completed by persons who use illicit drugs, and those who use alcohol might have been less inclined to join. Future work with a detailed assessment of alcohol consumption is required to further explore how levels of alcohol affect cannabis consumption.

The highest education achieved predicted cannabis consumption levels across sexes, and post-hoc analyses revealed small effect sizes ($d = 0.19$ to $d = 0.31$). Specifically, participants whose highest level of education was primary consumed more cannabis grams than those with up to tertiary education and on more days than those with higher education levels. Also, cannabis was used more often by persons whose highest education was lower secondary vs. tertiary. Consistently, previous work has also shown that lower educational achievement is associated with cannabis use (Fergusson et al., 2003; Horwood et al., 2010; Lorenzetti et al., 2020; Lynskey & Hall, 2000). Greater cannabis consumption in persons who completed primary school as well as higher education may be due to several reasons. Perhaps those whose highest education was primary had been using cannabis from an earlier age and for longer than the rest of the sample. Indeed, cannabis use by youth has been associated with lower school performance and school dropout (Lorenzetti et al., 2020), and

earlier cannabis use onset correlates with longer duration of use and greater cannabis consumption (e.g. dosage). Yet, this notion cannot be confirmed due to the lack of data on cannabis consumption parameters other than dosage and frequency.

In the alternative, different education levels may affect education on cannabis' legal status and risk perception, and consequently, cannabis consumption levels. However, emerging evidence does not corroborate this notion, with adults with different education levels (i.e. with vs. without college education) having comparable education on cannabis legalisation and similar proportions of great risk perception (Pacek et al., 2015). We could not corroborate this notion either, as we lacked information on people's education on cannabis legalisation. Further research is required to delineate which variables moderate the effect of educational achievement on cannabis consumption.

Employment status affected cannabis dosage and frequency, with complex differences between distinct types of employment status. These effects may stem from multiple psychosocial mechanisms associated with employment status. For example, lower time constraints and a lack of formal lines of reporting related to a person's occupation or other factors predating unemployment may affect the highest consumption levels (Okechukwu et al., 2019b), which were reported by self-employed part-time employees compared to those working full time, full-time students, and other occupations. Also, stress levels/lower mental health associated with unemployment may contribute to higher consumption levels (Hintikka et al., 2009; Mæhlisen et al., 2018), which were reported in our study by persons who are unemployed more frequently than those with other occupations and full-time students. Of note, unemployment may be related to illness (Hintikka et al., 2009) and therapeutic cannabis use, which was unmeasured in this study. Future work is warranted to measure medical and nonmedical cannabis use in relation to employment status and cannabis consumption levels.

Interestingly, lower cannabis consumption emerged in a few countries, with small effect sizes (from $d = 0.24$ to $d = 0.28$). Specifically, a lower amount of cannabis grams was reported in Latvia and several other countries, and a greater amount of cannabis use days was reported by participants residing in France than in Croatia. Such country-specific differences may be due to complex country-specific factors. For example, some countries, through their recruitment strategies, may have recruited heavier/lighter users, or differences in the legal status of cannabis might have contributed to country-specific effects. In our results, countries where recreational use was not mentioned as an offence tended to show greater cannabis dosage/frequency than those where recreational use was considered either an administrative or a criminal offence. For example, 4 out of 5 countries where cannabis dosage was higher do not penalise recreational cannabis use (i.e. Austria, Italy, Belgium, and Poland) compared to Latvia and Finland. Also, in 8 out of 12 countries that showed a higher frequency of use, recreational cannabis use was not considered an offence (except for France and Cyprus, where recreational use was penalised with 1 year or life imprisonment, respectively). Interestingly, in 6 of those 12 countries where recreational use was not considered an offence, penalties for possession appeared to be less and generally included administrative sanctions (e.g. driving license suspension) or a fine (e.g. euros 120 to 2500).

Importantly, variation in legal status across countries can change the perceived risk of cannabis use, attitudes, and social norms (Clarke et al., 2018; Park et al., 2022; Wen et al., 2019), and trends towards decriminalisation in the legal status of cannabis over time have been associated with a decrease in the perception of cannabis-related health risks in young people (Schuermeyer et al., 2014). Future research is warranted to systematically examine changes in cannabis consumption over time given the rapid changes observed in cannabis legislation, markets, and products. For example, new studies are

required to measure such changes in medical and nonmedical cannabis use in the USA, as they have been legalised by an increasing amount of US states (e.g. https://alcoholpolicy.niaaa.nih.gov/recently-adopted-cannabis-legalization-laws), and in Canada over time, where cannabis use-related activities (e.g. possession, sale, growth) are now legally regulated (www.justice.gc.ca/eng/cj-jp/cannabis/).

This is the first study of how risk perception by sex affects cannabis consumption levels, and the results from this study need to be considered in light of methodological limitations.

First, we lacked a precise measure of alcohol and nicotine consumption. Alcohol consumption was measured as the presence of alcohol use in the past month, and nicotine use was not measured. This issue was due to the focus of the European Web Survey on Drugs on illicit substances. As alcohol use and nicotine use are entrenched with cannabis use (Hindocha et al., 2017; Subramaniam et al., 2016; Yurasek et al., 2017), the effects reported in this study may have been (at least in part) driven by such variables. We aimed to mitigate this issue by accounting for alcohol use in all analyses, but future studies are warranted to measure and account for alcohol and nicotine consumption levels to clarify their roles. Yet, the emerging effects were unlikely to be due to the consumption of illicit substances other than cannabis, as we carefully excluded participants who endorsed any consumption of these substances. Another issue is the low prevalence of people who did not use alcohol in the past month (i.e. 16.3%), and our findings might generalise to people who use cannabis who endorse drinking behaviour.

Second, we had limited parameters of cannabis consumption (e.g. grams/past month and use days/past month) that were potentially affected by recall bias. It remains unclear if risk perception affects other key cannabis use and misuse parameters known to differ between sexes. They include (but are not limited to) cannabis concentrates, cannabis potency, medical and nonmedical cannabis use, the age of cannabis use onset, the presence and severity of problems with cannabis use, attempts to cut down or quit, problems with cannabis use, and others (Agrawal et al., 2008; Calakos et al., 2017; Copeland et al., 2001; Kerridge et al., 2018; Stewart & Brown, 1995). In particular, not collecting data on cannabis potency is also a limitation when translating more intensive cannabis use into greater risks (which might not be necessarily true if low-THC cannabis is used).

Future work is required to elucidate how risk perception affects distinct cannabis use parameters, particularly if high-risk perception delays the age of onset of cannabis use in youth males and females, which is a priority of distinct international health organisations (Commonwealth of Australia (Department of Health), 2017). We also warrant future studies to include internationally standardised assessment measures of consumption (e.g. Standard THC Unit (Freeman & Lorenzetti, 2019, 2020; Freeman & Lorenzetti, 2021) and the iCannToolkit (Lorenzetti et al., 2021)) to enable systematic integration of the evidence on cannabis consumption in both sexes and related health risks worldwide, across distinct cultures, world regions, and international jurisdictions.

Third, other variables may play a key role in determining sex differences in cannabis consumption, including but not limited to income (i.e. which was reported in a small portion of the sample and could not be used as a covariate), awareness of health risks (Leos-Toro et al., 2020), presence and severity of mental health problems (Cranford et al., 2009; Thornton et al., 2013), genetic determinants of cannabis use behaviours (Bogdan et al., 2016; Hillmer et al., 2021), the United Nations gender inequality index (https://hdr.undp.org/data-center/thematic-composite-indices/gender-inequality-index#/indicies/GII), pregnancy status in females, and cognitive variables including disinhibition (Felton et al., 2015; Preston, 2006). Future work is warranted to explore the role of such variables.

Fourth, different levels of risk perception were endorsed by different participant numbers, which may have somehow affected post hoc statistics. We mitigated this issue by using Mann–Whitney *U* tests that are robust to differences in the size of the groups examined (Peró & Guàrdia Olmos, 2013).

Fifth, we did not measure if people experience personal, social, or health consequences from cannabis use. Therefore, it is unclear if any of the people who used cannabis experienced negative consequences from their use. Future work is required to incorporate the measurement of mental ill health symptom scores to elucidate this notion. Also, we did not examine if risk perception, sex, and their interaction predicted specific levels of cannabis consumption, as it was measured with scalar variables (e.g. grams and number of days used in the past month) and not categorical variables (e.g. daily vs. nondaily use). Future work is warranted to identify how risk perception, sex, and risk perception by sex affect specific levels of cannabis exposure, e.g. daily use.

Finally, the web survey may have limited the representativeness of the examined samples by excluding people with limited to no access to digital facilities, including people with lower socio-economic status and homeless members of the community (Matias et al., 2019). These results should be replicated in a more representative sample from general population surveys. However, the feasibility of this suggested strategy might be hindered by the fact that general population surveys tend to represent a small proportion of illicit substance users, including cannabis (Matias et al., 2019). Therefore, knowledge generated from both survey types—the European Web Survey on Drugs used herein and general population surveys—could be used complementarily to unpack contemporary sex differences in cannabis use. Furthermore, the results from this survey may be replicated in other world regions that are undergoing rapid changes in sex differences in the prevalence of cannabis use and in the legal status of cannabis, e.g. North America and Oceania.

In conclusion, our study was the first to concurrently examine the effect of sex, risk perception, and risk perception by sex on cannabis consumption levels in people who currently use across 16 distinct countries, accounting for age, alcohol use, model of administration, highest education, employment status, and country. We found no significant effect of sex-by-risk perception on cannabis consumption levels, suggesting that both sexes are likely to be equally affected by different levels of risk perception. We also found that sex significantly affected cannabis consumption, with males reporting a greater cannabis dosage than females. This finding warrants further investigation by future studies so that other preventive strategies can be found. Furthermore, we confirmed that risk perception significantly affected cannabis consumption. Specifically, a lack of health risk perception and a slight risk perception were associated with significantly higher levels of cannabis frequency. The findings require replication in repeated-measure studies with longitudinal samples of people who use cannabis for medical or nonmedical purposes (or both), including those with problematic forms of use, while accounting for rapid changes in the legal status of cannabis products. Our results may have implications for informing discussions surrounding which public health strategies might be considered for targeting males and females with the heaviest level of cannabis consumption.

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Declarations

Ethical Standards—Human Rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Confirmation Statement The authors confirm that this paper has not been either previously published or submitted simultaneously for publication elsewhere.

Conflict of Interest The authors declare no conflict of interest.

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