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SPECIAL SECTION: IASR 2023 SYMPOSIUM ON INNOVATIVE FINDINGS IN THE STUDY OF BIRTH ORDER AND SEXUAL ORIENTATION

Asexuality: Its Relationship to Sibling Sex Composition and Birth Order

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Abstract

While recent research has advanced our understanding of asexuality, very little effort has been devoted to examining biomarkers and possible prenatal correlates of asexuality. In response, we recruited a large international sample ($N = 1634$ women and men) to explore associations between sibling composition and asexual sexual orientation ($n = 366$) and to replicate previously reported sibship effects in individuals with a same-sex attracted orientation ($n = 276$) and bisexual sexual orientation ($n = 267$) compared to heterosexual individuals ($n = 725$). Our analyses used two of the most recent statistical approaches that attempt to disentangle older sibling effects from family size effects (Ablaza et al., 2022; Khovanova, 2020). We found that higher overall number of siblings (female fecundity effect) predicted higher probability of asexuality in men and having fewer older sisters and being an only-child predicted higher probability of asexuality in women. Regarding the same-sex attracted orientations, higher number of older sisters increased likelihood of being a gay man (sororal birth order effect). Having fewer older sisters was associated with bisexual sexual orientation in women and higher overall number of siblings predicted increased likelihood of bisexuality in men. We did not find a fraternal birth order effect for gay, lesbian, bisexual or asexual groups using the Ablaza et al. (2022) method but the effect was significant for gay men using the Khovanova (2020) analytic approach. These findings point to potential sibship-related contribution to development of asexuality in women and men but future studies will need to replicate these results and articulate potential underlying mechanisms.

Keywords Asexuality · Fraternal birth order effect · Female fecundity effect · Sexual orientation · Biomarkers

Introduction

Relationship Between Sibling Composition and Asexuality

The first population estimate on prevalence of asexuality was offered by Bogaert (2004) and suggested that approximately 1% of the population self-identify as asexual, defined as a lack of sexual attraction. Research on asexuality is still limited; however, there seems to be general consensus among experts that asexuality is best conceptualized as a sexual orientation (Bogaert, 2015; Brotto & Yule, 2017; Brotto et al., 2010; Pagan Westfall, 2004). As such, it is appropriate that existing theories of non-heterosexual sexual orientation development be applied to asexuality in order to gain potential insight into asexuality's development. Differences in sexual attractions and sexual orientations are hypothesized to result from variations in biological processes that influence sexual differentiation in the brain by shifting it in a sex-atypical direction (Gooren, 2006). However, there has been very little research into how this might contribute to the lack of sexual attraction characteristic of asexuality. This study sought to extend the ample literature on sibling composition among gay men to asexual individuals. We also sought to replicate the findings on gay and lesbian individuals as well as on bisexual women and men.

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Fraternal Birth Order and Other Sibship Effects

The fraternal birth order effect (FBOE) is the well-documented finding that men who identify as homosexual have a greater number of older brothers than men who are not gay (Ablaza et al., 2022; Blanchard, 2021; Blanchard & Lippa, 2021; Blanchard et al., 2020). Blanchard and Bogaert (1996) first documented the FBOE by publishing their finding of a positive relationship between homosexuality and number of older brothers in men. The study found that the odds of identifying as gay increased by 33% with each additional older brother in a sibship. To explain the mechanism, Blanchard and Bogaert developed the leading hypothesis for the FBOE–the maternal immune hypothesis (MIH). According to this hypothesis, some mothers are immunized by male-specific antigens from male fetuses and the maternal antibodies created during that immunization interfere with the brain masculinization of later born male fetuses resulting in that later-born male to develop a gay sexual orientation (Bogaert & Skorska, 2011). As summarized first by Blanchard (2018) and more recently by Ablaza et al. (2022), while some studies have failed to replicate the general finding of a FBOE in men (Bearman & Brückner, 2002), it has been successfully demonstrated in a variety of different geographical regions and diverse populations. Additionally, while the FBOE has been demonstrated as a contributing factor in the development of sexual orientation, it should be noted that it is likely only a portion of a multifactorial explanation of sexual attractions (Bogaert et al., 2018).

Related to FBOE is the sororal birth order effect (SBOE), the finding that later-born male children with a greater number of older sisters have a higher probability of identifying as homosexual (Blanchard & Lippa, 2021; Blanchard et al., 2021). This theory is based on the reasoning that mothers who have delivered more female offspring are more likely to have experienced an immune response to a male fetus, given the finding that a mother's number of miscarriages is correlated with her number of liveborn children and that approximately half of miscarriages are male (Blanchard & Lippa, 2021). The SBOE effect has not been as consistently found as FBOE in predicting increased likelihood of male homosexuality, but the link between SBOE and later-born offspring with a same-sex orientation has been recently confirmed on a large population-level data set (Ablaza et al., 2022).

The female fecundity effect (FFE) is the finding that mothers of gay men have more offspring than mothers of heterosexual men (Blanchard et al., 2020). The evolutionary explanation behind this effect is the "balancing selection hypothesis," which combines the known heritability of homosexuality in men with the finding that gay men produce significantly fewer offspring than their heterosexual counterparts (Blanchard et al., 2020). The hypothesis explains the consistent levels of homosexuality in the male population, as reported in Blanchard et al. (2020), by positing that genes that predispose men to a same-sex attraction may offset their lack of reproduction by also increasing fecundity in their female relatives (Camperio-Ciani & Pellizzari, 2012; Camperio-Ciani et al., 2004). However, whereas the FBOE paradigm has been successfully demonstrated in an array of studies (Blanchard, 2018), the supporting evidence for the FFE is inconsistent. While some studies have reported evidence of a FFE previously (Iemmola & Camperio-Ciani, 2009; King et al., 2005), including in non-Western cultures (Semenyna et al., 2017; VanderLaan & Vasey, 2011), later studies by Blanchard et al. (2020), Blanchard and Lippa (2021), and Ablaza et al. (2022) have not found evidence to support the FFE in gay men. These studies found that once the number of older brothers is held constant, no significant difference in total number of siblings is found. In contrast, the FBOE is still found even after controlling for total number of siblings. These results suggest that the FFE found in previous studies might simply be a statistical artifact of the FBOE. Similar conclusions were reached by a few very recent studies. Raymond et al. (2023) re-analyzed existing data and found no support for the female fecundity effect. Lack of evidence for FFE was also reported by Semenyna et al. (2023) which studied male androphilia in Samoa and by Fořt et al. (2024) who studied fertility of the relatives of Czech gay men and lesbians. Along those lines, Blanchard and Lippa (2021) posited that the combination of recent studies lacking empirical support for the FFE calls into question the validity of the balancing selection hypothesis itself and the appropriateness of younger siblings as a measure of fecundity.

Another sibship-related finding reported in a few studies of same-sex attracted women is only-child status. Earlier studies found that samples of gender dysphoric women (who tend to be same-sex attracted) were characterized by elevated frequency of only-children (Schagen et al., 2012; VanderLaan et al., 2014) and this finding was confirmed by more recent study by Skorska and Bogaert (2020) that reported gynephilic/biphilic women more likely to be only-children compared to androphilic women.

Asexuality and Sibship Effects

While the FBO paradigm has been explored extensively in gay men, it has been explored minimally among individuals of other sexual orientations. As far as we are aware, the sibling composition effects have only been evaluated in a single study of asexual individuals (Yule et al., 2014), which found that asexual men had a significantly greater number of older

brothers and asexual women had significantly fewer older brothers compared to their respective heterosexual counterparts (Yule et al., 2014). While there was no significant difference between asexual and heterosexual men in number of older sisters, asexual women had significantly fewer older sisters compared to heterosexual women (Yule et al., 2014). Unfortunately, the researchers did not collect data on the proband's number of younger siblings, thus limiting their ability to examine all possible sibship effects. Moreover, the only-child status characteristic has never been examined in asexual women or men.

The objective of the current study was to evaluate the FBOE and other sibship effects in a larger sample of asexual individuals using a more recently developed statistical approach (Ablaza et al., 2022) which is superior to previously used methods. Additionally, we sought to resolve a key limitation of Yule et al. (2014) by collecting data on participants' younger brothers and sisters. As discussed by Ablaza et al. (2022), including the number of younger brothers and sisters in analyses is key to isolating the effects of increasing sibship size from the effects of birth order and older siblings' sex. Based on Yule et al.'s (2014) findings, we expected to find FBOE for asexual men and a deficit of older brothers and older sisters for asexual women. These hypotheses are strictly empirical and based on the very limited evidence. The mechanisms behind such findings have not been offered yet. One might speculate that the maternal immune reaction which is theorized to disrupt masculinization of the fetus' brain resulting in homosexuality might, in extreme cases, disrupt brain development to the point where no sexual attraction is formed resulting in asexuality. Our hope is to add to the body of research which would inform future theorizing on potential mechanisms behind any sibship effects that will be consistently found among asexual individuals.

In addition to potential contributions to our understanding of biological correlates of asexuality, this study sought to test the sibling effects on bisexual women and men in addition to replicating these well-known effects on gay and lesbian individuals. There have been only a few published studies testing FBOE on bisexual men (Apostolou, 2020; Blanchard & Lippa, 2021) and none on bisexual women that we are aware of. Therefore, the present study will contribute important new information on understudied populations (Blanchard, 2023). We expected to find fraternal and sororal birth order effects in bisexual women and men as well as in gay and lesbian individuals.

Different Ways of Measuring the Sibling Effects

In statistical analyses of birth order, a key conundrum is the disentanglement of sibship size and birth order. A few new approaches have been proposed in recent years as a solution to this dilemma, e.g., the Older Brother Odds Ratio (OBOR) approach presented by Blanchard (2018), and an approach that uses a subsample of only those with zero or one sibling proposed by Khovanova (2020). However, while those procedures provide clean separation of birth order and family size, they are limited by significant data loss and potential losses to statistical power and external validity (Ablaza et al., 2022). It is also possible for selected cases to differ significantly from excluded cases (Kabátek et al., 2022).

Ablaza et al. (2022) proposed a novel re-parametrization of Blanchard and Bogaert's (1996) original logistical regression approach. The advantages of this study included avoiding convenience sampling by using a large population-level sample ($n = 9{,}073{,}496$) with very limited data loss, including sisters in the analyses, and improving separation of birth order, sibship size, and sibling sex (Ablaza et al., 2022). The current study will adopt the logistical regression method proposed by Ablaza et al. (2022), with some further modifications. We will also test all sibship effects using Khovanova's (2020) method in order to evaluate the robustness of our findings.

Method

Participants

The study was advertised as "Online study: Diversity of sexual preferences" and its purpose was described as an exploration of different aspects of sexual identity among men and women who self-identify as asexual, bisexual, heterosexual, or homosexual. It was advertised through the Asexuality Visibility and Education Network (AVEN) website, in addition to local newspapers, Craigslist, Facebook, Twitter, and tear off advertisements around the university campus and in community centers, mental health clinics, public transit, and grocery stores. Many of the sites with asexuality-related content have international audience and we hoped this would allow us to reach more asexual participants. As well, participants were recruited through local asexuality meet-up groups, word-of-mouth, an email broadcast through the research institute affiliated with our research center, the university's Department of Psychology Human Subject Pool, a public platform listing members of the public and patients who are interested in research, and via contacting previous study participants who had consented to being contacted. The criteria for inclusion were: being 19 years or older, self-identifying as asexual, heterosexual, gay/lesbian, or bisexual, and being fluent in the English language. Individuals who did not meet these criteria were excluded. We stopped recruitment once 2000 participants were reached. We did not exclude participants who identified as trans or non-binary. The study was originally powered to detect significant odds ratio of 1.5

based on the value of pooled odds ratio of 1.47 found for the older brother effect in androphilic men in Blanchard (2018) meta-analysis. When aiming for power of 0.80 in a logistic regression with three continuous predictors (R^2 of the other predictors was estimated at 0.4) and the probability of the sexual minority group presence under the null hypothesis set at 0.2, a total sample of $n = 500$ was required. We hoped to exceed the conservative estimate of recruiting 20% sexual minority participants (used in power analysis) and aimed for $n = 250$ in each sexual orientation/sex subgroup resulting in 1000 women and 1000 men. After removing cases with incomplete information on sex/gender, a total of 1634 participants between the ages of 19 and 81 were ultimately included in the final sample. A flowchart illustrating recruitment numbers is presented in Fig. 1.

Measures and Procedure

Individuals interested in participating in the study contacted the study coordinator for more information by email, and

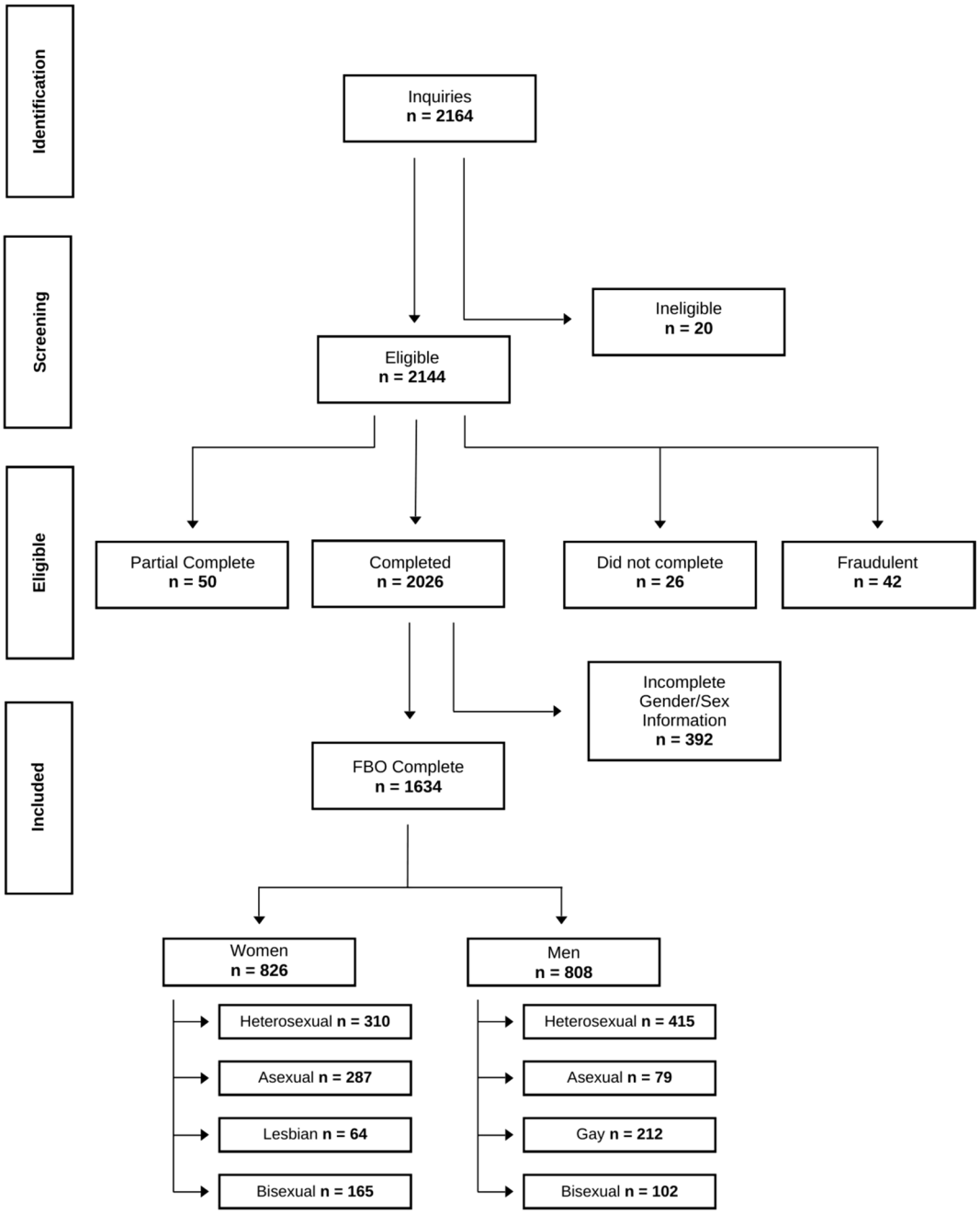

Fig. 1 CONSORT diagram for participants in sexual orientation groups

scheduled a telephone screening, in which to assess eligibility as well as explain study purpose and procedures. During the initial brief telephone screening, interested participants were informed in broad terms that this study was investigating sexual identity and a few personal questions about their sexuality would be asked to determine eligibility. Following the telephone screening, eligible participants received an individualized link to access the study questionnaires and a copy of the consent form, either through email or mail based on their preference. After providing consent, online questionnaires were completed using Qualtrics and took approximately 40 min to complete.

Data were collected on participants' personal demographic characteristics including age, ethnicity, country of origin, etc., and on their sexual orientation and history of sexual relationships. Sexual orientation was assessed by asking participants "What is your sexual orientation?" with asexual, bisexual, demisexual, heterosexual, homosexual, and pansexual as response options. Participants who chose demisexual were categorized as asexual ($n = 29$) and those who chose pansexual were excluded from analyses ($n = 35$). In order to check for any potential impact of these decisions on sibship effect findings, all the analyses using Ablaza et al. (2022) method were also conducted with asexual groups not including demisexual participants and with bisexual groups including pansexual participants and the pattern of results remained unchanged.

In addition, participants filled out a detailed sibling questionnaire (Blanchard, n.d.). The questionnaire collects information about each of participant's siblings: their birth order in relation to the participant, whether they have a twin, whether they have the same father or are a half-sibling, their age and sex, and whether or not they have ever had a live-in relationship with someone of the opposite sex. The questionnaire also asked several biodemographic questions about the participant's parents, such as their height, weight, and education.

Participants were asked separate questions about their sex (male or female), current gender (man, woman, and a number of non-binary options), and whether they had trans experience. Participant sex was taken from the sibling questionnaire in which participants listed themselves as well as their siblings. However, it became apparent that some participants with trans experience would list their sex as the one they identified as rather than the one they were assigned at birth. Sibling composition effects examined in this study have been predominantly theorized as having a biological basis consistently described by mechanisms and processes rooted in a binary and genetically determined male versus female sex. Therefore, in this very first study of all established sibling effects on population of asexual individuals, we elected to limit our examination to only those participants whose gender category (women and men) was accurately reflecting sex assigned at birth. Thus, participants were included in the analyses for this study and categorized as women if their self-reported sex was female, their self-reported gender was woman, and they indicated no trans experience. Equivalent criteria were used for assigning participants as men.

Participants also completed the Asexuality Identification Scale (AIS) developed and validated by Yule et al. (2015) that consists of 12 questions asking respondents about the level of their sexual attractions and their endorsement of asexual identity. The scale scores range from 12 to 60 with higher scores indicating stronger endorsement of asexuality. A total scale score of 40 or more (out 60) has been proposed as a cutoff value identifying people likely to self-identify as asexual (Yule et al., 2015).

Following completion of the questionnaires, participants were compensated either with a coffee gift card or a virtual Visa prepaid card at a value of $10 CAD based on their location.

Data Analysis

Sibling effects were analyzed using the latest technique first proposed by Ablaza et al. (2022) with additional simplification suggested by Ablaza et al. and explicated by Blanchard (2022). We are also introducing a further small modification to this method. We conducted logistic regressions in which sibling variables predicted the likelihood of a participant belonging to sexual minority versus being heterosexual. The analyses were conducted separately for men and women in each sexual minority (asexual, same-sex attraction, and bisexual). For each of those six comparisons, two logistic regressions were conducted with a dichotomous outcome coded as 0 for heterosexual participant and 1 for a particular sexual minority being tested. In the first logistic regression, three sibling variables used as predictors were number of all siblings, number of older brothers, and number of older sisters thus evaluating impact of each while keeping the other two predictors constant. In the second logistic regression, number of older siblings is added to number of all siblings and number of older brothers, in which case the older brothers variable determines the difference between the effect of older brothers and older sisters from the first model.

The statistical reasoning behind these models is explained in detail in Ablaza et al. (2022) and Kabátek and Blanchard (2024). We followed Kabátek and Blanchard's (2024) terminology for all the sibship effects (see this issue for their article) while somewhat reorganizing their models. In summary, the overall number of siblings variable evaluates the effect of adding one younger sibling to a participant's sibship without changing participant's rank in birth order or their older sibling composition. This effect is called Younger Sibling Addition Effect (YSAE) and reflects the FFE as seen in previous publications. Because all siblings and older sister numbers

are kept constant, the number of older brothers variable in the first model evaluates the impact of adding one older brother to replace a younger sibling; therefore, it is termed Older Brother Swap Effect (OBSE) and represents what has been known as FBOE. The number of older sisters variable, with all siblings and older brothers being constant, evaluates impact of adding one older sister to replace a younger sibling and is termed Older Sister Swap Effect (OSSE). This effect is roughly equivalent to SBOE. Thus, our first model differs from Kabátek and Blanchard's (2024) baseline parametrization model in that ours allowed us to evaluate both fraternal and sororal effects in the same analysis. The second model was conducted solely to evaluate the statistical significance of the difference between OBSE and OSSE. This was done by including the number of all siblings, the number of older siblings, and the number of older brothers. With all siblings and older siblings being held constant, the older brothers variable evaluates the impact of swapping one older sister for one older brother in the sibship; hence, the term Brother Sister Swap Effect (BSSE) and reflects what has been described previously as the FBOE-SBOE difference. The models are summarized in Table 1.

All four sibship effects were also tested using the Khovanova (2020) method in which proportions of participants with zero or one sibling of either sex (depending on which sibship effect is tested) are compared between heterosexual and other sexual orientation participants. The Blanchard and Lippa (2021) modification of the Khovanova method was used in order to test all four effects. This analysis includes only subsamples of participants with either zero or one sibling of a particular sex. The classic Khovanova results are reported as 2×2 proportion tables but in this study we transformed and reported them as odds ratios to be consistent with the main analysis that used the Ablaza et al. (2022) method.

The potential association of only-child status with asexuality and other sexual orientations was evaluated by a series of logistic regression models with dichotomized only-child status as a predictor of non-heterosexual sexual orientation.

Results

Participant Demographics

Participant demographic information is presented in Table 2. The final sample included 310 heterosexual, 287 asexual, 64 lesbian, and 165 bisexual women with mean ages of 26.9 (8.2), 26.6 (6.8), 29.8 (8.9), and 27.8 (7.4), respectively, and 415 heterosexual, 79 asexual, 212 gay, and 102 bisexual men with mean ages of 28.4 (9.9), 29.7 (9.4), 32.4 (11.4). and 31.0 (11.6), respectively. Lesbians were older than heterosexual and asexual women and gay and bisexual men were older than heterosexual men. Both asexual women and men reported lower household incomes than the other three sexual orientation groups. The most common racial group reported by sexual minority participants was White/European, especially for the asexual group in which 83% of women and 77% of men reported identifying as White. Other racial groups were more commonly endorsed by heterosexual participants, for example, 22% of heterosexual women and 20% of heterosexual men identified as Chinese. Participants reported 48 different countries of residence with the majority residing in Canada (62%) and the USA (28%). In order to test for potential impact of ethnic diversity in our sample all the sibship effect testing models were re-run with a dichotomous (White versus Non-White) covariate using Ablaza et al. (2022) method. The results, presented in the supplemental Table S1, showed the

Table 1 Parameterization of logistic regressions testing sibship effects

Predictor variable	Statistical interpretation of coefficient	Acronym	Full label	Theoretical interpretation
First model				
Number of Siblings	One younger sibling is added to sibship	YSAE	Younger Sibling Addition Effect	Female fecundity effect (FFE)
Number of Older Brothers	One older brother replaces one younger sibling	OBSE	Older Brother Swap Effect	Fraternal birth order effect (FBOE)
Number of Older Sisters	One older sister replaces one younger sibling	OSSE	Older Sister Swap Effect	Sororal birth order effect (SBOE)
Second model				
Number of Siblings	One younger sibling is added to sibship	YSAE	Younger Sibling Addition Effect	Female fecundity effect (FFE)
Number of Older Siblings	One older sister replaces one younger sibling	OSSE	Older Sister Swap Effect	Sororal birth order effect (SBOE)
Number of Older Brothers	One older brother replaces one older sister	BSSE	Brother–Sister Swap Effect	Difference between FBOE and SBOE

Table 2 Sociodemographic and sexuality-related information for participants across sexual orientation groups

Variable	Women				Men			
	Hetero-sexual ($n=310$)	Asexual ($n=287$)	Lesbian ($n=64$)	Bisexual ($n=165$)	Hetero-sexual ($n=415$)	Asexual ($n=79$)	Gay ($n=212$)	Bisexual ($n=102$)
Age*/*** *M* (SD)	26.9 (8.2)[a]	26.6 (6.8)[a]	29.8 (8.9)[b]	27.8(7.4)[ab]	28.4 (9.9)[a]	29.7 (9.4)[ab]	32.4 (11.4)[b]	31.0 (11.6)[b]
Yearly Household Income in ranges***/*** *M* (SD)	4.3 (2.8)[a]	3.3 (2.1)[b]	4.2 (2.3)[a]	3.9 (2.4)[a]	5.1 (2.9)[a]	3.7 (2.3)[b]	4.7 (2.5)[a]	4.7 (2.7)[a]
Range equivalent to mean	40 K–60 K	20 K–40 K	40 K–60 K	40 K–60 K	60 K–80 K	40 K–60 K	60 K–80 K	60 K–80 K
Race***/*** *N(%)*								
Arab/West Asian	8 (2.6)	2 (0.7)	1 (1.6)	1 (0.6)	11 (2.7)	1 (1.3)	3 (1.4)	2 (2.0)
Black	13 (4.2)	5 (1.8)	3 (4.8)	15 (9.3)	13 (3.1)	3 (3.8)	2 (1.0)	1 (1.0)
Chinese	68 (22.1)	9 (3.2)	5 (7.9)	6 (3.7)	82 (19.8)	3 (3.8)	16 (7.6)	9 (8.9)
Filipino	7 (2.3)	0 (0.0)	2 (3.2)	2 (1.2)	8 (1.9)	2 (2.6)	10 (4.8)	5 (5.0)
Hispanic/Latin American	11 (3.6)	16 (5.6)	5 (7.9)	7 (4.3)	25 (6.0)	2 (2.6)	16 (7.6)	7 (6.9)
Indigenous	0 (0.0)	0 (0.0)	1 (1.6)	5 (3.1)	2 (0.5)	0 (0.0)	3 (1.4)	0 (0.0)
Japanese	1 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.5)	0 (0.0)	0 (0.0)	0 (0.0)
Korean	2 (0.7)	1 (0.4)	0 (0.0)	0 (0.0)	16 (3.9)	0 (0.0)	2 (1.0)	1 (1.0)
South Asian	19 (6.2)	6 (2.1)	0 (0.0)	4 (2.5)	34 (8.2)	1 (1.3)	8 (3.8)	8 (7.9)
Southeast Asian	15 (4.9)	2 (0.7)	1 (1.6)	0 (0.0)	8 (1.9)	1 (1.3)	4 (1.9)	2 (2.0)
White/European	147 (47.9)	235 (82.7)	39 (61.9)	112 (69.1)	192 (46.4)	60 (76.9)	133 (63.3)	63 (62.4)
Other	16 (5.2)	8 (2.8)	6 (9.5)	10 (6.2)	21 (5.1)	5 (6.4)	13 (6.2)	3 (3.0)
Asexuality Identification Scale***/*** *M* (SD)	19.1 (7.4)[a]	50.5 (7.8)[c]	19.6 (7.6)[ab]	20.8 (8.1)[b]	17.6 (5.8)[a]	47.6 (8.2)[b]	18.2 (6.1)[a]	18.3 (6.4)[a]
Relationship status***/*** *N(%)*								
Single	98 (31.8)	201 (70.3)	16 (25.0)	42 (25.9)	149 (36.3)	56 (71.8)	80 (39.0)	29 (28.4)
Short-term relationship	44 (14.3)	7 (2.4)	8 (12.5)	16 (9.9)	58 (14.1)	5 (6.4)	29 (14.1)	12 (11.8)
Long-term relationship	157 (51.0)	70 (24.5)	37 (57.8)	98 (60.5)	19 (47.3)	14 (17.9)	87 (42.4)	52 (51.0)
Separated/Divorced /Widowed	9 (2.9)	8 (2.8)	3 (4.7)	6 (3.7)	9 (2.2)	3 (3.8)	9 (4.4)	9 (8.8)
Length of current relationship***/** *M* (SD)	2.6 (4.5)[a]	1.4 (3.4)[b]	2.2 (3.1)[ab]	3.2 (4.6)[a]	3.0 (5.2)[a]	1.2 (4.3)[b]	2.5 (5.4)[a]	3.1 (4.5)[a]
Length of longest relationship***/*** *M* (SD)	3.9 (4.7)[a]	2.3 (3.7)[c]	4.4 (3.8)[ab]	4.8 (4.6)[b]	4.4 (5.5)[a]	2.5 (4.4)[c]	4.4 (6.3)[ab]	5.7 (6.2)[b]
No. of sexual partners***/*** *M* (SD)	8.8 (13.7)[a]	2.7 (6.0)[c]	10.5 (11.1)[a]	15.4 (24.1)[b]	11.5 (21.1)[a]	5.7 (13.9)[a]	90.3 (221.9)[b]	24.1 (32.6)[a]
No. of romantic partners***/n.s. *M* (SD)	5.1 (6.7)[a]	2.5 (4.8)[c]	5.4 (5.3)[ab]	6.3 (7.4)[b]	5.3 (9.6)	4.2 (11.5)	5.1 (7.2)	5.6 (5.4)
Unwanted/non-consensual sexual contact***/*** *N(%)*								
Yes	145 (48.0)	121 (43.1)	36 (56.3)	104 (65.4)	87 (21.2)	29 (37.2)	89 (42.4)	48 (47.5)
No	157 (52.0)	160 (56.9)	28 (43.8)	55 (34.6)	324 (78.8)	49 (62.8)	121 (57.6)	53 (52.5)
Sexual difficulties n.s./* *N(%)*								
Yes	42 (13.8)	43 (16.2)	8 (12.5)	32 (19.9)	49 (11.9)	20 (26.0)	36 (17.1)	17 (17.0)
No	262 (86.2)	223 (83.8)	56 (87.5)	129 (80.1)	363 (88.1)	57 (74.0)	175 (82.9)	83 (83.0)
Treatment for sexual dysfunction *N(%)*								
Yes	8 (2.6)	5 (1.7)	1 (1.6)	3 (1.8)	13 (3.1)	4 (5.1)	17 (8.0)	6 (5.9)
No	302 (97.4)	282 (98.3)	63 (98.4)	161 (98.2)	401 (96.9)	75 (94.9)	195 (92.0)	95 (94.1)

Significance is marked by asterisks, first for women (left to the slash) and then for men (right to the slash) and is for omnibus tests, chi-square tests for categorical variables, and *F* tests (Welch test in case of homogeneity of variance assumption violation) for numerical variables

*$p<0.05$, **$p<0.01$, *** $p<0.001$

Means with no common letter superscripts (a, b, c) are significantly different at $p<.05$

same pattern of findings with very similar odds ratios and confidence intervals.

As expected, asexual participants scored above the suggested score of 39 on the Asexual Identification Scale (Table 2) with women obtaining a mean score of 51 (85% scored above 39) and men obtaining a mean of 48 (89% scored above 39). These mean scores were also significantly and largely higher than the AIS scores in all other sexual orientation groups whose mean scores ranged from 18 (heterosexual men) to 21 (bisexual women). There were no significant differences in AIS scores among non-asexual groups of men whereas bisexual women scored significantly higher on this asexuality measure than heterosexual women. With regards to other sexuality-related demographics, asexual women (70%) and asexual men (72%) were more likely to be single than other groups (< 32% of women and < 39% of men in the other three groups were single). Asexual participants with relationship experience reported their current relationship and their longest relationship to be shorter than those reported by other sexual orientation groups. Asexual women reported lower number of sexual and romantic partners than all other groups and bisexual women reported higher number of sexual partners than all other groups and higher number of romantic partners than heterosexual and asexual women. Same-sex attracted men reported more sexual partners than any other group of men; however, there were no significant differences among men regarding number of romantic partners. Bisexual women reported a higher rate of experiencing unwanted sex than heterosexual or asexual women whereas all three minority sexual orientation groups of men reported higher rate of experiencing unwanted sex than heterosexual men. Finally, asexual men reported more sexual concerns than heterosexual men.

Sibship Effects

The number of siblings in different categories for each sexual minority, by sex, is presented in Table 3. Among the women participants, asexuals reported lower number of older siblings and both asexual and bisexual groups reported fewer older sisters than heterosexual women. Bisexual women also reported more younger brothers than heterosexual women. Among men, all three sexual minority groups reported higher mean number of all siblings, with asexual men also reporting higher number of younger siblings and younger sisters and homosexual men reporting higher number of older siblings and higher number of older sisters than heterosexual men.

Table 3 also presents percentages of only-child participants in each sexual orientation group of women and men. Asexual women and lesbians exhibited higher proportion of only-children compared to heterosexual women (21% of asexual women and 21% of lesbians versus 14% of heterosexual women). Logistic regression revealed, however, that this difference was statistically significant only for asexual women ($OR = 1.60$, 95%CI [1.03, 2.47], $p = 0.035$) and did not reach statistical significance for lesbians ($OR = 1.64$, 95%CI [0.82, 3.28], $p = 0.161$). There was no indication of only-child status effect for any other sexual minority group of women or men.

Table 4 presents the ratio of older brothers to older sisters for each group. This ratio is calculated as number of older brothers over number of older sisters multiplied by 100. Each ratio is compared to 106 (which is the male to female birth ratio in the general population) using a binomial test. This comparison is most important for the heterosexual group because it allows one to evaluate how well our heterosexual participants represent the general, predominantly heterosexual, population. Our results suggest that the ratio is skewed for heterosexual women indicating that this group has a deficit of older brothers or, more likely when examined together with the results in Table 3, an excess of older sisters as compared to general population. Our sibling composition results will be discussed with this finding in mind.

The sibship effects tested by both the Ablaza et al. and Khovanova method are presented in Table 5. Using the Ablaza et al. approach, for women participants, having fewer older sisters was associated with a higher likelihood of being asexual or bisexual (odds ratio for OSSE significantly smaller than 1). For bisexual women, the BSSE effect was also significant indicating significant difference in magnitude between OSSE and OBSE for this group. For men, a higher number of siblings was associated with increased likelihood of being asexual or bisexual (odds ratio for YSAE significantly greater than 1) and a higher number of older sisters predicted higher likelihood of identifying as gay (odds ratio for OSSE significantly greater than 1). There was no significant older brother effect for any sexual minority group when compared with heterosexual group.

The analysis using the Khovanova approach produced two significant effects related to OBSE that were not found using Ablaza et al. method: gay men reported more older brothers than heterosexual men (FBOE) and bisexual women reported fewer older brothers than heterosexual women. Findings related to OSSE were fully corroborated by this analytical approach whereas the significant YSAE effects from Ablaza et al. approach did not reach significance.

Discussion

To our knowledge, this was the first attempt to collect complete sibling information in order to examine potential presence of fraternal birth order and other sibship effects in an asexual sample (the only other study on this topic, Yule et al.,

Table 3 Estimated means and standard errors of number of siblings and only-child percentages across sexual orientation groups

	Heterosexual	Asexual	Homosexual	Bisexual
Women				
Number of Siblings	1.50	1.37	1.63	1.57
	(0.07)	(0.08)	(0.16)	(0.09)
Number of Older Siblings	0.75	**0.56**	0.84	0.64
	(0.06)	(0.05)	(0.15)	(0.07)
Number of Younger Siblings	0.75	0.81	0.80	0.94
	(0.06)	(0.06)	(0.14)	(0.07)
Number of Older Brothers	0.33	0.30	0.47	0.36
	(0.03)	(0.03)	(0.10)	(0.05)
Number of Older Sisters	0.42	**0.26**	0.37	**0.29**
	(0.04)	(0.03)	(0.08)	(0.04)
Number of Younger Brothers	0.40	0.41	0.50	**0.55**
	(0.04)	(0.04)	(0.10)	(0.06)
Number of Younger Sisters	0.35	0.41	0.31	0.39
	(0.04)	(0.04)	(0.08)	(0.05)
n (%) of only-child participants	42 (13.9)	58 **(20.5)**	13 (21.0)	19 (11.9)
Men				
Number of Siblings	1.32	**1.66**	**1.58**	**1.64**
	(0.05)	(0.15)	(0.07)	(0.14)
Number of Older Siblings	0.68	0.70	**0.94**	0.86
	(0.04)	(0.09)	(0.06)	(0.12)
Number of Younger Siblings	0.64	**0.97**	0.64	0.78
	(0.04)	(0.14)	(0.06)	(0.10)
Number of Older Brothers	0.39	0.32	0.47	0.43
	(0.03)	(0.07)	(0.05)	(0.08)
Number of Older Sisters	0.30	0.38	**0.46**	0.42
	(0.03)	(0.07)	(0.05)	(0.07)
Number of Younger Brothers	0.34	0.46	0.36	0.48
	(0.03)	(0.08)	(0.05)	(0.08)
Number of Younger Sisters	0.30	**0.52**	0.29	0.30
	(0.03)	(0.10)	(0.04)	(0.05)
n (%) of only-child participants	70 (17.4)	10 (13.0)	27 (12.9)	13(13.5)

Bold print indicates for the number of sibling categories that the mean estimate is significantly different from the sample mean of the reference group (heterosexual respondents of the same gender) and for the only-child status that the percentage of only-children is different from % in heterosexual group at 5% significance level

Table 4 Ratio of older brothers to older sisters across sexual orientation groups

Sex	Sexual orientation			
	Asexual	Homosexual	Bisexual	Heterosexual
Men	120	102	102	130
Women	112	126	121	**77**

Ratio of older brothers to older sisters expresses number of older brothers per one hundred older sisters. Bold print indicates that the estimated sex ratio is significantly different from 106:100, and in this case it is significant at 1% level

2014, did not collect information on younger siblings). We recruited 366 asexual individuals of which 78% identified as women and 22% as men. This higher representation of women in our asexual group is consistent with other surveys done on the asexual population (Bogaert, 2004; Ginoza et al., 2014). Our asexual participants' characteristics such as relationship history and scores on the AIS measure provided quantitative support for their self-identification as asexual.

Our analyses were conducted using the most recent statistical approach that attempts to disentangle older sibling effects from family size effects (Ablaza et al., 2022) and the results were further verified using Khovanova (2020) method which also separates these two effects albeit on smaller subsamples. We found that higher overall number of siblings

Table 5 Impact of sibling composition variables on the odds of endorsing a minority sexual orientation identity versus heterosexual identity for women and men

Effect		Sexual orientation								
		Asexual versus Heterosexual			Lesbian/Gay versus Heterosexual			Bisexual versus Heterosexual		
		95% CI			95% CI			95% CI		
		OR	LL	UL	OR	LL	UL	OR	LL	UL
OBSE (equivalent to fraternal birth order effect, FBOE)										
Women	AEA	0.960	0.704	1.310	1.346	0.871	2.081	1.003	0.709	1.419
	KBL	0.615	0.338	1.119	0.958	0.304	3.016	0.295**	0.126	0.687
Men	AEA	0.638	0.406	1.002	1.146	0.848	1.550	0.871	0.598	1.270
	KBL	0.485	0.173	1.356	1.973*	1.092	3.566	1.261	0.587	2.709
OSSE (equivalent to sororal birth order effect, SBOE)										
Women	AEA	0.644**	0.475	0.871	0.812	0.513	1.285	0.617**	0.434	0.879
	KBL	0.437**	0.233	0.818	0.708	0.208	2.407	0.306**	0.136	0.688
Men	AEA	0.952	0.637	1.424	1.384*	1.028	1.863	1.078	0.748	1.556
	KBL	0.982	0.365	2.641	2.578**	1.333	4.986	0.818	0.286	2.343
BSSE (equivalent to difference between fraternal and sororal birth order effect, FSED)										
Women	AEA	1.491	0.977	2.276	1.658	0.890	3.090	1.625*	1.009	2.617
	KBL	1.408	0.673	2.947	1.354	0.337	5.440	0.963	0.335	2.765
Men	AEA	0.670	0.384	1.168	0.828	0.579	1.184	0.808	0.505	1.293
	KBL	0.494	0.139	1.749	0.765	0.384	1.525	1.541	0.503	4.723
YSAE (equivalent to female fecundity effect, FFE)										
Women	AEA	1.022	0.868	1.204	1.063	0.822	1.375	1.156	0.950	1.406
	KBL	0.850	0.510	1.417	0.468	0.189	1.162	1.666	0.869	3.193
Men	AEA	1.469**	1.146	1.883	1.114	0.901	1.377	1.328*	1.029	1.714
	KBL	1.336	0.594	3.005	0.754	0.417	1.365	1.114	0.516	2.405

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$;

Odds ratios are reported from logistic regression analyses in which the criterion variable is coded as heterosexual = 0, sexual minority = 1; OBSE (Older Brother Swap Effect) = Effect of older brothers on the odds of a sexual minority orientation, OSSE (Older Sister Swap Effect) = Effect of older sisters, BSSE (Brother–Sister Swap Effect) = Difference in magnitude between the effect of older brothers and the effect of older sisters, YSAE (Younger Sibling Addition Effect) = Effect of family size; AEA = method used in Ablaza et al. (2022); KBL = method used by Khovanova (2020) with Blanchard and Lippa's (2021) modification

(female fecundity effect) was associated with higher probability of asexuality in men (adding one younger sibling to the sibship increased the odds of the participant being asexual versus heterosexual by 47%). This effect is consistent with FFE found for the population of gay men (Camperio-Ciani et al., 2004), therefore, one may consider using balancing selection hypothesis to explain it. In other words, it is possible that genes that predispose men to be asexual may also increase fecundity in their female relatives. Thus, the evolutionary paradox of the presence of asexuality in men may be explained similarly to the presence of homosexuality in men–even though asexual men are probably even less likely to produce offspring than gay men, the genetic link between asexuality and the fecundity of their maternal female relatives balances the reduced direct fitness of asexual men. Such explanation, however, should be considered with caution given the inconsistency of the evidence for the balancing selection hypothesis in the research on homosexual men as discussed in the introduction of this paper.

The results of our study did not provide support for the fraternal birth order effect in asexual men, with the odds ratio for OBSE being 0.638 which is in the opposite direction to FBOE suggesting that a deficit rather than excess of older brothers is associated with asexuality in men. However, such a suggestion must be made with caution since the ratio did not reach statistical significance ($p = 0.051$). Such convincing lack of FBOE makes it unlikely that the maternal immune hypothesis is associated with the development of asexuality. Of course, as this is the first study to comprehensively examine the FBOE and sibship effects among asexual men and women, future studies should attempt to replicate these findings.

We also found that having fewer older sisters predicted an increased probability of asexuality in women (replacing one younger sibling with one older sister decreased the odds of

the participant being asexual versus heterosexual by 36%). This finding needs to be interpreted with caution in light of the fact that our control heterosexual sample of women was characterized by a deficit of older brothers (smaller than expected ratio of older brothers to older sisters which results in excess of older sisters) in comparison with general population which may indicate presence of stopping rules in our sample (parents using informal rules when deciding whether to have another child, often related to parental preference for a child of a particular sex). This caution is important because the Ablaza et al. (2022) method was not found to be more robust than other analytical methods against potential confounding effect of the stopping rules (Blanchard, 2022). However, this finding of an older sister deficit among asexual women is also consistent with the results of Yule et al. (2014), therefore, we are reluctant to dismiss it as a mere artifact of a biased control group. If considered a true reflection of the asexual women population having fewer older sisters than heterosexual women, and if replicated in future studies, such an effect can be seen as providing new evidence for a potential biological component in the development of asexual sexual orientation in women. A mechanism for this older sister deficit effect may be linked to a previously hypothesized explanation for our finding that asexual women are more likely to be only-children than heterosexual controls. Blanchard (2012) proposed that a maternal immune reaction to fetus separate from the one hypothesized to underly FBOE, may be responsible for frequent miscarriages (hence increased likelihood of a single offspring) and may affect the development of sexual orientation of the child. However, these findings can alternatively be viewed as reflecting a family socialization effect on sexual orientation development (Friedman et al., 2019). For example, it may be easier for women to identify as asexual (or bisexual) if they are not exposed to modeling of heterosexual behavior by older sisters. The same effect of an older sister deficit was found for bisexual women in our study. Again, this effect can either be attributed to the biased nature of our control group of heterosexual women (smaller than expected older brother to older sister ratio) or viewed as reflecting either still unknown biological mechanism in development of bisexuality in women or socialization component mentioned above.

Regarding the replication of sibship effects in relation to same-sex orientation, no significant sibling effects were found for women with a same-sex orientation (i.e., self-identifying as lesbian) although the effect testing FBOE was in the predicted direction (Odds Ratio = 1.346 indicating that having an older brother increased the odds of being a lesbian by 35%). The lack of significant findings for lesbian participants should be interpreted with caution due to these comparisons being underpowered (see below for more detailed discussion regarding power of our analyses). Regardless of our best efforts, the recruitment of lesbians fell short of the intended target. For same-sex attracted men (i.e., self-identifying as gay), although the fraternal birth order effect, female fecundity effect, and sororal birth order effect were in the predicted direction, none of them reached significance in the primary analysis using Ablaza et al. approach. However, fraternal birth order effect was found to be significant in the analysis using the Khovanova approach on a subsample. The diversity of our sample (discussed below) may be responsible for reducing the effect in the whole sample. Bisexual men, similarly to asexual men, showed female fecundity effect (adding one younger sibling to the sibship increased the odds of participant being bisexual versus heterosexual by 33%) prompting a speculation that the balancing selection hypothesis may be applicable. It is possible that genes that predispose men to be bisexual may also increase fertility in their female relatives.

Since this was the first study to fully evaluate sibship effects in an asexual sample, we employed particular gender and sex criteria. Our final analytic sample all identified as cisgender women and men (their gender identification as women and men aligned with their sex assignment at birth as female and male, respectively) and they all indicated absence of any transgender experience. This, however, excluded a substantial number of participants who identified as asexual because of very high rate of gender diversity in that population (Antonsen et al., 2020). In our study, 140 asexual participants reported trans/gender non-binary identity and were excluded from our analysis. Future studies of potential biological mechanisms of asexuality development should seek to include all asexuals regardless of gender identity. It is important to continue examining potential sibship effects in gender diverse asexual individuals in light of well-established correlation between gender identity and sexual orientation which points to biological contributions to the development of those two dimensions (Roselli, 2018).

Even though our sexual minority groups ended up considerably smaller than intended, it should not substantially negatively affect the power of our analysis for most comparisons. Our original power analysis estimated 20% of sexual minority participants for a given comparison under null hypothesis and a total sample of 500. So, the two models that might be considered somewhat underpowered were the one comparing lesbian participants to heterosexual women ($n = 364$ included in the analysis, 17% lesbian participants) and the one comparing asexual men to heterosexual men ($n = 478$, 16% asexual participants). The sample sizes included in other models ranged from 462 (bisexual versus heterosexual women) to 610 (gay versus heterosexual men) thus staying close to or exceeding the planned $n = 500$, and the percentages of sexual minority participants ranged from 19 to 48%. Our models also followed the 1 in 10 rule of thumb which requires at least ten events per predictor since the sexual orientation

minority groups (number of events) always well exceeded 30 (3 predictors × 10).

There are some limitations to our study that need to be considered. Our sample of asexual men was rather small ($n = 79$) and therefore may limit the generalizability of our results. Considering small prevalence of asexual sexual orientation among men it would be a challenge for any study to recruit a much bigger sample so the final conclusions about biological correlates of asexuality in men might rely on accumulation of studies and synthesizing of multiple study results in the future. Another limitation to generalizability of our results comes from the fact that vast majority of our asexual participants (83% of women and 77% of men) reported White/European ethnic origin. Finally, the deficit of older brothers/excess of older sisters in our control sample of heterosexual women (as compared to what would be expected in general population) introduced potential ambiguity when interpreting sibling composition effects in non-heterosexual orientation groups of women.

Our main recruiting goal was to obtain a large sample of individuals identifying as asexual. To this effect, we advertised the study as widely as possible, intentionally attempting to reach international audience which may have created a limitation related to a substantial diversity of the final sample. Our recruiting approach may have increased the likelihood of recruiting small groups of participants from a multitude of social, cultural, and ethnic contexts, with none of those populations being well represented and resulting in the inflation of sampling error. This, in turn, may be responsible for the lack of replication of some well-established sibship effects like fraternal birth order in gay men which we only found when using the Khovanova method analysis of a subsample. In an attempt to control for this diversity, we re-run all the logistic regression models with dichotomized ethnicity (White versus Other Than White) as a covariate but the pattern of results remained the same. It is likely that the diversity of our sample was related to other unmeasured variables.

Conclusions

Overall, from among the sibship effects documented in gay/lesbian population we only found one for asexual men: increased number of siblings (FFE) predicted higher probability of being asexual. We found the opposite to the sororal birth order effect for asexual and bisexual women (having fewer older sisters was associated with higher likelihood of asexuality), and we found elevated rate of only-child status among asexual women. We found no replication of sibship effects for lesbians and only partial replication for gay men (SBOE) and bisexual men (FFE). The implications of these findings point to potential sibship-related contribution to development of asexuality in women and men. Future studies should seek to replicate our findings and to forge hypotheses related to sibling composition including only-child status that would articulate potential mechanisms underlying such links and would allow for inclusion of gender diverse asexual participants.

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Declarations

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