

SUPPLEMENTARY MATERIALS FOR

Do psychosocial factors mediate sexual minorities' risky sexual behaviour? A twin study

Supplementary Table S1

Item-level Missingness

Variable	Phase of assessment	Total no of participants	Total number in analyses	Item missingness n (%)
Sexual orientation	1	9525 (216 – no interest/unsure)	9309	388 (4.00)*
Depressive symptoms	1	qc=77, no response=14, less than 6 items=3	9395	302 (3.11)
Item 1		9486		211 (2.18)
Item 2		9488		209 (2.16)
Item 3		9488		209 (2.16)
Item 4		9489		208 (2.14)
Item 5		9487		210 (2.17)
Item 6		9486		211 (2.18)
Item 7		9487		210 (2.17)
Item 8		9485		212 (2.19)
Generalized anxiety symptoms	2	Less than 8 responses =1	8483	235 (2.70)
Item 1		8484		234 (2.68)
Item 2		8484		234 (2.68)
Item 3		8483		235 (2.70)
Item 4		8483		235 (2.70)
Item 5		8484		234 (2.68)
Item 6		8483		235 (2.70)
Item 7		8481		237 (2.72)
Item 8		8483		235 (2.70)
Item 9		8482		236 (2.70)
Item 10		8483		235 (2.70)
Early-Life adversities	2		8607	111 (1.27)
Item 1		8644		74 (0.85)
Item 2		8640		78 (0.89)
Item 3		8628		90 (1.03)
Item 4		8629		89 (1.02)
Item 5		8625		93 (1.07)
Item 6		8624		94 (1.08)
Item 7		8626		92 (1.06)
Item 8		8621		97 (1.11)
Intimate Partner violence	1		9225	472 (4.87)
Item 1		9226		471 (4.86)
Item 2		9238		459 (4.73)
Item 3		9222		475 (4.90)
Item 4		9228		469 (4.84)
Item 5		9214		483 (4.98)
Item 6		9232		465 (4.80)

Supplementary Table S1 continued

Other illicit drugs	2		8396	322 (3.69)
Item 1		2689		31 (1.14)*
Item 2		2714		6 (0.22)*
Item 3		2699		21 (0.77)*
Item 4		2712		8 (0.29)*
Item 5		2716		4 (0.15)*
Item 6		2715		5 (0.18)*
Item 7		2715		5 (0.18)*
AUDIT	2	Less than 8 responses=1, qc=7	8531	187 (2.14)
Item 1		8178		3 (0.04)*
Item 2		7415		7 (0.09)**
Item 3		7412		10 (0.13)**
Item 4		7411		11 (0.15)**
Item 5		7414		8 (0.11)**
Item 6		7410		12 (0.16)**
Item 7		7412		10 (0.13)**
Item 8		7413		8 (0.11)**
Item 9		7413		9 (0.12)**
Item 10		7414		8 (0.11)**
Cannabis	2		8373	345 (3.96)
Item 1		2319		0 (0.00)*
Item 2		2319		0 (0.00)*
Item 3		2318		1 (0.04)*
Item 4		2318		1 (0.04)*
Item 5		2315		4 (0.17)*
Item 6		2317		2 (0.09)*
Lifetime sexual partners	1	8972		725 (7.48)

Sexual orientation: *missing includes 216 participants who were unsure or had no sexual interest

Alcohol: *n=8181, 371 had never taken alcohol; **n=7422, 759 responded never or almost never to first AUDIT question

Smoking: *n = 1118 (3712 had never smoked cigarettes, 3686 were not currently smoking)

Cannabis: *n=2319 (4213 had never used cannabis, 1844 had not used cannabis in the last 12 months)

Other illicit drugs: *n=2720 (5696 had never used any illicit drugs)

Qc = quality control item

Supplementary Table S2*Complete and incomplete twin pairs by sex and zygosity per variable*

Variable	MZM Complete/ Incomplete	DZM Complete/ Incomplete	MZF Complete/ Incomplete	DZF Complete/ Incomplete	DZO Complete/ Incomplete	Complete MZ/DZ	Total individuals
Sexual orientation	479/182	389/242	964/252	772/313	1070/683	1443/2231	9010
Depressive symptoms	479/185	403/232	975/242	785/304	1086/681	1454/2274	9100
Generalized anxiety symptoms	423/176	320/262	895/249	731/294	898/707	1318/1949	8222
Early-Life adversities	429/187	323/269	908/252	733/296	920/711	1337/1976	8341
Intimate Partner violence	455/193	375/250	964/248	777/308	1048/698	1419/2200	8935
Other illicit drugs	416/188	318/262	877/271	698/322	877/726	1293/1893	8141
AUDIT	426/181	321/265	902/255	727/300	904/710	1328/1952	8271
Cannabis	409/193	307/273	877/272	697/320	873/734	1286/1877	8118
Lifetime Sexual Partners	449/200	360/261	913/274	715/350	1011/707	1362/2086	8688

MZM and MZF = Monozygotic same-sex male and female twin pairs respectively, DZM, DZF
and DZO = Dizygotic same-sex male, female and opposite-sex twin pairs respectively.

Supplementary Table S3

Within-individual and cross-twin pair correlations and standard errors for observed variables by zygosity.

	1. Sexual orientation (SE)	2. Depressive symptoms (SE)	3. Generalized Anxiety symptoms (SE)	4. ELA (SE)	5. IPV (SE)	6. Other illicit drug use (SE)	7. Alcohol use (SE)	8. Cannabis use (SE)	9. LSP (SE)
Within-person									
1.	1.00								
2.	.22 (.01)	1.00							
3.	.24 (.02)	.53 (.01)	1.00						
4.	.19 (.02)	.26 (.01)	.27 (.01)	1.00					
5.	.09 (.01)	.24 (.01)	.22 (.01)	.21 (.01)	1.00				
6.	.15 (.02)	.09 (.01)	.11 (.01)	.13 (.01)	.13 (.01)	1.00			
7.	.07 (.02)	.09 (.01)	.09 (.01)	.08 (.01)	.06 (.01)	.43 (.01)	1.00		
8.	.06 (.02)	.06 (.01)	.07 (.01)	.10 (.01)	.09 (.01)	.45 (.01)	.19 (.01)	1.00	
9.	.11 (.01)	.06 (.02)	.01 (.02)	.09 (.02)	.21 (.01)	.36 (.01)	.39 (.01)	.15 (.01)	1.00

SE = Standard error, ELA = Early-Life Adversity, IPV = Intimate Partner Violence, LSP = Lifetime Sexual Partners

MZ = Monozygotic twins. DZ = Dizygotic twins

Supplementary Table S4

Within-individual and cross-twin pair correlations for latent factors by zygosity

	Sexual Orientation 1.	Psychosocial Adversity 2.	Substance Use 3.	Lifetime Sexual Partners 4.
Within-person				
1.	1.00			
2.	.33 (.29, .36)	1.00		
3.	.17 (.14, .21)	.21 (.18, .24)	1.00	
4.	.11 (.08, .14)	.10 (.08, .13)	.46 (.44, .49)	1.00
Cross-twin MZ				
1.	.56 (.49, .63)			
2.	.22 (.17, .27)	.67 (.62, .72)		
3.	.10 (.06, .15)	.15 (.11, .19)	.95 (.91, .99)	
4.	.06 (.02, .10)	.07 (.03, .10)	.39 (.36, .42)	.59 (.56, .062)
Cross-twin DZ				
1.	.22 (.14, .30)			
2.	.14 (.09, .19)	.34 (.28, .39)		
3.	.07 (.02, .12)	.08 (.04, .12)	.48 (.43, .53)	
4.	.02 (-.02, .06)	.04 (.00, .07)	.24 (.20, .27)	.30 (.26, .34)
	Standardised factor loadings	Standardised residual variance		
Sexual orientation	1.00			
Depressive symptoms	.50 (.48, .53)	.50 (.47, .52)		
GA symptoms	.51 (.48, .54)	.49 (.46, .52)		
ELA	.17 (.15, .19)	.83 (.81, .85)		
IPV	.12 (.11, .14)	.88 (.86, .89)		
Other illicit drug use	.67 (.64, .71)	.33 (.29, .36)		
Alcohol use	.29 (.27, .31)	.71 (.69, .73)		
Cannabis use	.26 (.24, .28)	.74 (.72, .76)		
LSP	1.00			

GA = Generalized Anxiety, ELA = Early-Life Adversity, IPV = Intimate Partner Violence, LSP = Lifetime Sexual Partners

MZ = Monozygotic twins, DZ = Dizygotic twins

Supplementary Table S5*Measurement invariance for phenotypic mediation model in male and female participants*

Model	χ^2 (df)	Comparison model	$\Delta\chi^2$ (Δdf)	Decision
M1: Configural Invariance	233860.9 (76828)	-	-	-
M2: Metric Invariance	234220.4 (76833)	M1	359.50 (5)***	Reject
M2a: Partial Metric Invariance	233862.2 (76830)	M1	1.34 (2)	Accept
M3: Scalar Invariance	234743.9 (76835)	M2a	881.68 (5)***	Reject
M3a: Partial scalar Invariance	233865.5 (76832)	M2a	3.23 (2)	Accept
M4: Residual Invariance	236021.5 (76839)	M3a	2155.99 (7)***	Reject
M4a: Partial Residual Invariance	233866.3 (76833)	M3a	0.82 (1)	Accept

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

df = degrees of freedom, Δ df = change in degrees of freedom

Supplementary Table S6*Phenotypic mediation relationships between latent factors*

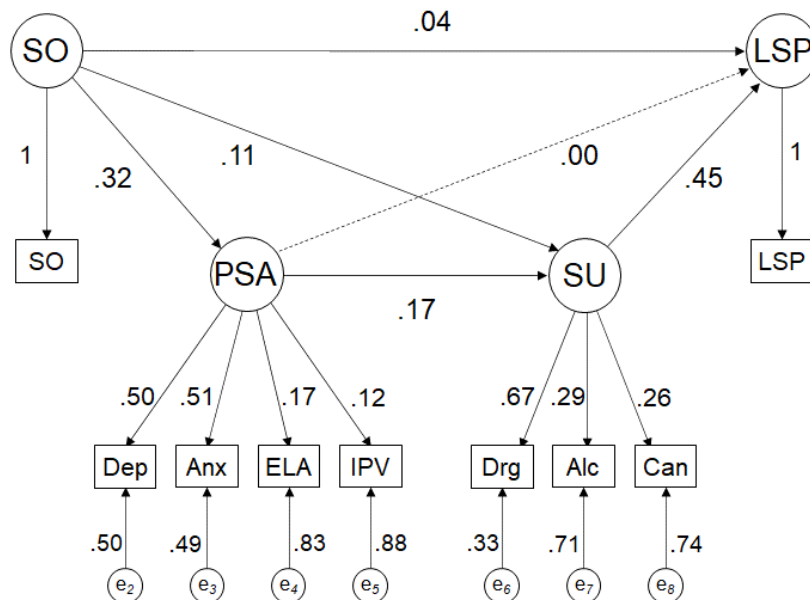
	Estimate	95% CI
Direct effect		
SO -> LSP	.04	(.03, .07)
Mediation paths		
SO -> PSA	.32	(.29, .33)
SO -> SU	.11	(.07, .12)
PSA -> SU	.17	(.17, .18)
PSA -> LSP	.00	(-.01, .00)
SU -> LSP	.45	(.42, .45)
Indirect effect	.07	(.07, .08)
Total effect	.11	(.10, .14)
Proportion mediated (%)	67.3	(48.5, 94.9)

Variables	Standardised factor loadings	Standardised residual variance
Sexual orientation	1.00	
Depressive symptoms	.50 (.50, .51)	.50 (.49, .50)
Anxiety symptoms	.51 (.50, .51)	.49 (.46, .52)
ELA	.17 (.15, .17)	.83 (.83, .85)
IPV	.12 (.12, .13)	.88 (.87, .88)
Other illicit drug use	.70 (.69, .70)	.30 (.30, .33)
Alcohol use	.28 (.28, .31)	.72 (.70, .74)
Cannabis use	.26 (.24, .28)	.74 (.74, .74)
Lifetime sexual partners	1.00	

Note. SO, PSA, SU and LSP = Sexual orientation, Psychosocial adversity, and Lifetime sexual partners latent factors respectively. ELA, IPV = Early-Life Adversity and Intimate Partner Violence variables respectively. Indirect effect derived as a sum of the indirect effects through the individual mediation paths. Model fit indices: -2LL = 241978.6, df = 76873, Model fit not significantly worse when the PSA-RSB path is dropped $\chi^2 [1] = 0.03, p = 0.87$.

Figure S1

Phenotypic factor mediation model



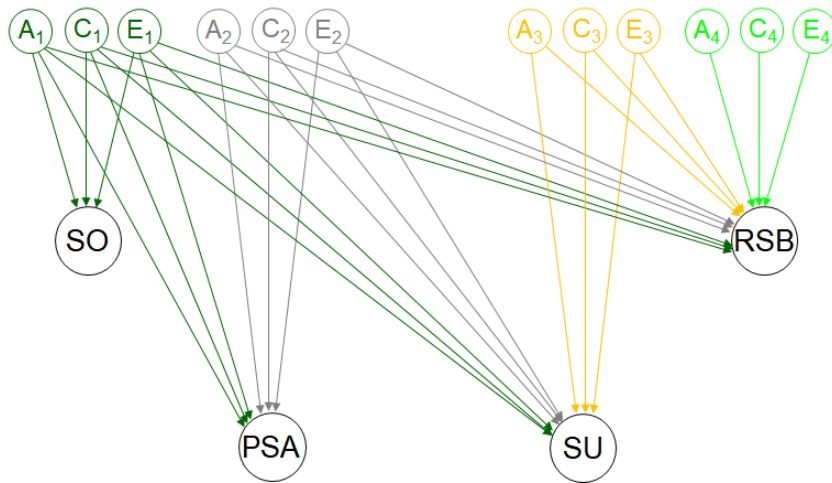
Note. Path diagram depicting mediation relationships between Sexual Orientation (SO), Psychosocial Adversity (PSA), SU (Substance Use) and Lifetime Sexual Partners (LSP) latent factors with standardised path coefficients. Factors were scaled by fixing one loading per factor to 1. SO = Sexual orientation, Dep = Depressive symptoms, Anx = Generalised anxiety symptoms, Alc = Alcohol Use, Can = Cannabis use, Drg = Other illicit drug use, ELA = Early-life adversity, IPV = Intimate partner violence. $e_1 - e_7$ = residual variances for corresponding indicator variables. Solid lines indicate significant paths while dotted lines indicate nonsignificant paths.

Supplementary Table S7*Phenotypic mediation relationships between latent factors in males and females*

	Male		Female	
	Estimate	95% CI	Estimate	95% CI
Direct effect				
SO -> LSP	.09	(0.04, 0.14)	-.03	(-0.07, 0.01)
Mediation paths				
SO -> PSA	.30	(0.24, 0.35)	.34	(0.30, 0.38)
SO -> SU	.07	(0.01, 0.12)	.15	(0.10, 0.19)
PSA -> SU	.23	(0.18, 0.28)	.22	(0.18, 0.27)
PSA -> LSP	-.07	(-0.12, -0.02)	-.01	(-0.05, 0.02)
SU -> LSP	.45	(0.40, 0.49)	.53	(0.50, 0.57)
Indirect effect	.04	(0.01, 0.07)	.11	(0.09, 0.14)
Total effect	.13	(0.08, 0.17)	.09	(0.05, 0.12)
Proportion mediated (%)	31.1	(29.2, 26.9)	130.6	(88.9, 291.3)

Variables	Standardised factor loadings	Standardised residual variance	Standardised factor loadings	Standardised residual variance
Sexual orientation	1.00	.00	1.00	.00
Depressive symptoms	0.52 (0.47, 0.57)	0.48 (0.43, 0.53)	0.49 (0.46, 0.52)	0.51 (0.48, 0.54)
Anxiety symptoms	0.54 (0.49, 0.59)	0.46 (0.41, 0.51)	0.50 (0.46, 0.53)	0.50 (0.47, 0.54)
ELA	0.13 (0.10, 0.16)	0.87 (0.84, 0.90)	0.19 (0.16, 0.22)	0.81 (0.78, 0.84)
IPV	0.08 (0.06, 0.11)	0.92 (0.89, 0.94)	0.14 (0.12, 0.17)	0.86 (0.83, 0.88)
Other illicit drug use	0.76 (0.72, 0.80)	0.24 (0.20, 0.28)	0.54 (0.50, 0.58)	0.46 (0.42, 0.50)
Alcohol use	0.27 (0.24, 0.31)	0.73 (0.69, 0.76)	0.35 (0.32, 0.39)	0.65 (0.61, 0.68)
Cannabis use	0.37 (0.33, 0.40)	0.63 (0.60, 0.67)	0.18 (0.15, 0.20)	0.82 (0.80, 0.85)
Lifetime sexual partners	1.00	.00	1.00	.00

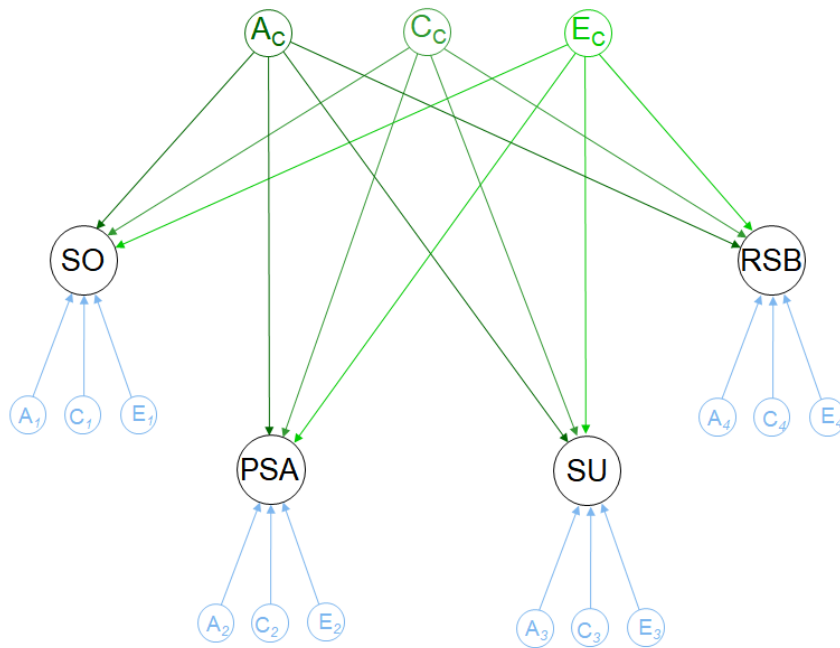
Note. SO, PSA, SU and LSP = Sexual orientation, Psychosocial adversity, and Lifetime sexual partners latent factors respectively. ELA, IPV = Early-Life Adversity and Intimate Partner Violence variables respectively. Indirect effect derived as a sum of the indirect effects through the individual mediation paths.

Figure S2a*Genetic Model 1*

Note. Path diagram depicting the Cholesky decomposition whereby the relationships between Sexual Orientation (SO), Psychosocial Adversity (PSA), SU (Substance Use) and Risky Sexual Behavior (RSB) latent factors are completely explained in terms of additive genetic (A), shared and individual-specific environmental (C and E respectively) influences. Better fit of this model compared with the biometric mediation model indicates that genetic and environmental influences confound the mediation relationships between SO, PSA, SU and RSB. Subscripts ₁, ₂, ₃, and ₄ indicate ACE influences specific to SO, PSA, SU and RSB latent factors respectively; indicator variables were omitted for ease of presentation.

Figure S2b

Genetic Model 2



Note. Path diagram depicting the Common Factor Independent Pathway (CFIP) model whereby the relationships between Sexual Orientation (SO), Psychosocial Adversity (PSA), SU (Substance Use) and Risky Sexual Behavior (RSB) latent factors can be understood as pleiotropic influences of shared additive genetic and shared and individual-specific environmental (A_c , C_c and E_c respectively, color green) while ACE influences specific to the latent factors are additionally specified as $A_1C_1E_1$ to $A_4C_4E_4$ respectively (color blue). Better fit of this model compared with the biometric mediation model indicates that pleiotropic $A_cC_cE_c$ influences on the latent factors confound the mediation relationships between SO, PSA, SU and RSB. Indicator variables were omitted for ease of presentation.

Supplementary Table S8*Comparison of model fit indices of the genetic factor models*

Models	Parameters	df	-2LL	AIC	BIC
Main analyses					
With 10 variables					
Cholesky	70	76847	240106.4	86412.43	-427290
CFIP	64	76853	240142.7	86436.70	-427306
Biometric mediation	58	76859	240119.6	86401.55	-427381
Sensitivity analysis					
With 6 variables					
Cholesky	44	51567	165258.2	62124.22	-282588
CFIP	44	51567	165266.9	62132.93	-282579
Biometric mediation	38	51573	165264.9	62118.85	-282633

Note. CFIP = Common Factor-Independent Pathway model

Supplementary Table S9

Standardised variance components influences on latent factors and standardised path coefficients in the biometric mediation model

Latent factors	h^2	c^2	e^2
Sexual orientation	.56 (.44, .62)	.00 (.00, .10)	.44 (.38, .50)
Psychosocial adversity	.59 (.49, .64)	.00 (.00, .08)	.41 (.36, .46)
Substance use	.80 (.70, .86)	.03 (.04, .12)	.17 (.14, .20)
Lifetime sexual partners	.58 (.52, .61)	.01 (.01, .05)	.42 (.39, .45)

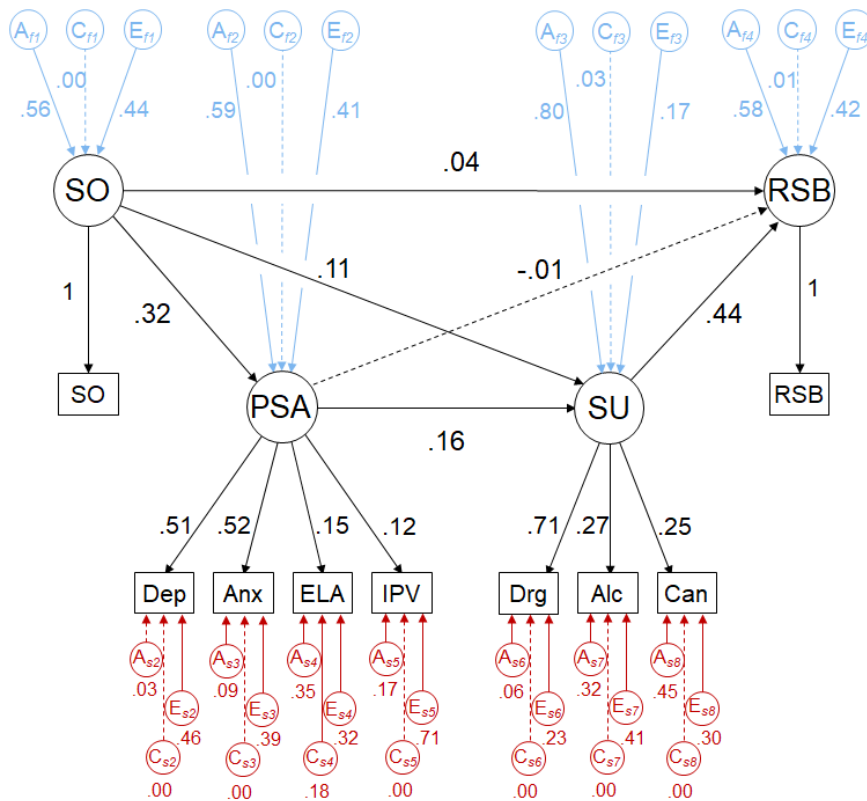
Path coefficients and mediated effects	Estimate	95% CI
Direct effect		
SO -> LSP	.04	(.01, .07)
Mediation paths		
SO -> PSA	.32	(.29, .35)
SO -> SU	.11	(.08, .25)
PSA -> SU	.16	(.13, .20)
PSA -> LSP	-.01	(-.04, .02)
SU -> LSP	.44	(.42, .47)
Indirect effect	.07	(.05, .09)
Total effect	.11	(.08, .14)
Proportion mediated (%)	65.8	(47.0, 93.4)

Variables	Standardised factor loadings	As	Cs	ES
Sexual orientation	1.00			
Depressive symptoms	.51 (.48, .54)	.03 (.00, .06)	.00 (.00, .04)	.46 (.42, .49)
Anxiety symptoms	.52 (.49, .55)	.09 (.04, .12)	.00 (.00, .03)	.39 (.36, .43)
ELA	.15 (.13, .17)	.35 (.27, .44)	.18 (.10, .24)	.32 (.29, .35)
IPV	.12 (.10, .13)	.17 (.09, .21)	.00 (.00, .06)	.71 (.67, .75)
Other illicit drug use	.71 (.67, .76)	.06 (.02, .10)	.00 (.00, .02)	.23 (.20, .25)
Alcohol use	.27 (.25, .30)	.32 (.26, .35)	.00 (.00, .05)	.41 (.38, .44)
Cannabis use	.25 (.23, .27)	.45 (.42, .49)	.00 (.00, .01)	.30 (.27, .33)
Lifetime sexual partners	1.00			

SO, PSA, SU and LSP = Sexual orientation, Psychosocial adversity, and Lifetime sexual partners latent factors respectively. ELA, IPV = Early-Life Adversity and Intimate Partner Violence variables respectively. Indirect effect derived as a sum of the indirect effects through the individual mediation paths. h^2 , c^2 , e^2 = Standardised proportions contributed by additive genetic, shared and unique environmental factors, respectively. As, Cs and Es = Standardised variable-specific additive genetic, shared and individual-specific influences.

Figure S3:

Biometric mediation model.



Note. Path diagram depicting mediation relationships between Sexual Orientation (SO), Psychosocial adversity (PSA), Substance use (SU) and Lifetime Sexual Partners (LSP) latent factors, standardised variance component influences on latent factors and standardised path coefficients. Factors were scaled by fixing one loading per factor to 1. SO = Sexual orientation, Dep = Depressive symptoms, Anx = Generalised anxiety symptoms, ELA = Early-life adversity, IPV = Intimate partner violence, Drg = Other illicit drug use, Alc = Alcohol Use, Can = Cannabis use. A_{f1} - A_{f4} , C_{f1} - C_{f4} and E_{f1} - E_{f4} = Factor-specific additive genetic and shared and individual-specific environmental influences respectively (in blue). A_{s2} - A_{s8} , C_{s2} - C_{s8} and E_{s2} - E_{s8} = Variable-specific additive genetic, shared and individual-specific environmental influences respectively (in red). Solid lines indicate significant paths while dotted lines indicate nonsignificant paths.

Supplementary Table S12

Standardised variance components influences on latent factors and standardised path coefficients in the biometric mediation model in males and females

Males				Females			
Latent factors	h ²	c ²	e ²	h ²	c ²	e ²	
Sexual orientation	.52 (.49, .63)	.01 (.01, .27)	.48 (.36, .61)	.54 (.30, .65)	.04 (.03, .24)	.42 (.35, .50)	
Psychosocial adversity	.47 (.18, .60)	.04 (.00, .28)	.48 (.39, .59)	.60(.41, .68)	.03 (.00, .19)	.37 (.31, .44)	
Substance use	.48 (.28, .47)	.34 (.31, .51)	.19 (.14, .24)	.76 (.76, .81)	.02 (.00, .03)	.22 (.18, .27)	
Lifetime sexual; partners	.43 (.26, .55)	.16 (.16, .30)	.41 (.36, .47)	.55 (.45, .60)	.03 (.00, .12)	.42 (.39, .46)	

Path coefficients and mediated effects	Estimate	95% CI	Estimate	95% CI
Direct effect				
SO -> LSP	.09	(.04, .15)	-.03	(-.07, .01)
Mediation paths				
SO -> PSA	.29	(.24, .35)	.34	(.30, .38)
SO -> SU	.07	(.01, .13)	.15	(.10, .20)
PSA -> SU	.22	(.17, .27)	.22	(.18, .27)
PSA -> LSP	-.07	(-.12, -.03)	-.02	(-.06, .01)
SU -> LSP	.44	(.40, .48)	.53	(.50, .57)
Indirect effect	.04	(.01, .07)	.11	(.09, .14)
Total effect	.13	(.08, .18)	.08	(.05, .12)
Proportion mediated (%)	28.6	(21.9, 31.0)	137.4	(101.0, 241.3)

Variables	Standardised factor loadings	As	Cs	Es	Standardised factor loadings	As	Cs	Es
Sexual orientation	1.00				1.00			
Depressive symptoms	.52 (.47, .58)	.00 (.00, .09)	.04 (.00, .09)	.43 (.38, .49)	.50 (.47, .54)	.04 (.00, .08)	.00 (.00, .06)	.46 (.42, .51)
Anxiety symptoms	.54 (.49, .60)	.07 (.00, .13)	.00 (.00, .07)	.38 (.32, .45)	.51 (.48, .55)	.09 (.02, .13)	.00 (.00, .05)	.40 (.35, .44)
ELA	.13 (.10, .16)	.46 (.09, .53)	.07 (.02, .39)	.34 (.30, .40)	.16 (.14, .19)	.20 (.10, .31)	.33 (.23, .43)	.30 (.27, .34)
IPV	.08 (.06, .10)	.20 (.06, .28)	.00 (.00, .11)	.72 (.65, .79)	.13 (.11, .16)	.16 (.06, .21)	.00 (.00, .08)	.71 (.65, .76)
Other illicit drug use	.75 (.70, .71)	.08 (.01, .14)	.00 (.00, .04)	.17 (.13, .21)	.54 (.49, .58)	.07 (.00, .18)	.07 (.00, .16)	.32 (.28, .36)
Alcohol use	.27 (.24, .31)	.28 (.13, .35)	.01 (.00, .14)	.44 (.38, .50)	.34 (.30, .37)	.26 (.14, .33)	.03 (.02, .14)	.37 (.33, .41)
Cannabis use	.36 (.33, .40)	.13 (.00, .25)	.10 (.01, .22)	.41 (.34, .49)	.19 (.17, .22)	.21 (.10, .28)	.03 (.00, .11)	.57 (.52, .63)
Lifetime sexual partners	1.00				1.00			

Note. SO, PSA, SU and LSP = Sexual orientation, Psychosocial adversity, and Lifetime sexual partners latent factors respectively. ELA, IPV = Early-Life Adversity and Intimate Partner Violence variables respectively. Indirect effect derived as a sum of the indirect effects through the individual mediation paths. h², c², e² = Standardised proportions contributed by additive genetic, shared and unique environmental factors, respectively. As, Cs and Es = Standardised variable-specific additive genetic, shared and individual-specific influences. Model fit indices: degrees of freedom = 76804, -2LL = 232340.3, AIC = 78732.32.