Sexual Orientation Disparities in Cardiovascular Biomarkers Among Young Adults

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Background: Emerging evidence from general population studies suggests that lesbian, gay, and bisexual (LGB) adults are more likely to experience adverse cardiovascular outcomes relative to heterosexuals. No studies have examined whether sexual orientation disparities exist in biomarkers of early cardiovascular disease risk.

Purpose: To determine whether sexual orientation disparities in biomarkers of early cardiovascular risk are present among young adults.

Methods: Data come from Wave IV (2008–2009) of the National Longitudinal Study for Adolescent Health (N=12,451), a prospective nationally representative study of U.S. adolescents followed into young adulthood (mean age=28.9 years). A total of 520 respondents identified as lesbian, gay, or bisexual. Biomarkers included C-reactive protein, glycosylated hemoglobin, systolic and diastolic blood pressure, and pulse rate. Analyses were conducted in 2012.

Results: In gender-stratified models adjusted for demographics (age, race/ethnicity); SES (income, education); health behaviors (smoking, regular physical activity, alcohol consumption); and BMI, gay and bisexual men had significant elevations in C-reactive protein, diastolic blood pressure, and pulse rate, compared to heterosexual men. Despite having more risk factors for cardiovascular disease, including smoking, heavy alcohol consumption, and higher BMI, lesbians and bisexual women had lower levels of C-reactive protein than heterosexual women in fully adjusted models.

Conclusions: Evidence was found for sexual orientation disparities in biomarkers of cardiovascular risk among young adults, particularly in gay and bisexual men. These findings, if confirmed in other studies, suggest that disruptions in core physiologic processes that ultimately confer risk for cardiovascular disease may occur early in the life course for sexual-minority men.
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Introduction

Sexual orientation has emerged as a robust indicator of risk for psychiatric morbidity in population-based surveys both in the U.S.[1–3] and abroad.[4] Far less is known about potential sexual orientation differences in adverse physical health outcomes, with the notable exception of HIV/AIDS. Recent studies, however, have begun to address this gap in knowledge. Data from a population-based survey in the Netherlands revealed that individuals engaging in same-sex sexual behaviors reported more health conditions than those with opposite-sex partners.[5] Similarly, adults with a minority sexual orientation (i.e., individuals who identify as lesbian, gay, or bisexual [LGB]) in the 2001–2008 Behavior Risk Factor Surveillance Survey in Massachusetts were more likely than heterosexuals to report activity limitations caused by disability.[6]

Within this broader literature on sexual orientation and physical health outcomes, several studies have documented elevated risk for certain cardiovascular outcomes among sexual-minority adults.[6–10] For instance, the prevalence of self-reported hypertension and heart disease was higher among gay men compared to heterosexual men in the California Quality of Life Survey.[7] Data from the 1999 Los Angeles County Health Survey indicated that lesbian and bisexual women were more likely to report a diagnosis of heart disease than were heterosexual women.[8]

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Life-course studies have established that many behavioral (e.g., diet, physical activity, smoking) and social (e.g., childhood adversity, stress) risk factors for adult cardiovascular disease (CVD) emerge early in development.[11–17] Given that LGB youths have higher levels of, and greater exposure to, both behavioral[18–21] and social[22–25] risk factors for CVD relative to heterosexual youth, sexual orientation disparities in CVD risk factors may already be evident by young adulthood. The current study examined this research question using recently released data from Wave IV of the National Longitudinal Study of Adolescent Health (Add Health), a nationally representative cohort study of young adults in the U.S. Wave IV of Add Health included measures of sexual orientation, a range of CVD biomarkers, and multiple potential confounders of the relationship between sexual orientation and these biomarkers.

For the current paper, the authors chose to examine CVD biomarkers that are established indicators of cardiovascular risk, including C-reactive protein (CRP); glycosylated hemoglobin (HbA1c); systolic and diastolic blood pressure; and pulse rate. Longitudinal studies consistently indicate that elevated blood pressure in adolescence and young adulthood are associated with the progression and onset of CVD later in life.[26–28] In addition, numerous recent studies have indicated that CRP (a marker of systemic inflammation, tissue damage, and infection) and HbA1c (a measure of long-term glycemic control) are associated concurrently and prospectively with greater CVD risk.[29–33]

There are at least three ways in which sexual orientation could be associated with these CVD biomarkers. First, relative to heterosexuals, LGB adolescents and young adults have higher rates of smoking,[18] heavy alcohol use,[20,21] and, among women, overweight/obesity.[19] These behavioral factors predict the development of CVD and are associated with each of our CVD biomarkers.[34–37] Second, experiences of stress and childhood adversity contribute to physiologic changes that confer risk for our CVD biomarkers, including CRP, elevations in blood pressure, and HbA1c.[38–47] Disproportionate exposure to childhood adversity and other stressors among LGB populations is well established,[3,22,23,48–50] and these experiences may in turn contribute to elevated risk for the CVD biomarkers examined here in LGB young adults.

Third, a large literature has linked the experience of racism to a range of CVD biomarkers in African Americans, including hypertension,[51–54] subclinical carotid disease,[55] coronary artery calcification,[56] coronary artery obstruction,[57] and increased CRP.[58] This research suggests that greater exposure to sexual orientation–related discrimination[3,48–50,59] similarly may explain disparities in blood pressure and CRP between LGB and heterosexual young adults. Based on these three potential explanations, we hypothesized that LGB young adults would have higher levels of each of the CVD biomarkers than their heterosexual peers.

Methods

Sample

Data were drawn from the National Longitudinal Study of Adolescent Health (Add Health), an ongoing nationally representative study of adolescents and young adults.[60] Add Health recruited a school-based sample of adolescents in Grades 7–12 in 1994 and has followed respondents into young adulthood. To date, there have been four waves of data collection. Details about Add Health have been described previously[31] (www.cpc.unc.edu/projects/addhealth/design). The current study utilized data from Wave 4.

Wave 1 (1994–1995) utilized a multistage sampling design to enroll adolescents. A systematic random sample of 80 high schools was selected proportional to enrollment size and stratified by region, urbanicity, school type, and percentage of white students; the largest feeder school for each high school also was invited to participate. A total of 134 schools (79%) participated. An in-school survey was completed by 90,118 students, and 20,745 students participated in a more detailed in-home interview (75.6% and 79.5% of eligible students, respectively). In Wave 4 (2008–2009), follow-up interviews were completed with 15,701 in-home Wave 1 respondents (80.25% of eligible respondents). Participants ranged in age from 24 to 32 years. Wave 4 involved an in-home survey and collection of numerous biological specimens.

In order to be included in the current analyses, respondents were required to (1) have information about sexual orientation; (2) have valid data for at least one of the cardiovascular biomarkers; (3) not be pregnant; (4) have no self-report of HIV/AIDS or hepatitis C; and (5) have valid data on each of the selected covariates. Accordingly, 13,789 respondents (94.4% of those with valid sexual orientation status) constituted the analytic sample for the present study. As described below, individuals were omitted also if they self-identified as "mostly heterosexual." Thus, the final analytic sample included 12,451 respondents.

Sexual Orientation

Classification of sexual orientation was based on a measure of sexual identity, which was assessed at Wave 4 with an item asking respondents to *Please choose the description that best fits how you think about yourself*. Six response options were given (numbers provided correspond to the final sample who met the above criteria): 100% heterosexual (straight) (n=11,931); mostly heterosexual but somewhat attracted to people of your own gender (some attraction) (n=1,342); bisexual (n=214); mostly homosexual, but somewhat attracted to people of the opposite gender (n=115); 100% homosexual (n=191); and not sexually attracted to either men or women (n=62). Respondents who indicated that they were not attracted to either men or women or did not answer this item (n=64) were excluded.

Consistent with prior studies, the "mostly homosexual" and 100% homosexual groups were combined to increase power.[18]

Because of evidence for different risk profiles for LGB men and women,[1,2,4,6] all analyses are shown stratified by gender. Because of the small sample size of LGB individuals, results are shown aggregated across lesbian and bisexual women (n=307) and across gay and bisexual men (n=213). Because adult studies on sexual orientation disparities in CVD risk factors have not included a "mostly heterosexual" group, the authors had no a priori hypothesis about this group and therefore omitted them from analyses.

Cardiovascular Disease Biomarkers

Several cardiovascular biomarkers were collected from Wave 4 respondents. Systolic and diastolic blood pressure were each measured using an oscillometric blood pressure monitor with an appropriately sized cuff placed on the right upper arm. Three blood pressure measurements were taken, separated by 30-second intervals. Systolic and diastolic blood pressure values represent the average of the second and third measurements (in mmHg). The blood pressure monitor also provided information on pulse rate at each of the three measurements. Pulse rate values represent the average of the second and third measurements in beats/minute (bpm).

Blood spot samples were obtained using a finger prick and were submitted for laboratory analysis of high-sensitivity CRP (mg/L) and HbA1c (%), reflecting average blood glucose over the preceding 8–12 weeks.[61] Following a standard protocol, trained interviewers collected blood spots on standardized filter paper using a sterile disposable lancet. Blood spots were dried overnight and then frozen until laboratory analysis. CRP was assayed from blood spots using a highly sensitive standardized enzyme immunoassay protocol (coefficients of variation provided in Appendix A, available online at www.ajpmonline.orghpp).

A validation study compared CRP concentrations of 87 pairs of plasma and dried blood spot samples and found that they were strongly correlated in a linear fashion (r=0.98),[62] consistent with previous validation studies.[63] Dried blood spot samples were adjusted to match serum levels of CRP (plasma CRP=dried blood spot CRP/0.4285).[62] For analyses of CRP, guidelines were followed that recommend excluding individuals with values > 10, because such values usually indicate infection, trauma, or pathology.[64,65] Because of the positively skewed distribution of CRP values, this measure was transformed to a natural-log scale for analyses, which normalized the distribution.

Blood spots were assayed for HbA1c using an immunoturbidimetric method for HbA1c quantitation and a colorimetric method for released hemoglobin (Hb) quantitation (coefficients of variation provided in Appendix B, available online at www.ajpmonline.org). HbA1c was calculated based on the HbA1c:Hb ratio using the formula: HbA1c (%) = 2.27 + 87.6 × (HbA1c ÷ Hb).[66] A validation study compared whole blood values of HbA1c to paired dried blood spots from 115 Wave 4 respondents. Blood spots values and a conventional HbA1c assay were strongly associated (r=0.99).[67] HbA1c values were natural-log-transformed prior to analysis to normalize the distribution. All of the outcomes were treated as continuous variables in analyses.

Covariates

The association between sexual orientation and CVD biomarkers was estimated in a series of models with progressively more controls for demographics, SES, health behaviors, and BMI. These four factors were chosen because they are associated robustly with CVD risk and are an established set of covariates that commonly are used in the research literature.[34–37] Demographic controls included age and race/ethnicity (non-Hispanic black, non-Hispanic white, Asian, Hispanic, and multiracial/Native American/Other). SES indicators included annual household income and educational attainment (Table 1).

Controls for health behaviors included current smoking, alcohol consumption, and physical activity. Cigarette smoking was defined as current (daily smoking for the past 30 days); intermittent or previous (smoking on 1–29 of the past 30 days or was previously a regular smoker); and none. Alcohol consumption was coded as heavy (individuals who drink daily or almost daily); light to moderate (individuals who drink ≤ 5 times per week); and none.[68] Physical activity was derived from a standard 7-day physical activity recall scale. Based on prior research, respondents who reported ≥ 5 bouts of moderate-to-vigorous physical activity in the past week were coded as engaging in regular physical activity.[69]

Height and weight were assessed using anthropometric methods for all respondents capable of standing without assistance. Height was measured in centimeters, while the respondent stood against a wall with his or her feet flat on the floor. Weight was measured using a digital scale with a ceiling of 200 kg. A value of 201 kg was assigned to respondents weighing > 200 kg. BMI was calculated by standard formula.

Interviewers assessed medication use at the Wave 4 in-home interview. Cardiac medication was a dichotomous variable that included all classes of medication that may lower blood pressure; it was used a control variable in models of systolic blood pressure, diastolic blood pressure, pulse rate, and CRP. Models of CRP additionally adjusted for use of aspirin and other anti-inflammatory drugs in the past 24 hours, and a dichotomous indicator of the presence of self-reported illness in the past 2 weeks. Anti-diabetes medication was controlled for in models predicting HbA1c.

Analysis Plan

Associations of sexual orientation with systolic and diastolic blood pressure, pulse rate, HbA1c, and CRP were estimated in a series of progressive linear regression models. Model 1 examined the age-adjusted association of sexual orientation with each outcome. Model 2 added controls for race/ethnicity and SES (annual household income and educational attainment). Model 3 included additional controls for health behaviors—smoking, alcohol consumption, and physical activity—and BMI. In all analyses, post-stratification weights were applied to adjust for selection probabilities and nonresponse, account for the complex sample design, and generate nationally representative estimates of association. Analyses were conducted in 2012.

Results

Distribution of Cardiovascular Risk Factor Covariates and Biomarkers by Sexual Orientation

Distribution of CVD biomarkers and risk factors (i.e., demographics, health behaviors, and BMI) across sexual orientation groups is presented in Table 1. With respect to CVD biomarkers, gay/bisexual men had lower HbA1c than heterosexual men. In contrast, gay/bisexual men had

Table 1. Weighted sample characteristics by gender and sexual orientation, National Longitudinal Study of Adolescent Health (N=12,451),[a] % (SE) unless otherwise noted

	Men (*n*=6438)			Women (*n*=6013)		
	Gay or bisexual (*n*=213) 2.92%	Heterosexual (*n*=6225) 97.08%	*p*-value	Lesbian or bisexual (*n*=307) 5.11%	Heterosexual (*n*=5706) 94.89%	*p*-value
Biomarker outcomes						
SBP (mean, mmHg)	131.01 (1.28)	129.74 (0.26)	0.31	121.94 (0.91)	120.20 (0.27)	0.07
DBP (mean, mmHg)	84.06 (1.22)	81.62 (0.20)	0.048	77.73 (0.75)	77.27 (0.21)	0.55
Pulse rate (mean, bpm)	75.64 (1.65)	72.48 (0.25)	0.05	75.78 (0.96)	75.47 (0.23)	0.76
CRP (mean, mg/L)	2.16 (0.23)	2.07 (0.05)	0.69	2.28 (0.15)	2.53 (0.05)	0.13
HbA1c (mean, %)	5.54 (0.04)	5.64 (0.02)	0.02	5.60 (0.05)	5.54 (0.02)	0.32
Age (years; M [SE])	29.04 (0.19)	29.03 (0.12)	0.94	28.52 (0.16)	28.95 (0.12)	<0.01
Race						
Black	11.33 (3.36)	14.56 (2.10)	0.36	16.11 (2.86)	16.45 (2.18)	0.25
Asian	2.74 (1.46)	3.12 (0.72)		1.23 (0.82)	3.03 (0.77)	
Hispanic	16.90 (4.22)	11.04 (1.66)		10.57 (2.55)	11.00 (1.90)	
Multiracial, Native American, other	6.10 (2.00)	5.54 (0.53)		5.32 (1.47)	5.30 (0.51)	
White	62.93 (5.31)	65.74 (2.96)		66.77 (4.19)	64.22 (3.18)	
Education						
<High school	6.65 (2.29)	10.44 (0.95)	0.02	14.89 (2.91)	6.85 (0.70)	0.001
High school degree	11.11 (3.28)	21.61 (1.19)		18.00 (2.96)	14.31 (0.96)	
Some college/ technical degree	41.95 (5.70)	41.96 (1.18)		46.66 (3.90)	44.16 (1.11)	
Bachelor's degree	29.72 (5.62)	20.27 (1.31)		17.11 (2.91)	25.51 (1.34)	
Graduate degree	10.56 (2.70)	5.72 (0.57)		3.34 (1.35)	9.18 (0.75)	
Household income ($)						
Missing	6.79 (2.42)	7.05 (0.68)	0.89	10.23 (2.80)	6.97 (0.75)	0.001
0–24,999	14.50 (2.67)	13.79 (0.88)		30.22 (3.56)	17.83 (1.10)	
25,000–39,999	18.06 (3.22)	14.72 (0.80)		16.25 (3.10)	15.04 (0.65)	
40,000–74,999	29.53 (4.65)	34.31 (1.05)		27.55 (3.31)	33.71 (1.03)	
75,000–99,999	14.27 (4.10)	15.23 (0.74)		7.34 (1.74)	13.02 (0.66)	
≥100,000	16.86 (3.52)	14.90 (0.85)		8.41 (2.30)	13.43 (0.76)	

(continued on next page)

Table 1. Weighted sample characteristics by gender and sexual orientation, National Longitudinal Study of Adolescent Health (N=12,451),a % (SE) unless otherwise noted *(continued)*

	Men (*n*=6438)			Women (*n*=6013)		
	Gay or bisexual (*n*=213) 2.92%	Heterosexual (*n*=6225) 97.08%	*p*-value	Lesbian or bisexual (*n*=307) 5.11%	Heterosexual (*n*=5706) 94.89%	*p*-value
Smoking status						
Current (smoked 30 days in past month)	29.10 (4.25)	27.23 (1.10)	0.92	31.20 (3.82)	20.83 (1.12)	<0.0001
Past/intermittent	23.57 (4.11)	23.70 (0.76)		32.45 (3.74)	19.76 (0.87)	
Never	47.33 (5.22)	49.07 (1.25)		36.35 (3.77)	59.41 (1.45)	
Alcohol consumption[b]						
Light to moderate drinker	77.29 (4.00)	73.00 (1.61)	0.54	70.43 (3.51)	67.33 (1.15)	0.047
Heavy drinker	3.68 (1.93)	4.07 (0.32)		5.30 (2.24)	1.23 (0.27)	
Abstainer	19.03 (3.51)	22.93 (1.17)		24.27 (3.31)	31.44 (1.15)	
Regular physical activity[c]	66.82 (4.62)	57.44 (1.06)	0.06	51.33 (4.15)	49.64 (1.12)	0.68
BMI (M [SE])	27.83 (0.64)	29.06 (0.14)	0.06	30.94 (0.89)	29.09 (0.21)	0.03
Illness, past 2 weeks[d]	37.30 (5.26)	29.57 (0.80)	0.14	40.84 (3.74)	35.30 (0.91)	0.16
Aspirin and other anti-inflammatory medication	25.79 (4.10)	25.29 (0.86)	0.90	39.30 (3.28)	31.90 (0.94)	0.04
Antidiabetic medication	0.67 (0.48)	0.88 (0.18)	0.69	1.83 (1.47)	1.57 (0.25)	0.86
Cardiac medication[e]	5.84 (2.23)	3.73 (0.34)	0.34	2.06 (1.06)	3.31 (0.30)	0.26

[a]Table presents weighted M and % and SE, taking into account the complex sample design. *P*-values are derived from chi-square tests for categoric variables, and an ANOVA test for age (i.e., the only continuous variable). Demographic characteristics are presented for respondents with at least one valid outcome; sample sizes are slightly different across the outcomes: SBP and DBP *n*=12,295; pulse rate *n*=12,224; CRP *n*=9900; HbA1c *n*=11,420.
[b]Reflects consumption in the past 12 months; light to moderate alcohol consumption includes individuals who drink up to 5 times per week; heavy drinkers refers to individuals who drink every day or almost every day.
[c]Regular physical activity was defined as ≥5 bouts of moderate or vigorous physical activity during the past 7 days.
[d]Illnesses in the past 2 weeks is an indicator variable to reflect self-reported cold or influenza symptoms, fever, nausea, vomiting, diarrhea, night sweats, blood in stool or urine, frequent urination, or skin rash in the past 2 weeks.
[e]Cardiac medication included all classes of prescription medication that might lower blood pressure (reference=*no*).
bpm, beats per minute; CRP, C-reactive protein; DBP, diastolic blood pressure; HbA1c, hemoglobin A1c; SBP, systolic blood pressure

higher diastolic blood pressure, pulse rate, and CRP than heterosexual men. Lesbian/bisexual women had marginally higher systolic blood pressure than heterosexual women. With respect to CVD risk factors, gay/bisexual men had higher educational attainment than heterosexual men, but had lower BMI. No sexual orientation differences in the other risk factors were observed for men. In contrast, lesbian/bisexual women reported more risk factors for CVD than heterosexual women, including lower SES (education and income); more unhealthy behaviors (smoking, greater alcohol consumption); and higher BMI.

Associations Between Sexual Orientation and Cardiovascular Biomarkers

Gay/bisexual men and lesbian/bisexual women exhibited elevations in blood pressure relative to heterosexuals (Table 2). Gay/bisexual men had higher diastolic blood pressure than heterosexual men in the unadjusted model ($\beta=2.4$, $p<0.01$), and this difference became more pronounced after controlling for SES, health behaviors, medications, and BMI ($\beta=3.0$, $p<0.05$). Lesbian/bisexual women had elevated systolic blood pressure compared to heterosexual women in unadjusted analysis ($\beta=1.9$, $p<0.05$); however, this association was strongly attenuated

Table 2. Results of linear regression analyses for cardiovascular biomarkers by gender[a]

	Men, gay/bisexual		Women, lesbian/bisexual	
	β (SE)	Adj. R^2	β (SE)	Adj. R^2[b]
Systolic blood pressure (mmHg)				
Model 1[b]	1.27 (1.25)	0.001	**1.89 (0.95)***	0.004
Model 2[c]	1.51 (1.28)	0.005	1.52 (0.93)	0.03
Model 3[d,e]	1.86 (1.19)	0.09	0.78 (0.05)	0.16
Diastolic blood pressure (mmHg)				
Model 1[b]	**2.43 (1.22)***	0.01	0.66 (0.77)	0.01
Model 2[c]	**2.70 (1.23)***	0.02	0.37 (0.76)	0.03
Model 3[d,e]	**2.98 (1.20)***	0.09	−0.07 (0.80)	0.11
Pulse rate (bpm)				
Model 1[b]	3.15 (1.62)†	0.003	0.34 (1.00)	0.00
Model 2[c]	**3.74 (1.66)***	0.03	−0.23 (0.99)	0.02
Model 3[d,e]	**4.16 (1.56)****	0.11	−0.14 (0.95)	0.07
Log C-reactive protein (mg/L)				
Model 1[b]	0.12 (0.11)	0.003	−0.08 (0.09)	0.00
Model 2[c]	0.17 (0.10)†	0.03	−0.12 (0.09)	0.02
Model 3[d–f]	**0.21 (0.09)***	0.22	**−0.18 (0.09)***	0.24
Log hemoglobin A1c (%)				
Model 1	**−0.01 (0.01)***	0.01	0.01 (0.01)	0.001
Model 2	−0.01 (0.01)	0.10	0.01 (0.01)	0.09
Model 3[g]	0.00 (0.01)	0.28	0.00 (0.01)	0.27

Note: Boldface indicates significance.

[a]Linear regression analyses were conducted separately by gender. Gay/bisexual and lesbian/bisexual categories were compared to heterosexuals (i.e., the reference category). All models take into account the complex sample design, and sample weights. Sample sizes are slightly different across the outcomes: SBP and DBP n=12,295; pulse rate n= 12,224; CRP n=9620; HbA1c n=11,420. Boldface indicates significance.

[b]Model 1 is adjusted for age.

[c]Model 2 is adjusted for age; race/ethnicity (ref=white); education (<high school, high school degree, some college/technical degree, bachelor's degree, graduate degree, ref=graduate degree); income ($0–$25K, $25–$40K, $40–$75K, $75–$100K, $100K+; ref=$100K+).

[d]Model 3 is adjusted for covariates in Model 2 plus smoking (never, previous/intermittent, regular smoker; ref=never); regular physical activity (dichotomous; ref=regular exercise); alcohol consumption (heavy, moderate, abstainer; ref=abstainer); and BMI.

[e]Model is additionally adjusted for cardiac medication use (ref=no cardiac medication).

[f]Model is additionally adjusted for self-reported illness in past 2 weeks (see details in Table 1; ref=no self-reported illness in past 2 weeks) and aspirin or other anti-inflammatory medications in the past 24 hours (ref=no aspirin or other anti-inflammatory medication use in past 24 hours).

[g]Model is additionally adjusted for antidiabetic medications (ref=no antidiabetic medication).

†$p<0.10$; *$p<0.05$; **$p<0.01$; ***$p<0.0001$

Adj., adjusted; bpm, beats per minute; CRP, C-reactive protein; DBP, diastolic blood pressure; HbA1c, hemoglobin A1c; SBP, systolic blood pressure

and became nonsignificant after adjustment for SES, health behaviors, medication use, and BMI.

Gay/bisexual men had marginally elevated pulse rate relative to heterosexual men in unadjusted analysis (β=3.2, $p<0.10$), and this difference became more pronounced after adjusting for all covariates (β=4.2, $p<0.01$). No sexual orientation differences in pulse rate were observed for women. Although no associations were observed between sexual orientation and CRP in unadjusted analysis, gay/bisexual men had higher levels of

CRP than heterosexual men (β=0.2, $p<0.05$) in models adjusted for SES, health behaviors, medication use, and BMI. In contrast, lesbian/bisexual women had lower levels of CRP than heterosexuals (β=−0.2, $p<0.05$) in the fully adjusted models.

Sensitivity analyses of CRP were conducted stratifying by self-reported illness in the past 2 weeks. Results (Appendix C, available online at www.ajpmonline.org) were similar for men and women with and without self-reported illness. Finally, although gay/bisexual men had lower HbA1c levels than heterosexual men, these associations were nonsignificant after adjustment for covariates. All analyses were re-run using list-wise deletion (Appendix D, available online at www.ajpmonline.org), and the direction and magnitude of the results remained unchanged from the complete cases analyses reported above. Models that depict the association between each covariate and outcome separately are provided in Appendixes A, B, E–G (available online at www.ajpmonline.org).

Discussion

Results from the current study indicate that sexual orientation disparities in CVD biomarkers emerge at a relatively early age. Using data from a nationally representative study of young adults, the study showed that gay/bisexual men had elevations in diastolic blood pressure, CRP, and pulse rate compared to heterosexual men. These disparities were robust to adjustment for potential confounding factors, including demographics, SES, health behaviors, and BMI. In fact, associations between sexual orientation and the CVD biomarkers typically became stronger among men after controlling for these additional risk factors. This is the first study, to our knowledge, to document sexual orientation disparities in measured biomarkers for cardiovascular risk among young adult men, suggesting that these disparities emerge earlier in the life course than previously recognized.

In contrast to the results for men, there were no sexual orientation differences in any of the CVD biomarkers among women, with the exception of CRP, which was lower among lesbian/bisexual women. Previous studies with adults have documented that lesbians report higher levels of heart disease than heterosexual women.[8] Consequently, it appears that disparities in CVD emerge later in the life course for lesbian/bisexual women than for gay/bisexual men. This finding is consistent with studies showing that women in general have delayed risk for CVD compared to men.[70,71] It also is possible that the pathways linking sexual orientation to changes in inflammatory markers operate differently in sexual-minority men and women. Further research is needed to understand why lesbian/bisexual women have lower levels of CRP than heterosexual women, despite having more CVD risk factors (i.e., smoking, drinking, and higher BMI).

Limitations

Although this study provides novel information regarding developmental precursors of adult CVD among LGB populations, the study has certain limitations. First, given small numbers of LGB respondents from racial/ethnic groups, it was not possible to examine interactions between sexual orientation and race/ethnicity, an additional risk factor for CVD.[56] Future studies with larger samples of racial/ethnic sexual minorities will provide an opportunity to determine whether the intersection of multiple stigmatized identities potentiates risk for CVD biomarkers. Second, the number of LGB respondents was too small to conduct analyses separately for gay/lesbian and bisexual respondents. Results from studies with LGB adults have indicated that patterns of cardiovascular risk factors are not always consistent across sexual orientation groups.[6] This analytic approach may therefore have obscured important subgroup differences.

Third, sexual orientation is a multidimensional construct including measures of sexual attraction, sexual behavior, and sexual identity. The current study used a single-item measure of sexual identity. Although this is a widely used measure that is correlated with the other dimensions of sexual orientation, future studies would benefit from additional measures of this construct to more comprehensively define the study population.[72] Finally, some important biomarkers (e.g., lipids) were not collected in Add Health; thus, it is unclear whether the current results are generalizable to other cardiometabolic risk factors.

Strengths

This study also has a number of noteworthy strengths, including data from a nationally representative sample. Many studies on the health of sexual minorities rely on convenience samples that use nonrandom sampling, which can produce biased associations between sexual orientation and health outcomes.[3,73] The use of a population-based sample in the current study overcomes many of these limitations and increases the generalizability of the findings. Add Health also had a relatively large number of LGB respondents. This sample therefore provided adequate statistical power to stratify analyses by gender, which revealed important gender differences in the outcomes that are often obscured in population-based studies with smaller sample sizes of LGB individuals.[48]

An additional methodologic strength is the use of measured biomarkers, rather than self-report measures of these risk factors. Finally, Add Health included a wide array of sociodemographic and behavioral measures that afforded the opportunity to control for several potential confounders of the relationship between sexual orientation and CVD biomarkers. These measures strengthen confidence that the observed associations are not simply reflecting differences in demographics or health behaviors as a function of sexual orientation.

Conclusion

There are currently no evidence-based interventions for cardiovascular risk that address the general[6,74–76] and unique[3] risk factors for CVD in LGB populations. The identification of mechanisms underlying the relationship between sexual orientation and cardiovascular risk will aid in the development of effective public health interventions that have the potential to reduce sexual orientation disparities in CVD, an important goal outlined in *Healthy People 2020*.[77]

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References

1. Cochran SD, Mays VM, Sullivan JG. Prevalence of mental disorders, psychological distress, and mental health services use among lesbian, gay, and bisexual adults in the U.S. J Consult Clin Psychol 2003;71(1):53–61.
2. Gilman SE, Cochran SD, Mays VM, Hughes M, Ostrow D, Kessler RC. Risk of psychiatric disorders among individuals reporting same-sex sexual partners in the National Comorbidity Survey. Am J Public Health 2001;91(6):933–9.
3. Meyer IH. Prejudice, social stress, and mental health in lesbian, gay, and bisexual populations: conceptual issues and research evidence. Psychol Bull 2003;129(5):674–97.
4. Sandfort TG, de Graaf R, Bijl RV, Schnabel P. Same-sex sexual behavior and psychiatric disorders: findings from the Netherlands Mental Health Survey and Incidence Study (NEMESIS). Arch Gen Psychiatry 2001;58(1):85–91.
5. Sandfort TG, de Graaf R, Bijl RV. Same-sex sexuality and quality of life: findings from the Netherlands Mental Health Survey and Incidence Study. Arch Sex Behav 2003;32(1):15–22.
6. Conron KJ, Mimiaga MJ, Landers SJ. A population-based study of sexual orientation identity and gender differences in adult health. Am J Public Health 2010;100(10):1953–60.
7. Cochran SD, Mays VM. Physical health complaints among lesbians, gay men, and bisexual and homosexually experienced heterosexual individuals: results from the California Quality of Life Survey. Am J Public Health 2007;97(11):2048–55.
8. Diamant AL, Wold C. Sexual orientation and variation in physical and mental health status among women. J Womens Health (Larchmt) 2003;12(1):41–9.
9. Wang J, Hausermann M, Vounatsou P, Aggleton P, Weiss MG. Health status, behavior, and care utilization in the Geneva Gay Men's Health Survey. Prev Med 2007;44(1):70–5.
10. Ungvarski PJ, Grossman AH. Health problems of gay and bisexual men. Nurs Clin North Am 1999;34(2):313–31.
11. Adair L, Dahly D. Developmental determinants of blood pressure in adults. Annu Rev Nutr 2005;25:407–34.
12. Slopen N, Kubzansky LD, McLaughlin KA, Koenen KC. Childhood adversity and inflammatory processes in youth: a prospective study. Psychoneuroendocrinology 2013;38(2):188–200.
13. Singh AS, Mulder C, Twisk JW, van Mechelen W, Chinapaw MJ. Tracking of childhood overweight into adulthood: a systematic review of the literature. Obes Rev 2008;9(5):474–88.
14. Groner JA, Joshi M, Bauer JA. Pediatric precursors of adult cardiovascular disease: noninvasive assessment of early vascular changes in children and adolescents. Pediatrics 2006;118(4):1683–91.
15. Taylor WC, Blair SN, Cummings SS, Wun CC, Malina RM. Childhood and adolescent physical activity patterns and adult physical activity. Med Sci Sports Exerc 1999;31(1):118–23.
16. Kuh DJ, Cooper C. Physical activity at 36 years: patterns and childhood predictors in a longitudinal study. J Epidemiol Community Health 1992;46(2):114–9.
17. Mikkila V, Rasanen L, Raitakari OT, Pietinen P, Viikari J. Consistent dietary patterns identified from childhood to adulthood: the cardiovascular risk in Young Finns Study. Br J Nutr 2005;93(6):923–31.
18. Austin SB, Ziyadeh N, Fisher LB, Kahn JA, Colditz GA, Frazier AL. Sexual orientation and tobacco use in a cohort study of US adolescent girls and boys. Arch Pediatr Adolesc Med 2004;158(4):317–22.
19. Austin SB, Ziyadeh NJ, Corliss HL, et al. Sexual orientation disparities in weight status in adolescence: findings from a prospective study. Obesity (Silver Spring) 2009;17(9):1776–82.
20. Russell ST, Driscoll AK, Truong N. Adolescent same-sex romantic attractions and relationships: implications for substance use and abuse. Am J Public Health 2002;92(2):198–202.
21. Marshal MP, Friedman MS, Stall R, et al. Sexual orientation and adolescent substance use: a meta-analysis and methodological review. Addiction 2008;103(4):546–56.
22. Corliss HL, Cochran SD, Mays VM, Greenland S, Seeman TE. Age of minority sexual orientation development and risk of childhood maltreatment and suicide attempts in women. Am J Orthopsychiatry 2009;79(4):511–21.
23. Balsam KF, Rothblum ED, Beauchaine TP. Victimization over the life span: a comparison of lesbian, gay, bisexual, and heterosexual siblings. J Consult Clin Psychol 2005;73(3):477–87.
24. Corliss HL, Goodenow CS, Nichols L, Austin SB. High burden of homelessness among sexual-minority adolescents: findings from a representative Massachusetts high school sample. Am J Public Health 2011;101(9):1683–9.
25. McLaughlin KA, Hatzenbuehler ML, Xuan Z, Conron KJ. Disproportionate exposure to early-life adversity and sexual orientation disparities in psychiatric morbidity. Child Abuse Neglect 2012;36(9):645–55.
26. Tirosh A, Afek A, Rudich A, et al. Progression of normotensive adolescents to hypertensive adults: a study of 26,980 teenagers. Hypertension 2010;56(2):203–9.
27. Tirosh A, Shai I, Afek A, et al. Adolescent BMI trajectory and risk of diabetes versus coronary disease. N Engl J Med 2011;364(14):1315–25.
28. Miura K, Daviglus ML, Dyer AR, et al. Relationship of blood pressure to 25-year mortality due to coronary heart disease, cardiovascular diseases, and all causes in young adult men: the Chicago Heart Association Detection Project in Industry. Arch Intern Med 2001;161(12):1501–8.

29. Koenig W, Sund M, Frohlich M, et al. C-Reactive protein, a sensitive marker of inflammation, predicts future risk of coronary heart disease in initially healthy middle-aged men: results from the MONICA (Monitoring Trends and Determinants in Cardiovascular Disease) Augsburg Cohort Study, 1984 to 1992. Circulation 1999;99(2):237–42.
30. Selvin E, Marinopoulos S, Berkenblit G, et al. Meta-analysis: glycosylated hemoglobin and cardiovascular disease in diabetes mellitus. Ann Intern Med 2004;141(6):421–31.
31. Selvin E, Steffes MW, Zhu H, et al. Glycated hemoglobin, diabetes, and cardiovascular risk in nondiabetic adults. N Engl J Med 2010;362(9): 800–11.
32. Meigs JB, Nathan DM, D'Agostino RB, Sr, Wilson PW. Fasting and postchallenge glycemia and cardiovascular disease risk: the Framingham Offspring Study. Diabetes Care 2002;25(10):1845–50.
33. Ridker PM, Hennekens CH, Buring JE, Rifai N. C-reactive protein and other markers of inflammation in the prediction of cardiovascular disease in women. N Engl J Med 2000;342(12):836–43.
34. Neaton JD, Wentworth D. Serum cholesterol, blood pressure, cigarette smoking, and death from coronary heart disease. Overall findings and differences by age for 316,099 white men. Multiple Risk Factor Intervention Trial Research Group. Arch Intern Med 1992;152(1): 56–64.
35. Hubert HB, Feinleib M, McNamara PM, Castelli WP. Obesity as an independent risk factor for cardiovascular disease: a 26-year follow-up of participants in the Framingham Heart Study. Circulation 1983;67(5): 968–77.
36. Rehm J, Room R, Graham K, Monteiro M, Gmel G, Sempos CT. The relationship of average volume of alcohol consumption and patterns of drinking to burden of disease: an overview. Addiction 2003;98(9): 1209–28.
37. Thompson PD. Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease. Arterioscler Thromb Vasc Biol 2003;23(8):1319–21.
38. Miller GE, Chen E, Parker KJ. Psychological stress in childhood and susceptibility to the chronic diseases of aging: moving toward a model of behavioral and biological mechanisms. Psychol Bull 2011;137(6):959–97.
39. Brady SS, Matthews KA. Chronic stress influences ambulatory blood pressure in adolescents. Ann Behav Med 2006;31(1):80–8.
40. Matthews KA, Zhu S, Tucker DC, Whooley MA. Blood pressure reactivity to psychological stress and coronary calcification in the Coronary Artery Risk Development in Young Adults Study. Hypertension 2006;47(3):391–5.
41. Low CA, Salomon K, Matthews KA. Chronic life stress, cardiovascular reactivity, and subclinical cardiovascular disease in adolescents. Psychosom Med 2009;71(9):927–31.
42. Danese A, Moffitt TE, Harrington H, et al. Adverse childhood experiences and adult risk factors for age-related disease: depression, inflammation, and clustering of metabolic risk markers. Arch Pediatr Adolesc Med 2009;163(12):1135–43.
43. Taylor SE, Lehman BJ, Kiefe CI, Seeman TE. Relationship of early life stress and psychological functioning to adult C-reactive protein in the coronary artery risk development in young adults study. Biol Psychiatry 2006;60(8):819–24.
44. Slopen N, Koenen KC, Kubzansky LD. Childhood adversity and immune and inflammatory biomarkers associated with cardiovascular risk in youth: a systematic review. Brain Behav Immun 2012;26(2):239–50.
45. Rich-Edwards JW, Spiegelman D, Lividoti Hibert EN, et al. Abuse in childhood and adolescence as a predictor of type 2 diabetes in adult women. Am J Prev Med 2010;39(6):529–36.
46. Thomas C, Hypponen E, Power C. Obesity and type 2 diabetes risk in midadult life: the role of childhood adversity. Pediatrics 2008;121(5): e1240–e1249.
47. Kaufman D, Banerji MA, Shorman I, et al. Early-life stress and the development of obesity and insulin resistance in juvenile bonnet macaques. Diabetes 2007;56(5):1382–6.
48. Mays VM, Cochran SD. Mental health correlates of perceived discrimination among lesbian, gay, and bisexual adults in the U.S. Am J Public Health 2001;91(11):1869–76.
49. Hatzenbuehler ML, Keyes KM, Hasin DS. State-level policies and psychiatric morbidity in lesbian, gay, and bisexual populations. Am J Public Health 2009;99(12):2275–81.
50. Hatzenbuehler ML, McLaughlin KA, Keyes KM, Hasin DS. The impact of institutional discrimination on psychiatric disorders in lesbian, gay, and bisexual populations: a prospective study. Am J Public Health 2010;100(3):452–9.
51. Krieger N, Sidney S. Racial discrimination and blood pressure: the CARDIA Study of young black and white adults. Am J Public Health 2010;100(3):452–9.
52. Guyll M, Matthews KA, Bromberger JT. Discrimination and unfair treatment: relationship to cardiovascular reactivity among African American and European American women. Health Psychol 2001;20(5):315–25.
53. Roberts CB, Vines AI, Kaufman JS, James SA. Cross-sectional association between perceived discrimination and hypertension in African-American men and women: the Pitt County Study. Am J Epidemiol 2008;167(5):624–32.
54. Sims M, Diez-Roux AV, Dudley A, et al. Perceived discrimination and hypertension among African Americans in the Jackson Heart Study. Am J Public Health 2012;102(S2):S258–S265.
55. Troxel WM, Matthews KA, Bromberger JT, Sutton-Tyrrell K. Chronic stress burden, discrimination, and subclinical carotid artery disease in African American and Caucasian women. Health Psychol 2003;22(3):300–9.
56. Lewis TT, Everson-Rose SA, Powell LH, et al. Chronic exposure to everyday discrimination and coronary artery calcification in African-American women: the SWAN Heart Study. Psychosom Med 2006;68(3):362–8.
57. Ayotte BJ, Hausmann LR, Whittle J, Kressin NR. The relationship between perceived discrimination and coronary artery obstruction. Am Heart J 2012;163(4):677–83.
58. Lewis TT, Aiello AE, Leurgans S, Kelly J, Barnes LL. Self-reported experiences of everyday discrimination are associated with elevated C-reactive protein levels in older African-American adults. Brain Behav Immun 2010;24(3):438–43.
59. Hatzenbuehler ML, O'Cleirigh C, Grasso C, Mayer K, Safren S, Bradford J. Effect of same-sex marriage laws on health care use and expenditures in sexual minority men: a quasi-natural experiment. Am J Public Health 2012;102(2):285–91.
60. Resnick MD, Bearman PS, Blum RW, et al. Protecting adolescents from harm. Findings from the National Longitudinal Study on Adolescent Health. JAMA 1997;278(10):823–32.
61. American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes Care 2011;34:S62–S69.
62. Whitsel EA, Cuthbertson CC, Tabor JW, et al. Measures of inflammation and immune function. Chapel Hill NC: University of North Carolina at Chapel Hill, 2012.
63. McDade TW, Burhop J, Dohnal J. High-sensitivity enzyme immunoassay for C-reactive protein in dried blood spots. Clin Chem 2003;50:652–4.
64. Pearson TA, Mensah GA, Alexander RW, et al. Markers of inflammation and cardiovascular disease: application to clinical and public health practice: a statement for healthcare professionals from the Centers for Disease Control and Prevention and the American Heart Association. Circulation 2003;107(3):499–511.
65. Yeh ET, Willerson JT. Coming of age of C-reactive protein: using inflammation markers in cardiology. Circulation 2003;107(3):370–1.
66. Rohlfing CL, Wiedmeyer HM, Little RR, England JD, Tennill A, Goldstein DE. Defining the relationship between plasma glucose and HbA(1c): analysis of glucose profiles and HbA(1c) in the Diabetes Control and Complications Trial. Diabetes Care 2002;25(2):275–8.
67. Whitsel EA, Tabor JW, Nguyen QC, et al. Add Health Wave IV documentation: measures of glucose homeostasis. Chapel Hill NC: University of North Carolina at Chapel Hill, 2012.

68. O'Connor MF, Bower JE, Cho HJ, et al. To assess, to control, to exclude: effects of biobehavioral factors on circulating inflammatory markers. Brain Behav Immun 2009;23(7):887–97.
69. Ornelas IJ, Perreira KM, Ayala GX. Parental influences on adolescent physical activity: a longitudinal study. Int J Behav Nutr Phys Act 2007;4:3.
70. Brochier ML, Arwidson P. Coronary heart disease risk factors in women. Eur Heart J 1998;19(SA):A45–A52.
71. Rossouw JE. Hormones, genetic factors, and gender differences in cardiovascular disease. Cardiovasc Res 2002;53(3):550–7.
72. Sell RL, Wells JA, Wypij D. The prevalence of homosexual behavior and attraction in the U.S., the United Kingdom and France: results of national population-based samples. Arch Sex Behav 1995;24(3):235–48.
73. Diamond LM. New paradigms for research on heterosexual and sexual-minority development. J Clin Child Adolesc Psychol 2003;32(4):490–8.
74. Lee JG, Griffin GK, Melvin CL. Tobacco use among sexual minorities in the USA, 1987 to May 2007: a systematic review. Tob Control 2009;18(4):275–82.
75. Case P, Austin SB, Hunter DJ, et al. Sexual orientation, health risk factors, and physical functioning in the Nurses' Health Study II. J Womens Health (Larchmt) 2004;13(9):1033–47.
76. Drabble L, Midanik LT, Trocki K. Reports of alcohol consumption and alcohol-related problems among homosexual, bisexual and heterosexual respondents: results from the 2000 National Alcohol Survey. J Stud Alcohol 2005;66(1):111–20.
77. DHHS. Office of Disease Prevention and Health Promotion. Healthy People 2020. Lesbian, gay, bisexual, and transgender health. www.healthypeople.gov/2020/topicsobjectives2020/overview.aspx?topicid=25.

Appendix

Supplementary data

Supplementary data associated with this article can be found, in the online version at http://dx.doi.org/10.1016/j.amepre.2013.01.027.