



# Religious Attendance and Biological Risk: A National Longitudinal Study of Older Adults

Hyungjun Suh<sup>1</sup> · Terrence D. Hill<sup>1</sup> · Harold G. Koenig<sup>2,3</sup>

Published online: 17 October 2018

© Springer Science+Business Media, LLC, part of Springer Nature 2018

## Abstract

Although several studies suggest that religious involvement is associated with healthier biological functioning in later life, most of this work is cross-sectional. We extend previous research by employing a longitudinal design. Our analysis of Health and Retirement Study (2006/2010) data suggests that older adults who attended religious services weekly or more in 2006 tend to exhibit *fewer* high-risk biomarkers in 2010 and greater *reductions* in allostatic load over the 4-year study period than respondents who attended yearly or not at all. These patterns persisted with adjustments for baseline allostatic load and a range of background variables.

**Keywords** Religion · Religious involvement · Biology · Allostatic load · Cystatin-C

## Introduction

Over the past three decades, numerous studies have shown that religious involvement—indicated by observable feelings, beliefs, activities, and experiences in relation to the spiritual, divine, or supernatural—tends to favor health and longevity in middle-aged and older adults. These patterns are remarkably consistent across a range of mental and physical health indicators, including anger (Carr 2003), depression (Hill et al. 2017a; Idler 1987; Idler and Kasl 1997a; Strawbridge et al. 1998), anxiety (Cicirelli 2002; Krause 2005), non-specific psychological distress (Fry 2001; Idler and Kasl 1997a), life satisfaction (Levin et al. 1996; Krause 2003, 2005), cognitive functioning (Hill et al. 2006; Reyes-Ortiz et al. 2008; Van Ness and Kasl 2003), self-rated health (Idler et al. 2009;

---

✉ Terrence D. Hill  
tdhill@email.arizona.edu

Hyungjun Suh  
suhhyungjun@email.arizona.edu

Harold G. Koenig  
harold.koenig@duke.edu

<sup>1</sup> School of Sociology, The University of Arizona, Social Sciences Building, Room 400, 1145 E. South Campus Drive, Tucson, AZ 85721, USA

<sup>2</sup> Departments of Psychiatry and Medicine, Duke University Medical Center, Durham, NC, USA

<sup>3</sup> Department of Medicine, King Abdulaziz University, Jeddah, Saudi Arabia

Krause 1998, 2006), physical functioning (Benjamins 2004; Hill et al. 2016a; Idler 1987; Idler and Kasl 1997b; Park et al. 2008), and stroke (Wolinsky et al. 2009). Not surprisingly, religious involvement is also associated with lower risk of all-cause mortality (Ellison et al. 2000; Gillum et al. 2008; Hill et al. 2005; Idler et al. 2017; Strawbridge et al. 1997) and mortality linked to circulatory diseases, respiratory diseases, and other specific causes (Hummer et al. 1999; Oman et al. 2002; Rogers et al. 2010).

Most recently, researchers have endeavored to establish links between religious involvement and biological functioning. In general, research shows that various indicators of religious involvement are associated with favorable biomarker profiles across sympathetic nervous, hypothalamic–pituitary–adrenal (HPA), cardiovascular, immune, and metabolic systems (Hill Hill 2010; Hill et al. 2016b; Seeman et al. 2003; Seybold 2007). When limited to studies of older adults, there is evidence that religious involvement is associated with lower levels of blood pressure (Das and Nairn 2016; Hill et al. 2014, 2017b; Koenig et al. 1998; Krause et al. 2002; Maselko et al. 2007), pulse rate (Hill et al. 2014, 2017b), c-reactive protein (Das and Nairn 2016; Ferraro and Kim 2014; Gillum et al. 2008; Hill et al. 2014, 2017a, b; King et al. 2001, 2002), interleukin-6 (Koenig et al. 1997; Lutgendorf et al. 2004), white blood cells (King et al. 2001), Epstein–Barr virus (Das and Nairn 2016; Hill et al. 2014), epinephrine (Maselko et al. 2007), cortisol (Ironson et al. 2002; Tobin and Slatcher 2016), and overall allostatic load or chronic over- or under-activity of the physiological stress response (Hill et al. 2014, 2017b; Maselko et al. 2007). However, evidence concerning the metabolic system is weak and mixed. Some research suggests that religious involvement is associated with lower levels of total cholesterol (Hill et al. 2017b). Other studies show that religious involvement is unrelated to glycosylated hemoglobin (Das and Nairn 2016; Hill et al. 2014, 2017b). While researchers consistently demonstrate that religious adults tend to exhibit larger body mass than their less religious counterparts (Bruce et al. 2007; Ferraro 1998; Godbolt et al. 2018; Idler and Kasl 1997a; Kim et al. 2003; Oman and Reed 1998; Strawbridge et al. 1997), other studies show the opposite pattern or no association (Godbolt et al. 2018; Hill et al. 2017b). Research also suggests that religious adults are less likely to be underweight (Hill et al. 2014; Musick et al. 2004), which is especially important for health and well-being in old age (Sergi et al. 2005).

We currently know very little about how religious involvement gets “under the skin” to contribute to healthier biological functioning. Nevertheless, previous research has proposed several potential social (e.g., social integration and social support), psychological (e.g., meaning and control beliefs), behavioral (e.g., drinking and smoking), and biological (e.g., stress) mechanisms (George et al. 2002; Hill 2010, 2016b, 2017a; Koenig et al. 2012; Seybold 2007). Religious involvement and religious meaning systems may help to buffer appraisals of stressful life conditions and, by extension, their physiological consequences. Social support, the sense of control, and moderate drinking practices could help adults to avoid stress appraisals, stressful life events, and chronic activation of the physiological stress response. In the event of stressful life conditions (and the activation of sympathetic systems), religious beliefs and practices, supportive relationships, strong self-concepts, and healthy lifestyles may also favor healthy coping strategies (and efficient activation of parasympathetic systems and various growth responses).

Because stress, mental health, and unhealthy behaviors are reliably linked to religious involvement and the activation of nervous, HPA, cardiovascular, immune, and metabolic systems (McEwen 1998, 2002), these factors (among others) may function as general mechanisms across markers of allostatic systems. We should note that these mechanisms cannot explain the somewhat inconsistent finding of a positive association between

religious attendance and body mass (an important marker of the metabolic system). Explanations for why religious adults tend to weigh more are not firmly established in the literature. However, there is some speculation that poor eating habits, lower rates of smoking, and the sedentary practice of religious media consumption may play a role (Cline and Ferraro 2006; Kim et al. 2003).

Although previous research has made significant contributions to our understanding of religious involvement and biological functioning in later life, most of this work is cross-sectional (for exceptions, see Hill et al. 2017a, b; Ferraro and Kim 2014; Tobin and Slatcher 2016). In the absence of longitudinal designs and controls for baseline health status, healthier adults can be “selected” into religious activities (Idler 1987; Maselko et al. 2012). The concept of health selection suggests that the apparent health benefits of religious involvement are merely artifacts of prior health status. It is often unclear why religious people appear healthier than their less religious counterparts. We tend to assume that religious involvement predicts health status, but health status might also predict religious involvement. Idler (1987:227) explains that any observed association between religious involvement and health could be driven by “the fact that health status may determine ability to participate in public religious services.” While some longitudinal studies control for some measure of baseline biological functioning or other measures like disability and overall self-rated health (Hill et al. 2017b; Ferraro and Kim 2014), others do not (Hill et al. 2017a; Tobin and Slatcher 2016). To our knowledge, Ferraro and Kim (2014) are the only researchers to report a statistically significant longitudinal association between some measure of religious involvement (religious attendance) and some measure of biological functioning (c-reactive protein) while adjusting for baseline biological functioning (c-reactive protein).

In this paper, we employ longitudinal data collected from a large national sample of older adults to examine the association between religious attendance and biological functioning. We contribute to previous research in several ways. First and foremost, we employ a longitudinal design that includes adjustments for baseline biological functioning. Second, we attempt to replicate previous studies by observing biomarkers that have been explored in the literature, including glycosylated hemoglobin, C-reactive protein, body mass, blood pressure, and overall allostatic load. Third, we examine associations with understudied or previously unexplored biomarkers that are also important for population health, including waist circumference, cystatin-C, non-high-density lipoprotein cholesterol, and pulse rate. Waist circumference, a direct measure of adiposity about the waist, is an important indicator of metabolic functioning in particular and allostatic load more broadly (McEwen 2002). Cystatin-C is an important marker of kidney function that is associated with inflammation and cardiovascular morbidity and mortality (Muslimovic et al. 2015). Non-high-density lipoprotein cholesterol is an important indicator of metabolic functioning that is associated with coronary atherosclerosis, heart disease, and increased mortality risk (Crimmins and Vasunilashorn 2011). Pulse rate is an alternative to blood pressure that is associated with heart disease and increased mortality (Crimmins and Vasunilashorn 2011). Finally, while acknowledging different coding conventions in the literature, we assess how associations with religious attendance might vary depending on how biological functioning is specified.

## Methods

### Data

We use data from the 2006 and 2010 Health and Retirement Study (HRS) to formally test our hypotheses. The HRS is a national panel study of older adults aged 50 and over who live in the USA (Servais 2010). In 2006, the HRS randomly selected households for an enhanced face-to-face interview (EFTF), including a set of performance tests, anthropometric measurements, and blood and saliva samples. Those who participated in 2006 were re-interviewed in 2010, which enables longitudinal analysis. The HRS collected blood specimens utilizing established dried blood spot (DBS) procedures (Crimmins et al. 2013). Measures of financial wealth were obtained from RAND HRS data. All analyses are limited to those respondents who completed blood tests in 2006 and 2010 and have records of nine cardiovascular disease (CVD) risk factors (explained below). After listwise deletion, our longitudinal analyses included 2912 respondents. Table 1 provides descriptive statistics for our sample.

### Measures

#### Religious Attendance (2006)

Religious involvement is indicated by religious attendance, the most commonly used measure of religiousness (Idler et al. 2003). Respondents were asked: “About how often have you attended religious services during the last year?” Original response included (1) not at all, (2) 1 or more times a year, (3) 2 or 3 times a month, (4) once a week, and (5) more than once a week. We combined categories of attendance that are theoretically and empirically similar. Specifically, categories 1–2 and 4–5, respectively, were combined in our final measure to capture (1) no attendance or yearly attendance, (2) monthly attendance, and (3) weekly attendance. Given that previous research shows little variation in religious attendance over time in older adults (Hill et al. 2017a), we only assess attendance at baseline to establish temporal order.

#### Biological Functioning (2006/2010)

Metabolic functioning is indicated by body mass index (BMI), waist circumference (WC), glycosylated hemoglobin (HbA1c), and non-high-density lipoprotein cholesterol (non-HDL-C). Continuous WC assesses the degree of central adiposity. Continuous BMI is measured using a standard formula:  $\text{weight (kg)}/\text{height}^2 \text{ (m)}$ . Continuous HbA1c represents blood glucose levels and is measured by the ratio of glycosylated to non-glycosylated hemoglobin. Continuous non-HDL-C is measured by subtracting high-density lipoprotein cholesterol from total cholesterol and reflects the cholesterol content of all “bad” lipoproteins, including low-density lipoprotein (LDL). Cardiovascular functioning is indicated by systolic blood pressure (SBP), diastolic blood pressure (DBP), and pulse rate. For most respondents, we use the average of two or three readings. If only one reading was obtained, we used that reading. Inflammatory markers include continuous C-reactive protein (CRP) and continuous cystatin-C (CC).

Following the recent work (Hill et al. 2014), we employ a multiple specification approach to overcome the limitations of any particular coding scheme (e.g., categorical

**Table 1** Descriptive statistics ( $n = 2912$ )

	MIN	MAX	MEAN	SD
Religious attendance				
≤ Yearly	0.00	1.00	0.43	
Monthly	0.00	1.00	0.12	
≥ Weekly	0.00	1.00	0.45	
Continuous allostatic load (2006)	0.95	4.25	2.47	0.47
Continuous allostatic load (2010)	1.40	4.52	2.78	0.43
Count allostatic load (2006)	0.00	8.00	2.34	1.76
Count allostatic load (2010)	0.00	8.00	2.29	1.71
Waist circumference (2010)	3.25	78.00	40.04	5.85
Glycosylated hemoglobin (2010)	3.90	15.90	6.11	1.00
C-reactive protein (2010)	0.06	177.41	3.62	8.22
Body mass index (2010)	16.00	60.80	28.26	5.67
Cystatin-C (2010)	0.06	4.50	0.80	0.33
Systolic blood pressure (2010)	77.33	225.00	132.46	20.43
Diastolic blood pressure (2010)	44.00	123.00	79.10	11.43
Pulse rate (2010)	36.33	133.00	68.92	11.21
Non-high-density lipoprotein cholesterol (2010)	26.00	276.00	138.76	32.47
Age	50.00	94.00	66.31	9.13
Female	0.00	1.00	0.58	
Married	0.00	1.00	0.72	
Employed	0.00	1.00	0.40	
Race/ethnicity				
Non-Hispanic white	0.00	1.00	0.80	
Non-Hispanic black	0.00	1.00	0.11	
Mexican American	0.00	1.00	0.07	
Other race/ethnicity	0.00	1.00	0.02	
Education				
< High school	0.00	1.00	0.15	
High school degree	0.00	1.00	0.37	
Some college	0.00	1.00	0.24	
≥ College degree	0.00	1.00	0.24	
Household wealth (Ln)	0.00	16.77	11.72	3.14
Financial debt	0.00	1.00	0.05	

assessments can be arbitrary and insensitive, while continuous or dimensional assessments ignore regions of clinical significance). We examine two specifications of overall allostatic load (i.e., an index of the individual biomarkers) and two specifications of each individual biomarker in 2006 and 2010. Our first specification treats each individual biomarker and overall allostatic load as continuous variables (Karlamañgla et al. 2002; Maselko et al. 2007). Each individual biomarker was standardized and averaged to create the continuous measure of overall allostatic load. We use ordinary least squares (OLS) regression to estimate associations with all continuous specifications.

Our second specification employs a high-risk cutoff criterion (Crimmins et al. 2003; Geronimus et al. 2006; Seeman et al. 2001). Respondents who scored in the top 25th percentile of each biomarker are coded (1) and all others (0). We use binary logistic regression to estimate associations with all binary specifications. We created another overall allostatic load index by taking the sum of the number of biomarkers for which the respondent exceeded the high-risk criterion. In this case, higher scores indicate greater biological risk. We use negative binomial regression to estimate associations with this count specification.

### Control Variables (2006)

Subsequent multivariate analyses control for several potential correlates of religious attendance and allostatic load. These correlates include *age* (measured in continuous years), *gender* (1 = female; 0 = male), *marital status* (1 = married; 0 = unmarried), *employment status* (1 = employed; 0 = unemployed), *race/ethnicity* (dummy variables for non-Hispanic white, non-Hispanic black, Mexican American, and other race/ethnicity), *education* (dummy variables for less than high school, high school graduates, some college, and college graduates and above), *household wealth* (measured in logged continuous U.S. dollars), and *financial debt* (1 = has debt; 0 = has no debt).

## Results

### Descriptive Statistics

Table 1 provides descriptive statistics, including variable ranges, means, and standard deviations. In 2006, 43% of respondents attended religious services once a year or less, 12% attended monthly, and 45% attended weekly. In 2010, we observed low levels of body mass (BMI), C-reactive protein (CRP), and cystatin-C (CC). We also observed moderate levels of waist circumference (WC), glycosylated hemoglobin (HbA1c), non-high-density lipoprotein cholesterol (non-HDL-C), systolic blood pressure, diastolic blood pressure, and pulse rate. With respect to allostatic load in 2006 and 2010, we found moderate overall levels in the sample, with the average respondent exhibiting approximately two high-risk biomarkers.

### Overall Allostatic Load

The first two columns of Table 2 present the OLS regression of the continuous specification of the 2010 allostatic load index. In this analysis, the dependent variable is a mean of the continuous individual biomarkers. In Model 1, we show unstandardized OLS coefficients that are interpreted as the difference in the *expected mean* of allostatic load for each one-unit change in an independent variable, while all other variables in the model are held constant. The coefficient for weekly religious attendance is marginally statistically significant ( $p < 0.10$ ) and negative. This result suggests that respondents who attended religious services once or more per week in 2006 tend to exhibit *lower* levels of allostatic load in 2010 than those respondents who attended yearly or not at all. The coefficient for monthly religious attendance is not statistically significant. This result indicates *comparable* levels of allostatic load for respondents who attended monthly versus yearly or not at all.

**Table 2** Ordinary least squares and negative binomial regression of allostatic load ( $n = 2912$ )

	Continuous allostatic load (2010)		Count allostatic load (2010)	
	Model 1	Model 2	Model 3	Model 4
Continuous allostatic load (2006)		0.58*** (0.01)		
Count allostatic load (2006)				0.22*** (0.01)
Religious attendance <sup>a</sup>				
Monthly	− 0.03 (0.03)	0.00 (0.02)	− 0.05 (0.04)	− 0.01 (0.04)
≥ Weekly	− 0.03 <sup>+</sup> (0.02)	− 0.02 <sup>+</sup> (0.01)	− 0.08* (0.03)	− 0.06* (0.03)
Age	− 0.00*** (0.00)	− 0.00* (0.00)	− 0.00 (0.00)	− 0.00 (0.00)
Female <sup>b</sup>	− 0.09*** (0.02)	− 0.01 (0.01)	− 0.10*** (0.03)	− 0.07* (0.03)
Race/ethnicity <sup>c</sup>				
Non-Hispanic black	0.17*** (0.03)	0.06** (0.02)	0.23*** (0.04)	0.09* (0.04)
Mexican American	0.03 (0.03)	− 0.01 (0.03)	0.02 (0.05)	− 0.02 (0.05)
Other race/ethnicity	0.03 (0.03)	− 0.01 (0.03)	0.02 (0.05)	− 0.02 (0.05)
Education <sup>d</sup>				
High school degree	− 0.01 (0.03)	− 0.00 (0.02)	− 0.02 (0.04)	− 0.01 (0.04)
Some college	− 0.05 <sup>+</sup> (0.03)	− 0.03 (0.02)	− 0.07 (0.05)	− 0.02 (0.04)
≥ College degree	− 0.13*** (0.03)	− 0.04 <sup>+</sup> (0.02)	− 0.21*** (0.05)	− 0.09 <sup>+</sup> (0.05)
Married <sup>e</sup>	− 0.02 (0.02)	− 0.02 (0.01)	− 0.03 (0.03)	− 0.03 (0.03)
Employed	− 0.03 (0.02)	0.00 (0.01)	− 0.06 <sup>+</sup> (0.03)	− 0.01 (0.03)
Household wealth (Ln)	− 0.02*** (0.01)	− 0.00 (0.00)	− 0.05*** (0.01)	− 0.01 <sup>+</sup> (0.01)
Financial debt <sup>f</sup>	− 0.21** (0.07)	− 0.03 (0.05)	− 0.40*** (0.11)	− 0.04 (0.10)

Health and Retirement Study (2006/2010). Shown are unstandardized ordinary least squares regression (Models 1–2) and negative binomial regression (Models 3–4) coefficients with standard errors in parentheses and two-tailed significance tests: \*\*\* $p < 0.001$ ; \*\* $p < 0.01$ ; \* $p < 0.05$ , + $p < 0.10$

Reference groups include: <sup>a</sup> ≤ yearly attendance, <sup>b</sup> male, <sup>c</sup> non-Hispanic white, <sup>d</sup> < than high school, <sup>e</sup> unmarried, <sup>f</sup> no debt

In Model 2, we add the 2006 allostatic load index to Model 1. The unstandardized OLS coefficients in this lagged endogenous dependent variable model are interpreted as the difference in the *expected change* in allostatic load for each one-unit change in an independent variable, while all other variables in the model are held constant. Once again, the coefficient for weekly attendance is marginally statistically significant ( $p < 0.10$ ) and negative. This suggests that respondents who attended religious services once or more per week in 2006 tend to exhibit *greater reductions* in allostatic load over the 4-year study period than those respondents who attended yearly or not at all. Because the coefficient for monthly attendance is not statistically significant, we observe *comparable* changes in allostatic load for respondents who attended monthly versus yearly or not at all.

The last two columns of Table 2 present the negative binomial regression of the 2010 count specification of allostatic load. In this analysis, the dependent variable is a count of individual biomarkers that have been dummy-coded to indicate high-risk (i.e., the high-risk quarter of the continuous biomarker distribution). In Model 3, we show unstandardized negative binomial coefficients that are interpreted as the difference in the *expected log count* of allostatic load for each one-unit change in an independent variable, while all other variables in the model are held constant. The coefficient for weekly religious attendance is statistically significant ( $p < 0.05$ ) and negative. This result is consistent with Model 1. Respondents who attended religious services once or more per week in 2006 tend to exhibit *fewer* high-risk biomarkers in 2010 than those respondents who attended yearly or not at all. When negative binomial coefficients are exponentiated ( $e^b$ ), the result is an incidence rate ratio (IRR). IRRs are interpreted as the difference in the expected allostatic load count for each one-unit change in an independent variable, while all other variables in the model are held constant. IRRs can be further manipulated ( $[IRR - 1] \times 100$ ) to describe the percent difference in the expected allostatic load count for each one-unit change in an independent variable. The IRR for weekly attendance is 0.92 ( $e^{-0.08}$ ). Because the IRR is less than one, the association between religious attendance and allostatic load is inverse. More specifically, the expected allostatic load count is 8% ( $[0.92 - 1] \times 100$ ) *lower* in 2010 than in 2006 for respondents who attended religious services weekly or more than for respondents who attended yearly or not at all. Because the coefficient for monthly attendance is not statistically significant, we observe comparable levels of allostatic load for respondents who attended monthly versus yearly or not at all.

In Model 4, we added the 2006 allostatic load count to Model 3. The unstandardized negative binomial regression coefficients in this lagged endogenous dependent variable model are interpreted as the difference in the *expected change* in the allostatic load count for each one-unit change in an independent variable, while all other variables in the model are held constant. Once again, the coefficient for weekly religious attendance is statistically significant ( $p < 0.05$ ) and negative. This suggests that respondents who attended religious services once or more per week in 2006 tend to exhibit *greater reductions* in the allostatic load count over the study period than those respondents who attended yearly or not at all. The IRR for weekly attendance is 0.94 ( $e^{-0.06}$ ). Because the IRR is less than one, the association between religious attendance and the allostatic load count is inverse. More specifically, the expected allostatic load count is 6% ( $[0.94 - 1] \times 100$ ) *lower* in 2010 than in 2006 for respondents who attended religious services weekly or more than for respondents who attended yearly or not at all. Because the coefficient for monthly attendance is not statistically significant, we observe *comparable* changes in the allostatic load count for respondents who attended monthly versus yearly or not at all.

## Individual Biomarkers

Our multivariate analysis of allostatic load consistently shows that respondents who attend religious services weekly or more tend to exhibit lower levels of overall allostatic load than those respondents who attend yearly or not at all. The regression results presented in Table 3 assess whether the general associations between religious attendance and overall allostatic load are driven by specific biomarkers. To accomplish this, Table 3 presents associations between religious attendance and each of the nine 2010 biomarkers with adjustments for the appropriate 2006 biomarker and control variables.

Table 3 shows that religious attendance is *unrelated* to waist circumference (WC), glycosylated hemoglobin (HbA1c), body mass index (BMI), and systolic blood pressure (SBP) across specifications. Consistent with our results in Table 2, coefficients for monthly religious attendance are null across models. However, there is some evidence to suggest that weekly religious attendance is associated with lower levels of C-reactive protein (CRP), cystatin-C (CC), non-high-density lipoprotein cholesterol (non-HDL-C), diastolic blood pressure (DBP), and pulse rate (Pulse).

In Table 3, respondents who attended religious services weekly or more in 2006 tend to exhibit *greater reductions* in C-reactive protein in the OLS specification ( $p < 0.10$ ). This pattern is confirmed in the binary logit specification ( $p < 0.10$ ). When unstandardized binary logit coefficients are exponentiated ( $e^b$ ), the result is an odds ratio. Odds ratios (ORs) are interpreted as the estimated difference in the *expected change* in the odds of high biological risk for each one-unit change in an independent variable, while all other variables in the model are held constant. ORs can be manipulated ( $[OR - 1] \times 100$ ) to describe the percent difference in the odds of high biological risk for each one-unit change in an independent variable. In this case, there are *greater reductions* in the odds of being classified in the high-risk quarter of the CRP distribution over the study period for respondents who attended religious services weekly. More specifically, the change in the odds of having high CRP is 16% ( $[0.83 - 1] \times 100$ ) *lower* for respondents who attended weekly or more as compared with respondents who attended yearly or not at all.

Attending religious services weekly or more is also consistently associated with *greater reductions* in levels of cystatin-C in the OLS specification ( $p < 0.10$ ) and the odds of high cystatin-C in the binary logit specification ( $p < 0.05$ ). In fact, the change in the odds of having high CC is 20% *lower* for respondents who attended weekly or more as compared with respondents who attended yearly or not at all. Although religious attendance is *unrelated* to the OLS specifications of non-high-density lipoprotein cholesterol and diastolic blood pressure, attending weekly or more is associated with a 16% *reduction* in the odds of being classified in the high-risk quarter of the non-HDL-C distribution ( $p < 0.10$ ) and a 17% *reduction* in the odds of being classified in the high-risk quarter of the DBP distribution ( $p < 0.10$ ). Finally, while weekly attendance is associated with *lower* pulse rates ( $p < 0.05$ ) in the OLS specification, religious attendance is *unrelated* to pulse in the binary logit specification.

## Discussion

Although several studies suggest that religious involvement tends to favor healthier biological functioning in later life, most of this work is cross-sectional. We extended recent longitudinal research (Hill et al. 2017a, b; Ferraro and Kim 2014; Tobin and Slatcher 2016) by employing a longitudinal design that includes adjustments for baseline biological

**Table 3** Ordinary least squares and binary logistic regression of individual biomarkers ( $n = 2912$ )

	WC (2010)	HbA1c (2010)	CRP (2010)	BMI (2010)	Cystatin-C (2010)	Non-HDL-C (2010)	SBP (2010)	DBP (2010)	Pulse (2010)
<b>OLS models</b>									
Continuous biomarker (2006)	0.85*** (0.01)	0.79*** (0.02)	0.40*** (0.04)	0.91*** (0.01)	0.87*** (0.02)	0.24*** (0.01)	0.47*** (0.02)	0.43*** (0.02)	0.53*** (0.02)
<b>Religious attendance<sup>a</sup></b>									
Monthly	- 0.14 (0.18)	0.03 (0.05)	0.56 (0.50)	- 0.08 (0.16)	- 0.00 (0.02)	1.13 (1.87)	0.62 (1.07)	- 0.35 (0.63)	- 0.57 (0.58)
≥ Weekly	0.11 (0.12)	0.02 (0.03)	- 0.64 <sup>+</sup> (0.33)	- 0.02 (0.11)	- 0.02 <sup>+</sup> (0.01)	- 1.74 (1.26)	- 0.17 (0.72)	- 0.33 (0.42)	- 0.77* (0.39)
<b>Logit models</b>									
Binary biomarker (2006)	3.68*** (0.12)	2.26*** (0.10)	2.06*** (0.10)	3.92*** (0.13)	1.99*** (0.10)	1.00*** (0.09)	1.38*** (0.10)	1.31*** (0.09)	1.71*** (0.10)
<b>Religious attendance<sup>a</sup></b>									
Monthly	- 0.08 (0.20)	- 0.07 (0.16)	0.03 (0.15)	- 0.06 (0.21)	- 0.09 (0.16)	0.15 (0.14)	0.02 (0.15)	- 0.11 (0.15)	- 0.16 (0.16)
≥ Weekly	0.06 (0.13)	0.09 (0.11)	- 0.18 <sup>+</sup> (0.11)	- 0.01 (0.14)	- 0.22* (0.11)	- 0.18 <sup>+</sup> (0.10)	- 0.08 (0.10)	- 0.19 <sup>+</sup> (0.10)	- 0.13 (0.10)

Health and Retirement Study (2006/2010). Shown are unstandardized ordinary least squares regression and binary logistic regression coefficients with standard errors in parentheses and two-tailed significance tests: \*\*\* $p < 0.001$ ; \*\* $p < 0.01$ ; \* $p < 0.05$ ; + $p < 0.10$

WC waist circumference, HbA1c glycosylated hemoglobin, CRP C-reactive protein, BMI body mass index, Non-HDL-C non-high-density lipoprotein cholesterol, SBP systolic blood pressure, DBP diastolic blood pressure

Reference group is <sup>a</sup> ≤ yearly attendance. All regression estimates are adjusted for age, gender, marital status, employment status, race/ethnicity, education, household wealth, and financial debt

functioning and by examining associations with biomarkers that have been explored (e.g., glycosylated hemoglobin, C-reactive protein, body mass, blood pressure, and overall allostatic load) and understudied (e.g., waist circumference, cystatin-C, non-high-density lipoprotein cholesterol, and pulse rate) in previous work.

Our primary findings suggest that older adults who attended religious services once per week or more in 2006 tend to exhibit *fewer* high-risk biomarkers in 2010 and greater *reductions* in allostatic load over the 4-year study period than those respondents who attended yearly or not at all. These patterns persisted with adjustments for baseline allostatic load, age, gender, race/ethnicity, education, marital status, employment status, household wealth, and financial debt. Because monthly attenders were statistically indistinguishable from those who attended yearly or not at all, there was a clear threshold in the association between religious attendance and overall allostatic load. Taken together, our results confirm previous cross-sectional (Hill et al. 2014; Maselko et al. 2007) and longitudinal (Hill et al. 2017b) studies.

Our secondary findings concerning individual biomarkers reveal several interesting patterns. First, religious attendance is *unrelated* to waist circumference, glycosylated hemoglobin, body mass index, and systolic blood pressure across specifications. Second, in the OLS specification, weekly religious attendance is associated with *greater reductions* in C-reactive protein ( $p < 0.10$ ), cystatin-C ( $p < 0.10$ ), and pulse rate ( $p < 0.05$ ). In the logit specification, weekly religious attendance is associated with *greater reductions* in the odds of being classified in the high-risk quarter of the distributions for C-reactive protein ( $p < 0.10$ ), cystatin-C ( $p < 0.05$ ), non-high-density lipoprotein cholesterol ( $p < 0.10$ ), and diastolic blood pressure ( $p < 0.10$ ). Finally, once again, monthly attendance is statistically indistinguishable from yearly attendance or less across all individual biomarkers and specifications.

The null patterns for glycosylated hemoglobin, body mass, and systolic blood pressure are in line with previous research (Das and Nairn 2016; Godbolt et al. 2018; Hill et al. 2014, 2017b). The results for C-reactive protein, non-high-density lipoprotein cholesterol, pulse rate, and diastolic blood pressure are also consistent with previous studies (Das and Nairn 2016; Ferraro and Kim 2014; Gillum et al. 2008; Hill et al. 2014, 2017a, b; King et al. 2001, 2002; Koenig et al. 1998; Krause and Ironson 2017; Krause et al. 2002; Maselko et al. 2007). However, the findings for waist circumference are inconsistent with recent research (Godbolt et al. 2018; Hill et al. 2017b; Krause and Ironson 2016). To the best of our knowledge, this is the first study to document an association between religious involvement and cystatin-C.

The contrast between our primary analyses of overall allostatic load and our secondary analyses of the individual biomarkers is striking. The association between weekly religious attendance and the summary measures of allostatic load is consistent across continuous and count specifications. Our results for the individual biomarkers are more sporadic. We tested 36 associations between religious attendance and the individual biomarkers. Approximately 80% of these associations are null. Nearly 14% are marginally statistically significant ( $p < 0.10$ ), and 6% are statistically significant at conventional levels ( $p < 0.05$ ). With the exception of C-reactive protein and cystatin-C, there is no consistency across specifications.

We acknowledge that our analyses are limited in four key respects. First, our measure of allostatic load has restricted content validity. It includes indicators of metabolic function, cardiovascular function, and immune function. However, to fully represent the concept, we would also need indicators of the HPA axis (e.g., cortisol and DHEAS) and autonomic nervous system (e.g., epinephrine and norepinephrine). Second, our analyses are limited to

a single indicator of religious involvement. Although religious attendance is commonly used and comparable to previous research, single items are generally low in reliability. Third, the relatively short follow-up period may artificially constrain the variability in our biomarkers over time. Given low reliability in religious attendance and low variability in biomarkers, our analyses are likely to underestimate the role of religious involvement in later life due to low statistical power. For this reason, we report marginal statistical significance in our results. Finally, the average age of the sample was 66 at baseline. This means that the average participant was born in 1950 and would largely consist of older baby boomers (born 1946–1964) and those in the generation just before baby boomers (silent/mature generation born 1925–1945). These cohorts tended to be more religious than current cohorts, but are pretty similar to one another (Pew Research Center 2014). They probably do not differ much from the current generation of older adults (only 8–12 years younger than our participants). Thus, the findings largely reflect those of older adults today, perhaps a bit more for the older old, where the consequences of high-risk biomarkers and allostatic load on health are most likely having their greatest effects.

## Conclusion

Our longitudinal analyses confirm that religious attendance is associated with healthier overall biological functioning among older adults. This general pattern is primarily driven by C-reactive protein, cystatin-C, non-high-density lipoprotein cholesterol, diastolic blood pressure, and pulse rate. These results suggest that the general health benefits of religious involvement are due more to a complex combination of biological processes than to any particular biomarker. Additional longitudinal research is needed to confirm our findings across measures of religious involvement and in diverse populations. We must also begin to articulate and test viable mediators of the effects of religious involvement on general (e.g., allostatic load) and specific indicators of biological risk (e.g., cystatin-C). Although some studies have considered indicators of biological risk (e.g., interleukin-6 and CRP) as mechanisms linking religious involvement and longevity, future work should also explore general and specific biological links to mental and physical health. Because substantive interpretations often depend on the choice of several valid biomarker specifications, we recommend that researchers continue to employ a multiple specification approach instead of focusing on any particular coding scheme. Research along these lines will provide a more thorough and extensive understanding of religious variations in late life biological functioning.

## Compliance with Ethical Standards

**Conflict of interest** All the authors declare that they have no conflict of interest.

**Ethical Approval** This article does not contain any studies with human participants performed by any of the authors. The current study employs secondary data analysis on de-identified, publicly available data, and therefore did not require IRB approval.

## References

- Benjamins, M. (2004). Religion and functional health among the elderly: Is there a relationship and is it constant? *Journal of Aging and Health, 16*, 355–374.
- Bruce, M., Sims, M., Miller, S., Elliott, V., & Ladipo, Marian. (2007). One size fits all? Race, gender and body mass index among U.S. adults. *Journal of the National Medical Association, 99*, 1152–1158.

- Carr, D. (2003). A “good death” for whom? Quality of spouse’s death and psychological distress among older widowed persons. *Journal of Health and Social Behavior*, *44*, 215–232.
- Cicirelli, V. (2002). Fear of death in older adults: Predictions from terror management theory. *Journal of Gerontology: Psychological Sciences*, *57B*, P358–P366.
- Cline, K. M. C., & Ferraro, K. F. (2006). Does religion increase the prevalence and incidence of obesity in adulthood? *Journal for the Scientific Study of Religion*, *45*, 269–281.
- Crimmins, E., Faul, J., Kim, J. K., Guyer, H., Langa, K., Ofstedal, M. B., et al. (2013). *Documentation of biomarkers in the 2006 and 2008 Health and Retirement Study*. Ann Arbor, MI: Survey Research Center, Institute for Social Research.
- Crimmins, E., Johnston, M., Hayward, M., & Seeman, T. (2003). Age differences in allostatic load: An index of physiological dysregulation. *Experimental Gerontology*, *38*, 731–734.
- Crimmins, E., & Vasunilashorn, S. (2011). Links between biomarkers and mortality. In R. Rogers & E. Crimmins (Eds.), *International handbook of adult mortality* (pp. 381–398). Netherlands: Springer.
- Das, A., & Nairn, S. (2016). Religious attendance and physiological problems in late life. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *71*, 291–308.
- Ellison, C., Hummer, R., Cormier, S., & Rogers, R. (2000). Religious involvement and mortality risk among African American adults. *Research on Aging*, *22*, 630–667.
- Ferraro, K. F. (1998). Firm believers? Religion, body weight, and well-being. *Review of Religious Research*, *39*, 224–244.
- Ferraro, K. F., & Kim, S. (2014). Health benefits of religion among black and white older adults? Race, religiosity, and C-reactive protein. *Social Science and Medicine*, *120*, 92–99.
- Fry, P. (2001). The unique contribution of key existential factors to the prediction of psychological well-being of older adults following spousal loss. *The Gerontologist*, *41*, 69–81.
- George, L. K., Ellison, C. G., & Larson, D. B. (2002). Explaining the relationships between religious involvement and health. *Psychological Inquiry*, *13*, 190–200.
- Geronimus, A., Hicken, M., Keene, D., & Bound, J. (2006). “Weathering” and age patterns of allostatic load scores among blacks and whites in the United States. *American Journal of Public Health*, *96*, 826–833.
- Gillum, R., King, D., Obisesan, T., & Koenig, H. (2008). Frequency of attendance at religious services and mortality in a U.S. national cohort. *Annals of Epidemiology*, *18*, 124–129.
- Godbolt, D., Vaghela, P., Burdette, A. M., & Hill, T. D. (2018). Religious attendance and body mass: An examination of variations by race and gender. *Journal of Religion and Health*, *57*, 2140–2152.
- Hill, T. (2010). A biopsychosocial model of religious involvement. In K. Whitfield (Ed.), *Annual review of gerontology and geriatrics* (pp. 179–200). New York: Springer.
- Hill, T., Angel, J., Ellison, C., & Angel, R. (2005). Religious attendance and mortality: An 8-year follow-up of older Mexican Americans. *Journal of Gerontology: Social Sciences*, *60B*, S102–S109.
- Hill, T. D., Burdette, A. M., Angel, J. L., & Angel, R. J. (2006). Religious attendance and cognitive functioning among older Mexican Americans. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *61*, P3–P9.
- Hill, T. D., Burdette, A. M., & Bradshaw, M. (2016a). Health and biological functioning. In D. Yamane (Ed.), *Handbook on religion and society* (pp. 11–28). New York: Springer.
- Hill, T. D., Burdette, A. M., Taylor, J., & Angel, J. L. (2016b). Religious attendance and the mobility trajectories of older Mexican Americans: An application of the growth mixture model. *Journal of Health and Social Behavior*, *57*, 118–134.
- Hill, T. D., Rote, S. M., & Ellison, C. G. (2017a). Religious participation and biological functioning in Mexico. *Journal of Aging and Health*, *29*, 951–972.
- Hill, T. D., Rote, S. M., Ellison, C. G., & Burdette, A. M. (2014). Religious attendance and biological functioning: A multiple specification approach. *Journal of Aging and Health*, *26*, 766–785.
- Hill, T. D., Vaghela, P., Ellison, C. G., & Rote, S. (2017b). Processes linking religious involvement and telomere length. *Biodemography and Social Biology*, *63*, 167–188.
- Hummer, R., Rogers, R., Nam, C., & Ellison, C. (1999). Religious involvement and U.S. adult mortality. *Demography*, *36*, 273–285.
- Idler, E. (1987). Religious involvement and the health of the elderly: Some hypotheses and an initial test. *Social Forces*, *66*, 226–238.
- Idler, E., Blevins, J., Kiser, M., & Hogue, C. (2017). Religion, a social determinant of mortality? A 10-year follow-up of the Health and Retirement Study. *PLoS ONE*, *12*, e0189134.
- Idler, E., & Kasl, S. (1997a). Religion among disabled and nondisabled persons I: Cross-sectional patterns in health practices, social activities, and well-being. *Journal of Gerontology: Social Sciences*, *52B*, S294–S305.

- Idler, E., & Kasl, S. (1997b). Religion among disabled and nondisabled persons II: Attendance at religious services as predictor of the course of disability. *Journal of Gerontology: Social Sciences*, *52B*, S306–S316.
- Idler, E., McLaughlin, J., & Kasl, S. (2009). Religion and the quality of life in the last year of life. *Journal of Gerontology: Social Sciences*, *64B*, S528–S537.
- Idler, E. L., Musick, M. A., Ellison, C. G., George, L. K., Krause, N., Ory, M. G., et al. (2003). Measuring multiple dimensions of religion and spirituality for health research: Conceptual background and findings from the 1998 General Social Survey. *Research on Aging*, *25*, 327–365.
- Ironson, G., Solomon, G., Balbin, E., O’Cleirigh, C., George, A., Kumar, M., et al. (2002). The Ironson-Woods Spirituality/Religiousness Index is associated with long survival, health behaviors, less distress, and low cortisol in people with HIV/AIDS. *Annals of Behavioral Medicine*, *24*, 34–48.
- Karlamangla, A., Singer, B., McEwen, B., Rowe, J., & Seeman, T. (2002). Allostatic load as a predictor of functional decline: MacArthur studies of successful aging. *Journal of Clinical Epidemiology*, *55*, 696–710.
- Kim, K., Sobal, J., & Wethington, E. (2003). Religion and body weight. *International Journal of Obesity*, *27*, 469–477.
- King, D., Mainous, A., & Pearson, W. (2002). C-reactive protein, diabetes, and attendance at religious services. *Diabetes Care*, *25*, 1172–1176.
- King, D., Mainous, A., Steyer, T., & Pearson, W. (2001). The relationship between attendance at religious services and cardiovascular inflammatory markers. *International Journal of Psychiatry in Medicine*, *31*, 415–425.
- Koenig, H., Cohen, H., George, L., Hays, J., Larson, D., & Blazer, D. (1997). Attendance at religious services, interleukin-6, and other biological parameters of immune function in older adults. *International Journal of Psychiatry in Medicine*, *27*, 233–250.
- Koenig, H., George, L., Hays, J., Larson, D., Cohen, H., & Blazer, D. (1998). The relationship between religious activities and blood pressure in older adults. *International Journal of Psychiatry in Medicine*, *28*, 189–213.
- Koenig, H., King, D., & Carson, V. (2012). *Handbook of religion and health* (2nd ed.). New York: Oxford University Press.
- Krause, N. (1998). Neighborhood deterioration, religious coping, and changes in health during late life. *The Gerontologist*, *38*, 653–664.
- Krause, N. (2003). Religious meaning and subjective well-being in late life. *Journal of Gerontology: Social Sciences*, *58B*, S160–S170.
- Krause, N. (2005). God-mediated control and psychological well-being in late life. *Research on Aging*, *27*, 136–164.
- Krause, N. (2006). Gratitude toward God, stress, and health in late life. *Research on Aging*, *28*, 163–183.
- Krause, N., & Ironson, G. (2016). Receiving support, giving support, neighborhood conditions, and waist/hip ratios. *Journal of Religion and Health*, *55*, 1123–1135.
- Krause, N., & Ironson, G. (2017). Stress, religious involvement, and cholesterol: Is it better to give than to receive? *Journal of Applied Biobehavioral Research*, *22*, e12064.
- Krause, N., Liang, J., Shaw, B., Sugisawa, H., Kim, H., & Sugihara, Y. (2002). Religion, death of a loved one, and hypertension among older adults in Japan. *Journal of Gerontology: Social Sciences*, *57B*, S96–S107.
- Levin, J., Markides, K., & Ray, L. (1996). Religious attendance and psychological well-being in Mexican Americans: A panel analysis of three generations data. *The Gerontologist*, *36*, 454–463.
- Lutgendorf, S., Russell, D., Ullrich, P., Harris, T., & Wallace, R. (2004). Religious participation, interleukin-6, and mortality in older adults. *Health Psychology*, *23*, 465–475.
- Maselko, J., Hayward, R. D., Hanlon, A., Buka, S., & Meador, K. (2012). Religious service attendance and major depression: A case of reverse causality? *American Journal of Epidemiology*, *175*, 576–583.
- Maselko, J., Kubzansky, L., Kawachi, I., Seeman, T., & Berkman, L. (2007). Religious service attendance and allostatic load among high-functioning elderly. *Psychosomatic Medicine*, *69*, 464–472.
- McEwen, B. (1998). Protective and damaging effects of stress mediators. *The New England Journal of Medicine*, *338*, 171–179.
- McEwen, B. (2002). *The end of stress as we know it*. Washington, DC: Joseph Henry Press.
- Musick, M., House, J., & Williams, D. (2004). Attendance at religious services and mortality in a national sample. *Journal of Health and Social Behavior*, *45*, 198–213.
- Muslimovic, A., Tulumovic, D., Hasanspahic, S., Hamzic-Mehmedbasic, A., & Temimovi, R. (2015). Serum cystatin C—Marker of inflammation and cardiovascular morbidity in chronic kidney disease stages 1–4. *Materia Socio-Medica*, *27*, 75–78.

- Oman, D., Kurata, J., Strawbridge, W., & Cohen, R. (2002). Religious attendance and cause of death over 31 years. *International Journal of Psychiatry in Medicine*, 32, 69–89.
- Oman, D., & Reed, D. (1998). Religion and mortality among the community-dwelling elderly. *American Journal of Public Health*, 88, 1469–1475.
- Park, N., Klemmack, D., Roff, L., Parker, M., Koenig, H., Sawyer, P., et al. (2008). Religiousness and longitudinal trajectories in elders' functional status. *Research on Aging*, 30, 279–298.
- Pew Research Center. (2014). *Religious landscape study: Generational cohort*. Washington, DC: Religious Group. <http://www.pewforum.org/religious-landscape-study/generational-cohort/>.
- Reyes-Ortiz, C. A., Berges, I. M., Raji, M. A., Koenig, H. G., Kuo, Y. F., & Markides, K. S. (2008). Church attendance mediates the association between depressive symptoms and cognitive functioning among older Mexican Americans. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 63, 480–486.
- Rogers, R., Krueger, P., & Hummer, R. (2010). Religious attendance and cause-specific mortality in the United States. In C. Ellison & R. Hummer (Eds.), *Religion, families, and health: Population-based research in the United States* (pp. 292–320). New Brunswick, NJ: Rutgers University Press.
- Seeman, T., Dubin, L., & Seeman, M. (2003). Religiosity/spirituality and health: A critical review of the evidence for biological pathways. *American Psychologist*, 58, 53–63.
- Seeman, T., McEwen, B., Rowe, J., & Singer, B. (2001). Allostatic load as a marker of cumulative biological risk: MacArthur studies of successful aging. *Proceedings of the National Academy of Sciences of the United States of America*, 98, 4770–4775.
- Sergi, G., Perissinotto, E., Pisent, C., Buja, A., Maggi, S., Coin, A., et al. (2005). An adequate threshold for body mass index to detect underweight condition in elderly persons: The Italian Longitudinal Study on Aging (ILSA). *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 60, 866–871.
- Servais, M. A. (2010). *Overview of HRS public data files for cross-sectional and longitudinal analysis*. Ann Arbor, MI: Survey Research Center, Institute for Social Research.
- Seybold, K. (2007). Physiological mechanisms involved in religiosity/spirituality and health. *Journal of Behavioral Medicine*, 30, 303–309.
- Strawbridge, W., Cohen, R., Shema, S., & Kaplan, G. (1997). Frequent attendance at religious services and mortality over 28 years. *American Journal of Public Health*, 87, 957–961.
- Strawbridge, W., Shema, S., Cohen, R., Roberts, R., & Kaplan, G. (1998). Religiosity buffers effects of some stressors on depression but exacerbates others. *Journal of Gerontology: Social Sciences*, 53B, S118–S126.
- Tobin, E. T., & Slatcher, R. B. (2016). Religious participation predicts diurnal cortisol profiles 10 years later via lower levels of religious struggle. *Health Psychology*, 35, 1356–1363.
- Van Ness, P., & Kasl, S. (2003). Religion and cognitive dysfunction in an elderly cohort. *Journal of Gerontology: Social Sciences*, 58B, S21–S29.
- Wolinsky, F., Bentler, S., Cook, E., Chrischilles, E., Liu, L., Bright, K., et al. (2009). A 12-year prospective study of stroke risk in older medicare beneficiaries. *BMC Geriatrics*, 9, 1–11.