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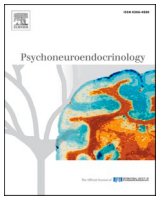

Religiosity, spiritual practices, and epigenetic aging: Insights from a population-based sample of middle-aged US adults

Jason J. Ashe [a,*], Jemar R. Bather [b], Alisha A. Crump [c], Mario Sims [d], Karyn E. Faber [c], David R. Williams [e,f], Adolfo G. Cuevas [c]

[a] Department of Religion, Emory University, Atlanta, GA, USA
[b] Department of Biostatistics, NYU School of Global Public Health, New York, NY, USA
[c] Department of Social and Behavioral Sciences, NYU School of Global Public Health, New York, NY, USA
[d] Department of Social Medicine, Population and Public Health, University of California, Riverside School of Medicine, Riverside, CA, USA
[e] Department of Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health, Boston, MA, USA
[f] Department of African and African American Studies, Harvard University, Cambridge, MA, USA

A B S T R A C T

Objectives: Religiosity and spirituality (R/S) are considered protective factors linked to extended longevity and optimal physiological health, but how these influences manifest remains unclear. Growing evidence suggests that the impact of R/S may be observable at the cellular level. This study aimed to investigate whether multiple dimensions of R/S were significantly associated with slower biological aging processes through changes in DNA methylation patterns.

Methods: Participant data were taken from the Midlife in the United States (MIDUS) Study ($N = 1310$). R/S measures included spirituality, religious centrality, religious/spiritual coping, private religious practices, and daily spiritual experiences. Two epigenetic clocks (DNA methylation-based indicators) – GrimAge2 and DunedinPACE – were assessed as separate outcome variables using multivariable linear regression analyses. Models controlled for race/ethnicity, sex, age, marital status, education, household income, smoking status, alcohol consumption, and body mass index (BMI).

Results: In models adjusted for demographic and socioeconomic characteristics, all dimensions of R/S were significantly associated with slower epigenetic age acceleration as measured by GrimAge2, and greater spirituality, religious/spiritual coping, and daily spiritual experiences were similarly associated with a slower pace of aging vis-à-vis DunedinPACE. However, after accounting for smoking status, alcohol consumption, and BMI, only the association between religious/spiritual coping and DunedinPACE remained statistically significant.

Conclusion: Several dimensions of R/S appeared to offer biomolecular advantages linked with aging processes. Future research should seek to investigate additional measures of R/S and explore how these psychosocial resources directly influence cellular-level biological mechanisms.

1. Introduction

It has long been established that religiosity and spirituality (R/S) influence various aspects of life, health, and well-being (Koenig, 2015). Religiosity is the adherence to a set of religious beliefs and practices grounded in faith traditions, while spirituality more broadly encompasses the search for meaning in life, connectedness to others, and experiences with or beliefs in the supernatural. R/S are profoundly ubiquitous in the US. Approximately 70 % of all American adults identify with at least one religious tradition and consider spirituality important in their lives (Pew Research Center, 2023, 2025). R/S also influence health behaviors, lifestyle choices, medical decision-making, chronic disease management, and both mental and physical wellbeing (Koenig, 2015). Within recent decades, research has also shown that R/S may be associated with extended longevity (Bruce et al., 2022; Chida et al., 2009; McCullough et al., 2000), though the mechanisms remain unclear. Frequent religious and spiritual engagement (e.g., attending religious services, praying) has been linked to favorable health outcomes across various biological indicators of chronic disease risk and onset (Bell et al., 2012; Bruce et al., 2017; Seeman et al., 2003; Suh et al., 2019), which, to some degree, may help explain the lower risk of premature mortality observed. Indeed, religious individuals tend to live longer than their non-religious counterparts (McCullough et al., 2000), but findings are complicated (Chida et al., 2009; Shor and Roelfs, 2013), and several critical questions remain about the biological underpinnings connecting greater R/S with extended longevity.

First, R/S are multidimensional constructs, comprising public and private activities, beliefs, and coping behaviors, including religious service attendance, prayer and/or meditation, congregational support, and importance of religion and spirituality in navigating daily life

* Correspondence to: Department of Religion, Emory University, S214 Callaway Center, 537 Kilgo Circle, Atlanta, GA 30322, USA.
E-mail addresses: Jasonjashe@gmail.com, jason.ashe@emory.edu (J.J. Ashe).

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activities and decisions (Hill et al., 2000). Notwithstanding, most studies in this line of empirical research have singularly examined frequency of religious service attendance as the quintessential measure predicting mortality and biological health outcomes, showing that frequent attenders regularly display a reduced mortality risk and more optimal physiological functioning compared to nonattenders (Bruce et al., 2022; Gillum et al., 2008; Idler et al., 2017; Oman et al., 2002; Strawbridge et al., 1997; Suh et al., 2019; VanderWeele et al., 2017). Surprisingly, however, not all aspects of practiced R/S private religious, spiritual behaviors, or beliefs have yielded advantageous effects. For example, VanderWeele et al. (2017) found that religious service attendance robustly predicted favorable mortality risk among Black women, but there were weaker, inverse, or no effects across religious coping, religious identification, and prayer frequency. Similarly, Idler et al. (2017) reported that, despite the lowered mortality risk associated with frequent religious service attendance in a sample of older adults, those who claimed that religion was of great importance in their lives showed a higher hazard risk ratio, and no association was observed for religious affiliation. In sum, while these findings provide evidence that R/S yield salubrious effects on health and extended longevity, they do so idiosyncratically, suggesting that frequent religious service attendance is the strongest predictor linking religiosity to better health. While this may appear to be valid, some have argued that this measure strongly overlaps with cultural norms and other social mechanisms, like having a large social support network vis-à-vis congregational support and opportunities for social gatherings (Ferraro and Kim, 2014). Because religious service attendance is easy to report of this, studies that rely too heavily on this sole religious activity might claim its robustness while simultaneously missing the importance of other private measures of R/S. In fact, it is quite plausible that frequent engagement in private religious and spiritual activities, such as prayer, meditation, and turning to religion for comfort during stressful times can temper stress-induced physiological dysregulation linked with poorer health (Koenig and Cohen, 2006). Indeed, such positive effects have been noted across endpoints like cortisol levels among individuals who employ positive religious and spiritual coping strategies compared to those who may engage in unhelpful behaviors (DeAngelis et al., 2023; Tobin and Slatcher, 2017). Consequently, additional work is needed to unpack the complexities between the multidimensional aspects of R/S and prolonged lifespan.

To this end, greater R/S may be salubriously associated with biological aging processes. Mounting evidence has demonstrated promising relationships between certain aspects of R/S, like religious service attendance, prayer, and religious coping, and biological markers of decelerated aging, including lower levels of inflammatory markers (Britt et al., 2024; Ironson et al., 2018; Vagnini et al., 2024), lower allostatic load scores (Bruce et al., 2017; Maselko et al., 2007; Suh et al., 2019), and longer telomeres (Doolittle et al., 2025; Hill et al., 2016). It has been posited that R/S can act on multiple psychological and social pathways, contributing to better mental health and increased social networks, which all lead to positive biological outcomes (Koenig, 2015). R/S can also shape how people assess anxiety-provoking situations and construe meaning during hardships, thus, potentially curtailing physiological responses to chronic stressors (i.e., modulating stress hormone signaling, immune reactivity, and cardiometabolic activity) that can lead to disease risk (Koenig and Cohen, 2006; Tobin and Slatcher, 2017). Although novel, limited research has examined the potential influence of R/S on cellular-level biological processes.

Accordingly, DNA methylation is a major epigenetic factor that influences gene function and cellular activities, which has gained significant traction in recent research on population health and biological aging (López-Otín et al., 2013; rMoore et al., 2013). DNA methylation is the chemical process wherein methyl groups are added to DNA molecules, and while this does not change the nucleotide sequence of the DNA, subsequent gene expression can be altered (Richardson, 2003). DNA methylation patterns change systematically with age, with specific genomic sites showing predictable methylation changes over time (Jones et al., 2015). These consistent, site-specific aging patterns have enabled researchers to develop epigenetic clocks, sophisticated mathematical models that can accurately predict an individual's chronological age based on their methylation profile (Horvath and Raj, 2018). Research has demonstrated robust relationships between epigenetic clocks and incident rates across various diseases (e.g., cardiovascular diseases) and mortality (Beydoun et al., 2025; Mendy and Mersha, 2025; Zhu et al., 2025). Remarkably, whereas chronic psychosocial stress exposure has also been shown to drive epigenetic age acceleration (Zannas, 2019), to our knowledge, no study has examined the relationships between multiple dimensions of R/S and epigenetic clocks in a diverse sample of midlife and older adults.

The present study addresses these gaps. We explored the associations between several dimensions of R/S and two epigenetic clocks, GrimAge 2 and DunedinPACE, to determine whether specific aspects of R/S might offer potential health benefits relative to slower biological aging. We selected these two epigenetic clocks because of their precision and robustness in predicting health across the lifespan, mortality risk, and the biological consequences of aging due to stress exposure. GrimAge2 is an advanced biomarker that has been introduced to the field of epigenetic aging in that it uses DNA methylation surrogates for plasma proteins to predict mortality risk (Lu et al., 2022). DunedinPACE measures the rate at which the body ages, or the pace of aging, to provide an estimation of how fast the aging process is occurring above and beyond biological age predictions (Belsky et al., 2022). In this way, DunedinPACE captures physiological wear-and-tear of the body and is less sensitive to cohort effects and differences (Belsky et al., 2022). Both epigenetic clocks are particularly sensitive to psychosocial stress exposure and their influences on biological aging processes (Cuevas et al., 2024). While GrimAge2 is a robust predictor of all-cause mortality and aging-related disease risk and incidence, including cardiovascular and respiratory diseases (Lu et al., 2022; Zhu et al., 2025), DunedinPACE accurately foretells of cognitive decline and Alzheimer's related dementias, cardiovascular diseases, and premature death (Belsky et al., 2022). Compared to other original or earlier versions of epigenetic clocks, GrimAge2 and DunedinPACE were selected for this study's primary analyses because of their precision in predicting mortality and their potential for interpreting clinically meaningful aging-related disease outcomes.

We also primarily prioritized private practices of R/S as potential predictors of positive associations with biological aging; these measures include spirituality, religious centrality (i.e., importance of religion in identity and daily life), private religious practices (e.g., prayer, meditation), religious/spiritual coping, and daily spiritual experiences. These variables were selected *a priori* based on previously published empirical studies and established theories linking faith and spiritual beliefs with psychoneuroimmunology (Koenig and Cohen, 2006). Each variable was assessed singularly to assess the effects and strengths of these associations per each dimension of R/S, with the aims of highlighting unique contributions to biological aging processes and to ascertain whether similar associations emerge across each dimension. Given that prior reports have also explored cumulative R/S as a primary predictor variable, claiming to understand how overall religiousness may be linked with health (Koenig et al., 2016), we similarly tested this approach. We hypothesized that greater R/S would offer protective associations and be linked with slower biological aging patterns vis-à-vis epigenetic clocks.

2. Methods

2.1. Study design and setting

The Midlife in the United States (MIDUS) Study is a population-based cohort research initiative focused on adults throughout the United States (Brim et al., 2004). To qualify for participation, individuals had to be between the ages of 25 and 74, speak English, and not live in institutional settings. During the initial phase from 1995 to 1996, MIDUS

recruited 7108 individuals using random digit dialing. To enhance the racial and ethnic diversity of the sample, MIDUS added 592 African American participants from Milwaukee, Wisconsin, to the base MIDUS cohort in Wave 2 (MIDUS 2) during 2004–2005. The MIDUS Refresher Study was initiated in 2011 to replenish the base MIDUS cohort and conducted enrollment until 2014, recruiting 4085 new participants. This sample included 508 African American residents from Milwaukee.

Participants from both MIDUS cohorts engaged in follow-up biomarker projects: the MIDUS 2 Biomarker Project (n = 1255) and MIDUS Refresher Biomarker Study (n = 863) (Dienberg Love et al., 2010). They underwent comprehensive health assessments that gathered various biological indicators during a two-day clinic visit at Georgetown University, the University of Wisconsin-Madison, or the University of California, Los Angeles. Among the 2118 biomarker participants, 1310 participants had epigenetic aging scores. All participants provided informed consent. The study protocols received approval from the University of Wisconsin Institutional Review Board, and further details are described elsewhere (Brim et al., 2004; Dienberg Love et al., 2010; Radler, 2014). The New York University Institutional Review Board classified this secondary analysis as exempt from review given that the data were deidentified and publicly available. This investigation adhered to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines (Von Elm et al., 2008).

2.2. Ascertainment of epigenetic age

The MIDUS DNA methylation data were collected and processed according to the Minimum Reporting Recommendations for Epigenetic Sample Collection, Processing, and Storage and DNA methylation data initial QC from Illumina's Infinium Methylation arrays (University of Wisconsin Institute on Aging and UCLA Social Genomics Core Laboratory, 2023). On the second day of the clinic visit, whole blood samples were collected in EDTA tubes and stored frozen until DNA extraction. DNA yield and integrity were assessed prior to methylation profiling on the Illumina Methylation EPIC array (University of Wisconsin Institute on Aging and UCLA Social Genomics Core Laboratory, 2023). Raw data were processed using the noob normalization procedures implemented in the *minfi* R package to reduce technical variation. Processed beta values, reflecting methylation at cytosines in CpG sites, were mapped to the 450 K probe set for calculation of epigenetic clock measures. Standard quality control procedures were applied, including evaluation of probe detection p-values, sample call rates, and sex concordance, with all samples meeting quality thresholds. The cleaned methylation data were subsequently used to compute GrimAge2 and DunedinPACE scores as indicators of epigenetic age acceleration (Belsky et al., 2022; Lu et al., 2022). We standardized GrimAge2 and DunedinPACE scores to have mean = 0 and standard deviation (SD) = 1.

2.3. Religiosity and spiritual practices

Spirituality. Two questions assessed spirituality at Wave 2: (1) "How spiritual are you?" and (2) "How important is spirituality in your life?" (Garfield et al., 2001; Rossi, 2001). Participants responded using a Likert-type scale ranging from *1 (Very)* to *4 (Not at all)*. These responses were reverse-coded and summed such that higher total scores reflected higher spirituality levels (Cronbach's $\alpha = 0.92$).

Religious Centrality. Seven items measured religious centrality at Wave 2: (1) "How religious are you?" (2) "How important is religion in your life?" (3) "How important is it for you – or would it be if you had children now – to send your children for religious or spiritual services or instruction?" (4) "How closely do you identify with being a member of your religious group?" (5) "How much do you prefer to be with other people who are the same religion as you?" (6) "How important do you think it is for people of your religion to marry other people who are the same religion?" and (7) "How important is it for you to celebrate or practice on religious holidays with your family, friends, or members of your religious community?" (Garfield et al., 2001; Rossi, 2001) Response options for each item ranged from *1 (Very)* to *4 (Not at all)*. We reverse-coded these responses and totaled them such that higher scores indicated greater religious centrality (Cronbach's $\alpha = 0.91$).

Private Religious Practices. Three items measured private religious practices at Wave 2 (Koenig et al., 1997). The questionnaire asked participants to report the frequency with which they engaged in the following activities: (1) "Pray in private?" (2) "Meditate or chant?" and (3) "Read the Bible or other religious literature?" Response options were coded on a 6-point scale: *1 (Once a day or more), 2 (A few times a week), 3 (Once a week), 4 (1–3 times per month), 5 (Less than once per month),* and *6 (Never)*. These responses were reverse-coded and totaled such that higher scores denoted greater frequency of private religious practices (Cronbach's $\alpha = 0.72$).

Religious/Spiritual Coping. Two items assessed religious/spiritual coping strategies at Wave 2 (Garfield et al., 2001; Rossi, 2001). The first item asked: "When you have problems or difficulties in your family, work, or personal life, how often do you seek comfort through religious or spiritual means such as praying, meditating, attending a religious or spiritual service, or talking to a religious or spiritual advisor?" The second item asked: "When you have decisions to make in your daily life, how often do you ask yourself what your religious or spiritual beliefs suggest you should do?" Responses were coded on a 4-point scale from *1 (Often)* to *4 (Never)*. Scores were reverse-coded and summed such that higher scores indicated greater use of religious/spiritual coping strategies (Cronbach's $\alpha = 0.88$).

Daily Spiritual Experiences. Five items measured daily spiritual experiences at Wave 2 (Fetzer Institute/National Institute on Aging Working Group, 1999). Participants were asked to report how often they experienced the following on a daily basis: (1) "A feeling of deep inner peace or harmony," (2) "A feeling of being deeply moved by the beauty of life," (3) "A feeling of strong connection to all of life," (4) "A sense of deep appreciation," and (5) "A profound sense of caring for others." Participants responded to each item using a 4-point scale ranging from *1 (Often)* to *4 (Never)*. These responses were reverse-coded and summed. Higher scores reflected a higher frequency of daily spiritual experiences (Cronbach's $\alpha = 0.90$).

Cumulative Religiosity/Spirituality. We constructed a cumulative religiosity/spirituality z-score by standardizing the sum of the following z-scores: religious/spiritual coping, spirituality, religious centrality, daily spiritual experiences, and private religious practices.

2.4. Covariates

We controlled for various demographic, socioeconomic, and health-related characteristics measured at Wave 2 to mitigate confounding bias. The demographic characteristics included age, sex, race/ethnicity, and marital status. Age was analyzed as a continuous variable. Sex was defined as sex assigned at birth. Race/ethnicity was classified into non-Hispanic White, non-Hispanic Black, Hispanic, and non-Hispanic Other groups. The non-Hispanic Other group included those who identified as Asian, Native American, Alaska Native, Native Hawaiian, and Pacific Islander. Marital status was categorized as married, divorced/separated/widowed, or never married.

Socioeconomic status variables included educational attainment and annual household income. Educational attainment was categorized as high school or less, some college/associate's degree, or college degree or higher. Annual household income was operationalized into sample quartiles ($0 to $11,000; $11,000 to $48,750; $49,250 to $93,500; $93,500 +).

Health-related characteristics comprised smoking status, alcohol consumption, and body mass index (BMI). Smoking status was categorized as never smoker, former smoker, or current smoker. Alcohol consumption in the past month was classified into four frequencies: never, less than one day per week, one to two days per week, or three or more days per week. BMI was analyzed as a continuous variable.

2.5. Analytic strategy

Sample characteristics were described using frequencies and percentages for categorical variables and as means and standard deviations (SDs) for continuous measures. Zero-order correlations were computed to assess the interrelationships between religiosity/spirituality measures. We constructed several multivariable models to investigate whether the z-scores for GrimAge2 and DunedinPACE exhibited statistically significant differences as a function of religiosity/spirituality z-scores. Model 1 controlled for demographic variables including age, sex, race/ethnicity, and marital status. Model 2 further adjusted for socioeconomic status (educational attainment and annual household income). To evaluate the potential impact of health-related characteristics on the religiosity/spirituality coefficient, Model 3 incorporated additional variables, namely smoking status, alcohol consumption, and BMI.

Missing data were handled using multivariate imputation by chained equations, implemented via the *mice* R package (Stef van Buuren, 2011). We applied method-specific imputation techniques tailored to each variable's characteristics: predictive mean matching for continuous variables (BMI, religiosity/spirituality, and GrimAge2); multinomial logistic regression for nominal measures (race/ethnicity and marital status); and ordinal logistic regression for ordered categorical variables (educational attainment and annual household income). Results from multivariable analyses were combined across ten imputed datasets following Rubin's combining rules (Rubin, 1987). All analyses were performed using R version 4.4.3 (R Core Team, 2024).

3. Results

Sample characteristics are presented in Table 1. Participants had a mean age of 51.3 years (SD = 12.5), with 55 % female, 67 % non-Hispanic White, and 58 % never smokers. Religious/spiritual coping was highly correlated (all $p < 0.001$) with private religious practices (r = 0.757), religious centrality (r = 0.687), and spirituality (r = 0.676; Table 2). We also observed high correlations (all $p < 0.001$) of private religious practices with religious centrality (r = 0.676) and spirituality (r = 0.657). Compared to the MIDUS parent study, this study's sample had more individuals with higher educational attainment and a greater representation of both non-Hispanic Black and Other adults.

Multivariable analyses revealed significant associations between religiosity/spirituality domains and epigenetic aging biomarkers (Table 3). For GrimAge2, Model 1 (adjusted for demographic factors) showed that four domains and the cumulative measure were significantly associated with slower epigenetic aging: religious centrality (0.03 SD decrease, 95 % CI: 0.01–0.06, $p = 0.045$), private religious practices (0.03 SD decrease, 95 % CI: 0.01–0.06, $p = 0.022$), religious/spiritual coping (0.03 SD decrease, 95 % CI: 0.01–0.06, $p = 0.010$), daily spiritual experiences (0.05 SD decrease, 95 % CI: 0.02–0.07, $p = 0.001$), and cumulative z-score (0.04 SD decrease, 95 % CI: 0.02–0.07, $p = 0.002$). These associations remained statistically significant when further adjusted for socioeconomic status in Model 2 but attenuated to non-significance when health-related characteristics were further controlled for in Model 3.

For DunedinPACE, Model 1 revealed that three religiosity/spirituality domains and the cumulative measure were significantly associated with slower pace of aging: spirituality (0.06 SD decrease, 95 % CI: 0.01–0.11, $p = 0.033$), religious/spiritual coping (0.06 SD decrease, 95 % CI: 0.01–0.11, $p = 0.022$), daily spiritual experiences (0.07 SD decrease, 95 % CI: 0.01–0.12, $p = 0.012$), and cumulative z-score (0.06 SD decrease, 95 % CI: 0.01–0.11, $p = 0.027$). These associations sustained statistical significance in Model 2, but only religious/spiritual coping (0.05 SD decrease, 95 % CI: 0.01–0.10, $p = 0.036$) maintained statistical significance in Model 3. Exploratory analyses examined whether race/ethnicity, gender, age, or socioeconomic status potentially moderated these associations, but no significant interactions emerged (data not shown).

Table 1
Characteristics of 1310 participants from the Midlife in the United States Study.

Characteristic	N = 1310
Age, Mean (SD)	51.3 (12.5)
Sex, No. (%)	
Male	584 (44.6)
Female	726 (55.4)
Race/ethnicity, No. (%)	
non-Hispanic White	879 (67.1)
non-Hispanic Black	309 (23.6)
Hispanic	43 (3.3)
non-Hispanic Other	71 (5.4)
Missing	8 (0.6)
Educational attainment, No. (%)	
High school or less	296 (22.6)
Some college/associate's degree	387 (29.5)
College degree or higher	625 (47.7)
Missing	2 (0.2)
Annual household income (quartile), No. (%)	
$0 to $11,000	312 (23.8 %)
$11,000 to $48,750	312 (23.8 %)
$49,250 to $93,500	312 (23.8 %)
$93,500 +	312 (23.8 %)
Missing	62 (4.7)
Marital status, No. (%)	
Married	776 (59.2)
Divorced/Separated/Widowed	292 (22.3)
Never married	239 (18.2)
Missing	3 (0.2)
Smoking status, No. (%)	
Never	756 (57.7)
Past	380 (29.0)
Current	174 (13.3)
Alcohol consumption, No. (%)	
Never	426 (32.5)
< 1 day a week	353 (26.9)
1–2 days a week	228 (17.4)
3 + days a week	303 (23.1)
Body mass index, Mean (SD)	28.9 (6.8)
Missing, No. (%)	33 (2.5)
Religious/spiritual coping, Mean (SD)	5.5 (2.2)
Missing, No. (%)	16 (1.2)
Spirituality, Mean (SD)	6.4 (1.7)
Missing, No. (%)	9 (0.7)
Religious centrality, Mean (SD)	19.1 (6.1)
Missing, No. (%)	11 (0.8)
Daily spiritual experiences, Mean (SD)	15.7 (3.3)
Missing, No. (%)	14 (1.1)
Private religious practices, Mean (SD)	9.6 (4.5)
Missing, No. (%)	13 (1.0)
Cumulative Z-score, Mean (SD)	0.0 (1.0)
Missing, No. (%)	24 (1.8)
GrimAge2, Mean (SD)	62.7 (10.7)
Missing, No. (%)	1 (0.1)
DunedinPACE, Mean (SD)	1.0 (0.1)

4. Discussion

The research literature has examined the biological mechanisms connecting R/S with lower morbidity and mortality risk. To our knowledge, no prior study has explored the potential associations between dimensions of R/S and epigenetic clocks in a diverse sample of middle-aged and older adults. We found that greater spirituality, religious centrality, religious/spiritual coping, private religious practices, daily spiritual experiences, and cumulative R/S were significantly related to slower epigenetic age acceleration (GrimAge2), and greater spirituality, religious/spiritual coping, daily spiritual experiences, and cumulative R/S were significantly associated with a slower pace of aging (DunedinPACE), in analyses controlling for demographic characteristics (age, sex, race/ethnicity, and marital status) and socioeconomic status (educational attainment and annual household income). However, almost all of these associations lost significance after adjustment for health-related factors (smoking status, alcohol consumption, and BMI). Only the association between religious/spiritual coping and

Table 2
Zero-order correlations among key study variables.

	1	2	3	4	5	6	7
1. Religious/spiritual coping							
2. Spirituality	0.676***						
3. Religious centrality	0.687***	0.611***					
4. Daily spiritual experiences	0.381***	0.434***	0.312***				
5. Private religious practices	0.757***	0.657***	0.676***	0.405***			
6. Cumulative Z-score	0.871***	0.839***	0.816***	0.631***	0.868***		
7. GrimAge2	0.000	0.052	0.029	0.143***	0.067*	0.072*	
8. DunedinPACE	0.002	0.017	0.061*	0.011	0.099***	0.047	0.525***

*p < 0.05; **p < 0.01; ***p < 0.001

Table 3
Adjusted associations between religiosity/spirituality and epigenetic aging in the Midlife in the United States Study.

	Model 1			Model 2			Model 3		
	Beta	**95 % CI**	**p-value**	**Beta**	**95 % CI**	**p-value**	**Beta**	**95 % CI**	**p-value**
GrimAge2									
Spirituality	-0.03	(-0.05, 0.00)	0.062	**-0.03**	**(-0.05, −0.01)**	**0.043**	-0.01	(-0.03, 0.01)	0.52
Religious centrality	**-0.03**	**(-0.05, −0.01)**	**0.045**	**-0.04**	**(-0.06, −0.01)**	**0.007**	0.00	(-0.02, 0.03)	0.82
Private religious practices	**-0.03**	**(-0.06, −0.01)**	**0.022**	**-0.04**	**(-0.06, −0.01)**	**0.006**	-0.01	(-0.04, 0.01)	0.24
Religious/spiritual coping	**-0.03**	**(-0.06, −0.01)**	**0.010**	**-0.04**	**(-0.06, −0.01)**	**0.004**	-0.01	(-0.03, 0.01)	0.33
Daily spiritual experiences	**-0.05**	**(-0.07, −0.02)**	**0.001**	**-0.04**	**(-0.06, −0.01)**	**0.003**	-0.01	(-0.03, 0.01)	0.34
Cumulative z-score	**-0.04**	**(-0.07, −0.02)**	**0.002**	**-0.05**	**(-0.07, −0.02)**	**0.001**	-0.01	(-0.03, 0.01)	0.39
DunedinPACE									
Spirituality	**-0.06**	**(-0.11, −0.01)**	**0.033**	**-0.06**	**(-0.11, −0.01)**	**0.014**	-0.04	(-0.08, 0.01)	0.088
Religious centrality	-0.02	(-0.07, 0.03)	0.42	-0.04	(-0.09, 0.01)	0.15	-0.01	(-0.05, 0.04)	0.82
Private religious practices	-0.02	(-0.07, 0.04)	0.54	-0.03	(-0.08, 0.02)	0.30	-0.01	(-0.06, 0.03)	0.55
Religious/spiritual coping	**-0.06**	**(-0.11, −0.01)**	**0.022**	**-0.07**	**(-0.12, −0.02)**	**0.008**	**-0.05**	**(-0.10, −0.01)**	**0.036**
Daily spiritual experiences	**-0.07**	**(-0.12, −0.01)**	**0.012**	**-0.06**	**(-0.11, −0.01)**	**0.029**	-0.02	(-0.07, 0.03)	0.39
Cumulative z-score	**-0.06**	**(-0.11, −0.01)**	**0.027**	**-0.07**	**(-0.12, −0.02)**	**0.011**	-0.03	(-0.08, 0.01)	0.17

Bold font indicates p < 0.05. Regression results were pooled across ten imputed datasets.
Model 1 controlled for age, sex, race/ethnicity, and marital status.
Model 2 controlled for age, sex, race/ethnicity, marital status, educational attainment, and annual household income.
Model 3 controlled for age, sex, race/ethnicity, marital status, educational attainment, annual household income, smoking status, past month alcohol consumption, and body mass index.

DunedinPACE remained. Exploratory analyses also found potential effect moderation by race/ethnicity, such that the associations of religious/spiritual coping on epigenetic aging were less prominent among historically racially minoritized adults. Altogether, our findings suggest that various measures of R/S may yield salubrious effects on aging processes.

Consistent with prior research, our study found that positive associations may exist between multiple dimensions of R/S and indicators of biomolecular activity. To illustrate, a study using cross-sectional participant data from the MIDUS cohort and a longitudinal report comprising middle-aged and older adults from the Health and Retirement Study both found that several measures of R/S (i.e., greater spirituality, daily spiritual experiences, religious coping, R/S-based mindfulness, and stronger religious and spiritual beliefs) were associated with lower levels of inflammatory markers (interleukin-6, C-reactive protein) linked with aging-related disease pathogenesis (Britt et al., 2024; Vagnini et al., 2024). Another study demonstrated favorable relationships between frequent attendance at religious services, prayer, and religious identity with leukocyte telomere length among 1252 community-dwelling adults (Hill et al., 2016). Our findings showed similar trends, providing corroborating evidence that greater R/S were related to slower rates of cumulative aging across the lifespan (GrimAge2) and a slower pace of aging (DunedinPACE). Here, we found that most of these aspects of greater R/S (spirituality, religious centrality, religious/spiritual coping, private religious practices, and daily spiritual experiences) correlated with slower rates of epigenetic age acceleration, but the strengths of these associations varied in the presence of other sociodemographic characteristics and biobehavioral confounding variables. Such fluctuations have been observed in other epidemiological studies as well (Hill et al., 2017; Suh et al., 2019), in which the biological health advantages yielded from different measures of R/S attenuated or lost significance after controlling for cigarette smoking history, BMI, or alcohol consumption. Religious values, faith traditions, and spiritual beliefs can influence whether people engage in or abstain from risk behaviors. In this way, the interplay between R/S and health behaviors may provide an upstream pathway contributing to protective biological health outcomes (Koenig, 2015; Koenig and Cohen, 2006). In tandem with our study's results, the unique associations of R/S with biological markers of aging might be complemented by how and why individuals engage in positive health behaviors. Spiritual practices and religious dogma may encourage healthier lifestyle choices, thereby leading to optimal physiological health.

Of note, this body of work connecting faith and religion to biological mechanisms underlying aging-related processes has indeed presented mixed findings across measures of R/S and biological aging respectively. For instance, in a sample of female caregivers, Koenig et al. (2016) found that religiosity was only positively linked with telomere length among individuals who were at least somewhat religious, but among nonreligious individuals, longer telomeres were observed. In this study, it is unclear if the authors examined nonlinearity relationships (e.g., U-shaped) explicitly. Whereas some reports have observed race-specific associations (DeAngelis et al., 2023; Ferraro and Kim, 2014; Steffen et al., 2001; Vagnini et al., 2024), others reported no differences across sociodemographic characteristics and factors (Bell et al., 2012; Bruce et al., 2017; Hill et al., 2016; Koenig et al., 2016), or suggested no associations were present altogether. A longitudinal study utilizing participant data from 1658 White and African American middle-aged women in SWAN (Study of Women's Health Across the Nation) found no noticeable

differences in cardiometabolic marker levels across individuals who engaged in few spiritual experiences compared to those who practiced daily (Fitchett and Powell, 2009). It is unclear why these studies report such vastly different results. When situating our findings alongside these other reports, these inconsistencies potentially point to differences across population characteristics as well as measurement dissimilarities. That notwithstanding, our study detected modest effect sizes due to R/S, comparable to other chronic psychological and social stressors (Protsenko et al., 2023; Rentscher et al., 2023). This may lend to potential clinical significance as well, especially considering the predictive power and robustness of DunedinPACE with comorbid disorders and mortality risk (Belsky et al., 2022). Even though our study found possible salutary cellular-level activities were linked with greater religious practices and spiritual beliefs, the lack of congruency across these associations and the breadth of mixed findings across racial groups suggest that more is left to be determined.

Biological underpinnings may also be another plausible pathway that can explain this relationship. Theories underscoring psychoneuroimmunology suggest that R/S might act as protective factors by modulating neural and physiological responses to chronic psychosocial stressors (Koenig and Cohen, 2006). When we experience a stressful situation, the sympathetic nervous system becomes activated, eliciting a range of physiological changes and responses (e.g., increased heart rate, vasoconstriction). The hypothalamic-pituitary-adrenal (HPA) axis releases hormones into the bloodstream and separately triggers the upregulation of proinflammatory proteins (Dickerson and Kemeny, 2004). Sustained dysregulation of these interconnected systems can lead to increased DNA methylation in the promoter regions of specific genes, which subsequently affects the expression of those genes that regulate HPA feedback signaling (e.g., transcription factor suppression) (Argentieri et al., 2017; Matosin et al., 2017). Nevertheless, increasing evidence suggests that environmental and psychosocial stressors, like neighborhood disadvantage and discrimination, may be driving accelerated aging and epigenetic modification (Choi and Ailshire, 2024; Cuevas et al., 2024, 2025; Prigerson et al., 2025). Conversely, frequent engagement with religious and spiritual practices may help to mitigate the body's physiological responses to stress. For example, a longitudinal report found that greater religious participation offered protective effects on neuroendocrine signaling (i.e., healthier cortisol levels) over a 10-year period, which was attributable to fewer religious struggles and strained spiritual issues (Tobin and Slatcher, 2017). Some studies have also found that at higher levels of engagement, R/S might even buffer the associations between chronic psychosocial stressors and markers of inflammation (Lee et al., 2018; Tavares et al., 2019). Our findings indicate that R/S, as protective resilience factors, might "get under the skin" and offer biological advantages to cellular aging mechanisms.

Still, our study is not without its limitations. Despite assessing multiple dimensions of R/S in our analyses, several of these independent variables were self-reported, subjective measures that relied on one- or two-item scales and included categorical Likert responses, which can be difficult to interpret, because of the increased variability across participants. There has been growing concern in religion-focused epidemiological research regarding scales and measurements that assess spirituality, primarily due to its broad definition, colloquial ambiguity (i.e., some laypersons claim to be spiritual and not religious, whereas others might endorse being both), and potential overlap with positive factors such as emotional wellness and optimism (Koenig and Carey, 2024). While such elements have shown similar expected associations too (Felix et al., 2022; Prigerson et al., 2025), it is crucial to confirm this study's findings with other epidemiological cohorts that measured more comprehensive religious behaviors and spiritual beliefs. In similar fashion, it is widely accepted in this line of work that religious service attendance is the strongest predictor of better health outcomes, which we did not test in this study. We recommend that future work explore how this specific dimension of religion might yield comparable findings, as other studies have shown that service attendance might be necessary in DNA methylation-related gene expression (Zhen-Duan et al., 2025). Furthermore, although these analyses should be understood as a set of theory-driven hypothesis tests rather than multiple exploratory comparisons, we did not apply formal multiple-comparison corrections because our aim was not to control the family-wise error rate across unrelated tests, but to evaluate distinct theoretically motivated hypotheses. Whereas strict corrections in this context can increase Type II error and obscure substantively meaningful effects, we also acknowledge that our approach in seeking to preserve theoretical clarity and avoid multicollinearity among correlated dimensions of R/S also allowed for the potential increased Type I error by using separate models to test each dimension. Additionally, we could not adjust for blood cell-type composition because the MIDUS methylation data do not include raw beta values. This is a key limitation since DNA methylation patterns differ substantially across leukocyte subtypes, and variation in immune cell composition can influence epigenetic clock estimates (Qi and Teschendorff, 2022). Without such adjustment, associations may reflect differences in cell composition rather than intrinsic biological aging. Future studies should incorporate estimated cell-type proportions to more accurately distinguish aging-related methylation changes from immune variation. Lastly, because our study is cross-sectional, we were unable to infer causality. Correspondingly, religious and spiritual beliefs, more so than behaviors and practices, can fluctuate and change over time, especially during midlife adulthood, when people experience major life transitions and circumstances. Future work should consider the inclusion of time-varying R/S measurements to assess whether different results might emerge.

Altogether, our results reveal that individuals reporting greater R/S exhibit slower epigenetic aging. This study extends the current literature by utilizing cross-sectional data to examine the associations between multiple dimensions of R/S with epigenetic clocks, offering more precision in capturing biological aging processes, and demonstrating the multidimensionality of R/S as protective of potential accelerated aging. Aging is a major risk factor for morbidity and mortality. In naming R/S as resilience factors, we seek to uncover how these potential salubrious associations between religion, spirituality, and biological aging might be linked to extended longevity. More empirical work is needed to explore and improve our understanding of how religious practices and spiritual beliefs might reduce mortality risk.

Clinical trial number

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CRediT authorship contribution statement

Faber Karyn E: Writing – review & editing, Writing – original draft, Conceptualization. **Crump Alisha A:** Writing – review & editing, Writing – original draft, Conceptualization. **Mario Sims:** Writing – review & editing, Writing – original draft, Conceptualization. **Ashe Jason J:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Bather Jemar R:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Williams David R:** Writing – review & editing, Writing – original draft, Conceptualization. **Cuevas Adolfo G:** Writing – review & editing, Writing – original draft, Supervision, Resources, Funding acquisition, Conceptualization.

Declaration of Competing Interest

none.

Data availability statement

The data that support this study's findings are publicly available on the MIDUS Colectica Portal.

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