

Socioeconomic Status, Financial Strain, and Leukocyte Telomere Length in a Sample of African American Midlife Men

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Abstract

Background African American men in the USA experience poorer aging-related health outcomes compared to their White counterparts, partially due to socioeconomic disparities along racial lines. Greater exposure to socioeconomic strains among African American men may adversely impact health and aging at the cellular level, as indexed by shorter leukocyte telomere length (LTL). This study examined associations between socioeconomic factors and LTL among African American men in midlife, a life course stage when heterogeneity in both health and socioeconomic status are particularly pronounced. **Methods** Using multinomial logistic regression, we examined associations between multiple measures of SES and tertiles of

LTL in a sample of 92 African American men between 30 to 50 years of age.

Results Reports of greater financial strain were associated with higher odds of short versus medium LTL (odds ratio (OR)=2.21, $p = 0.03$). Higher income was associated with lower odds of short versus medium telomeres (OR=0.97, $p = 0.04$). Exploratory analyses revealed a significant interaction between educational attainment and employment status ($\chi^2 = 4.07$, $p = 0.04$), with greater education associated with lower odds of short versus long telomeres only among those not employed (OR=0.10, $p = 0.040$).

Conclusion Cellular aging associated with multiple dimensions of socioeconomic adversity may contribute to poor aging-related health outcomes among African American men. Subjective appraisal of financial difficulty may impact LTL independently of objective dimensions of SES. Self-appraised success in fulfilling traditionally masculine gender roles, including being an economic provider, may be a particularly salient aspect of identity for African American men and have implications for cellular aging in this population.

Keywords African American men · Telomere length · Socioeconomic status · Financial strain

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Introduction

Socioeconomic status (SES) has been linked to multiple health outcomes, including reduced life expectancy [1, 2], increased risk of heart disease [3], lower self-rated health [4], and major depressive disorder [5]. In general, higher SES is associated with improved health outcomes across the life course. SES-related health disparities are particularly pronounced in midlife, but gradually narrow with increasing age [6]. These disparities are observed not only among more

disadvantaged segments of society, but across the socioeconomic gradient [1, 6], suggesting that there is no “poverty threshold” beyond which individuals attain parity in health. Because African Americans tend to have lower incomes, lower levels of education, and are more likely to be unemployed than Whites in the USA [7], the health burden associated with lower SES is likely an important factor in explaining well-documented racial disparities in morbidity and mortality [8]. Studies among African Americans have reported associations between lower SES and risk factors for morbidity such as elevated blood pressure, higher levels of systemic inflammation, and poorer self-rated physical health [9–11]. Furthermore, there is evidence for a socioeconomic gradient among African Americans in diabetes prevalence, incidence of dementia, and all-cause mortality rates [12–14].

African American men may experience their socioeconomic contexts in ways that differ from other race and gender groups [15]. For midlife African American men, fulfilling traditionally masculine social roles, including that of economic provider, is typically a key aspect of African American masculine identity [16]. However, African American men face substantial barriers to achieving economic success. For example, they face covert discrimination in employment and housing [17, 18], receive harsher penalties from the judicial system for similar offenses [19], and earn less income at each level of education than their White counterparts [20]. This combination of traditionally masculine social expectations and structural barriers to economic success creates a particularly strong potential for strains related to socioeconomic status. A study of stress among midlife and older African American men found that the primary sources of stress in their lives were (1) performing socially important masculine gender roles and (2) being an African American man in a racially unequal society [21]. Study participants perceived that experiencing these intersecting challenges meant that African American men face more stress and stressors of a different kind than men of other races [21]. In addition to facing barriers to socioeconomic success, African American men may experience fewer psychosocial benefits from higher SES. While other groups in the USA, including African American women, report less stress with higher levels of SES, African American men tend to report more stress with higher SES [22, 23]. Given the evidence that socioeconomic factors affect African American men in distinct ways, along with the poor health outcomes experienced by African American men compared to those of other race and gender groups [24], research that examines processes leading to socioeconomic disparities in health among African American men is critical.

Though consistently linked with health outcomes, objective measures of SES, such as income and education, may not adequately capture an individual’s subjective experience of their socioeconomic circumstances. Furthermore, there are nuances of SES (e.g., quality of education, financial

obligations to family members, neighborhood environments) that may not be reflected in objective measures. Measuring financial strain, the perceived sufficiency of available resources to meet one’s economic needs, may be instrumental in addressing these limitations. It has been proposed that financial strain may affect health by impacting individual and interpersonal factors such as psychological distress, relationships, and personal control [25]. Financial strain has been linked to a range of outcomes, including self-rated health [26], mortality [27], depression [28], and impaired fasting glucose [29] independently of objective measures of SES such as income, education, and wealth.

Though socioeconomic disparities in health are well established in the epidemiologic literature, the psychosocial and biological mechanisms underlying them are less apparent. However, it has been proposed that the stresses and strains associated with socioeconomic disadvantage may promote physiologic dysregulation and increase susceptibility to pathological processes [30]. Along these lines, accelerated biological aging, due to the effects of elevated oxidative stress and inflammation, may be one such process [31]. Leukocyte telomere length (LTL) in particular has emerged as an indicator of general systemic aging and has been linked to a number of aging-related health outcomes, including cardiovascular disease [32], mortality risk [33], and dementia [34].

Telomeres are repeat TTAGGG DNA sequences capping the ends of chromosomes that allow cell division and replication to occur without the loss of genomic information [35]. Telomeric sequences are lost and shorten with successive rounds of cell division and generally shorten with advancing chronological age [35]. Oxidative damage and inflammatory load appear to contribute to this attrition [36, 37]. There is increasing evidence that psychosocial adversities negatively impact LTL, possibly mediated by inflammatory and oxidative stress pathways [37, 38]. For example, studies have reported shorter telomeres in individuals with mood disorders, caregivers of Alzheimer’s patients, and those who experienced early childhood adversity [39–41].

Findings concerning the link between SES and LTL have been somewhat mixed; while most have reported positive associations [e.g., 42–46], others have found no relationship [47, 48]. Inconsistencies may be due to differences across studies in the measures and analytic approaches employed. Despite indications that LTL is the most predictive of morbidity and mortality in midlife [32, 33], few of these studies have explicitly examined the association between SES and LTL among midlife individuals. Robertson et al. [43], however, examined associations between various socioeconomic measures and LTL in three cohorts of men and women approximately 35, 55, and 75 years of age. For the cohort aged 35, home tenure, area-level deprivation, parental social class, years of education, educational achievement, and family car ownership in childhood were significantly associated with

LTL. Among those aged 55, only family car ownership in childhood was significantly associated with LTL. In the oldest cohort, there were no associations between SES measures and LTL that were consistent across gender. These results suggest that the strength of the relationship between SES and LTL may diminish with age. Given the strong links between SES and health in middle age, further investigation of the association between SES and LTL among midlife individuals is warranted.

The present study aims to extend the literature on SES and LTL in several ways. It examines multiple measures of SES, including a subjective measure of financial strain, in relation to LTL among African American men, a group characterized by socioeconomic disadvantage and high risk for aging-related morbidity and mortality. Income, financial strain, work status, and education are conceptually distinct and may influence LTL in this group through different mechanisms. Income plays a significant part in African American men's ability to meet masculine gender norms and fulfill the role of a provider, and thus may have particularly important implications for physiologic outcomes in this population. Financial strain is a more subjective assessment of whether financial resources are sufficient in meeting financial needs; it is a function of income, as well as savings and other reserves. Financial strain reflects these additional dimensions of SES, as well as their psychological aspects. Work or employment is a means of obtaining financial resources and may also be a critical component of self-definition and identity for African American men. Education is a more stable dimension of SES, reflecting credentials, skills, and knowledge. Accordingly, each of these specific SES measures may impact LTL through unique pathways, including those related to tangible, psychological, and stress-related channels. This study examines each of these SES dimensions in relation to LTL in a sample of African American men of middle age, a stage in life course in which SES-related disparities in health may be particularly apparent.

Methods

Study Design and Procedures

This study uses data from the Bay Area Heart Health Study, which recruited 95 African American men between the ages of 30 and 50 from the San Francisco Bay Area between February of 2010 and May of 2010 [49, 50]. In order to be eligible, participants had to report being between 30 and 50 years of age, self-identify as African American, report US nativity and parental US nativity, be free of any serious or unstable illness (e.g., cancer, HIV, hepatitis, tuberculosis), and be able to read, write, and understand English.

Participants were recruited from socioeconomically diverse neighborhoods through self-referral, posted advertisements,

and word-of-mouth. Trained lay research staff performed data collection in a university or church room. Interviewers administered a questionnaire to assess basic demographic characteristics. Participants then completed a self-administered computer-assisted questionnaire that included psychological, socioeconomic, and behavioral measures. A minimally invasive physical was performed during which time anthropometric data and dried blood spots (DBS) were collected. Study participants were compensated with \$70. The University of California, San Francisco Committee on Human Research approved all study protocols.

Outcome Variable: Leukocyte Telomere Length

LTL was assayed from DBS. To collect these samples, each participant's finger was pricked with a micro-lancet, and the first drop of blood was wiped away. Four subsequent drops of about 50 μ L were applied to filter paper, allowed to dry, and stored at -80 C [51]. Genomic DNA was purified from the DBS samples, and telomere length was measured twice on each DBS sample with an average coefficient of variance of 6.3% between the two runs for the entire sample of 95 specimens. The telomere length assay protocol has been previously described [52, 53]. Preliminary analyses suggested an absence of a linear relationship between predictor variables and LTL. Therefore, following the example of a number of recent studies examining telomere length quantiles [e.g., 54], we examined LTL in tertiles categorized as "short," "medium," and "long."

Main Predictors: Socioeconomic Variables

Income, education, financial strain, and work status were examined as predictors of LTL category. To assess income, participants were asked to select the option that reflected their individual monthly wages after taxes. The available choices were in increments of \$500, from "\$0–500" up to "\$9501" or more. Individuals were then assigned the middle value of their chosen category as their monthly wages. To estimate yearly income, monthly wages were multiplied by twelve. To aid interpretability, income was scaled to increments of \$1000.

Education was grouped into five levels (1=no formal education, elementary or grade school, or junior high school; 2=high school or GED/high school equivalent; 3=some college but did not graduate or associate degree/community college; 4=college degree; and 5=graduate degree) and examined continuously. Those with current full- or part-time employment were categorized as "employed," and all others were categorized as "not employed." Financial strain was assessed as self-reported difficulty in making monthly bill payments (0=not difficult at all, 1=slightly difficult, 2=somewhat difficult, 3=very difficult, and 4=extremely difficult).

Covariates

Covariates included self-reported measures of the following: chronological age in years; relationship status categorized as married or unmarried; smoking status, classified as current (≥ 100 cigarettes smoked in lifetime, smoking daily or occasionally now), former (≥ 100 cigarettes smoked in lifetime, not smoking now, and smoked occasionally or daily in the past), or never (all others); self-rated health, evaluated as 1=poor, 2=fair, 3=good, 4=very good, or 5=excellent; and the number of health conditions assessed from a checklist of 22 common diseases (e.g., arthritis, asthma, diabetes). To measure blood pressure, four consecutive measurements were taken using an automatic monitor. The mean of the last three measurements was used, disregarding the first. Both diastolic and systolic blood pressure data were available, but only diastolic was used due to collinearity. Waist and hip circumference were measured in inches, and the waist measurement was divided by the hip measurement to create the waist-hip ratio.

Data Analysis

Two observations with outlying values for LTL more than three standard deviations away from the mean were excluded from analyses [50]. Another participant with a missing value for income was excluded, leaving a final sample size of 92 used for analysis. Bivariate analyses were performed, using ANOVA tests for continuous variables and chi-square tests for categorical variables. Because the proportional odds assumption for ordinal logistic regression was not met, a series of multinomial logistic regression models predicting tertiles of LTL were specified. Covariates were selected to control for the potential confounding effects of demographic factors and health status. The final model consisted of income, financial strain, education level, work status, age, relationship status, number of chronic conditions, self-rated health, diastolic blood pressure, waist-hip ratio, and smoking status. Analyses were performed using SAS 9.3.

Results

The mean LTL in each category was 5.11 kilobase pairs (kbp), 5.45 kbp, and 5.96 kbp in the short, medium, and long tertiles of LTL, respectively. These values are within the range of those reported in other recent studies using similar laboratory methods [e.g., 46, 55]. Thirty-eight participants had a high school degree or less (41.3%); forty-six participants had some college but did not graduate (50%); only eight participants had a college degree or more (8.7%). Half of participants reported no difficulty ($n = 22$; 23.9%) or slight difficulty ($n = 24$; 26.1%) in paying monthly bills. Thirty-two participants (34.8%) reported that making monthly bills payments was

somewhat difficult; a minority of participants reported that doing so was “very difficult” ($n = 11$; 12.0%) or “extremely difficult” ($n = 3$; 3.3%). Income and education were positively correlated ($r = 0.28$, $p = 0.007$). Financial strain was not significantly correlated with education ($r = -0.01$, $p = 0.933$) or income ($r = -0.11$, $p = 0.305$). In bivariate analyses, age ($p = 0.002$) and diastolic blood pressure ($p = 0.041$) were significantly different across categories of telomere length. Income ($p = 0.053$) and smoking status ($p = 0.058$) approached significance. Additional characteristics of the sample overall and by LTL tertiles are presented in Table 1.

Results from multinomial regression analyses predicting tertiles of LTL are presented in Table 2. In order to present comparisons between each of the LTL tertiles, the referent group was rotated. We found that greater income was associated with lower odds of being in the short versus medium LTL category (odds ratio (OR)=0.97, 95% confidence interval (CI)=0.93, 1.00, $p = 0.043$). Greater financial strain was associated with greater odds of being in the short versus medium LTL category (OR=2.21, 95% CI=1.09, 4.41, $p = 0.029$). Work status was not significant in our models. Similarly, education also did not show any main effect on LTL tertiles. Examining education as a categorical variable did not change results. Of the covariates, age, chronic conditions index, self-rated health, diastolic blood pressure, waist-hip ratio, and smoking status were significantly associated with LTL.

Due to the difficulty in interpreting odds ratios in multinomial logistic regression, predicted probabilities were calculated for significant variables. For each significant variable being examined, all other variables were set constant to their mean for those which were continuous or set to the proportion belonging to a group for those which were categorical. Table 3 presents predicted probabilities of being in a LTL category for income, financial strain, and other significant covariates: age, chronic conditions index, self-rated health, diastolic blood pressure, waist-hip ratio, and smoking status. To demonstrate relationships for income, we chose \$20,000 increments. For financial strain, chronic conditions, and self-rated health, the values selected were the highest, lowest, and middle values for each scale or index. For age, diastolic blood pressure, and waist-hip ratio, the values used were the mean, one standard deviation above the mean, and one standard deviation below the mean. For smoking, predicted probabilities for each category were calculated (current, former, never).

Predicted probabilities were graphed for socioeconomic variables that significantly differentiated between tertiles of LTL. Figure 1 illustrates that increasing income is associated with greater probability of being in the medium LTL tertile and lower probability of being in the short tertile. Predicted probabilities for financial strain are presented in Fig. 2, which shows that increasing financial strain is associated with greater probability of being in the short LTL category and lower probability of being in the medium category.

Table 1 Characteristics of African American men by tertiles of leukocyte telomere length in the Bay Area Heart Health Study, 2010 (*n* = 92)

	Short (<i>n</i> = 31)	Medium (<i>n</i> = 30)	Long (<i>n</i> = 31)	Total (<i>n</i> = 92)
Income in \$1000, mean (SD)	15.8 (14.0)	25.8 (30.0)	14.2 (10.4)	18.5 (20.3)
Financial strain, mean (SD)	1.8 (1.0)	1.2 (1.1)	1.4 (1.1)	1.4 (1.1)
Education level, mean (SD)	2.6 (0.9)	2.8 (1.0)	2.5 (0.7)	2.7 (0.84)
Working, <i>n</i> (%)	16 (32.0)	18 (36.0)	16 (32.0)	50 (54.4)
Age, mean (SD)*	46.4 (4.1)	43.7 (5.5)	41.5 (6.4)	43.8 (5.7)
Single, <i>n</i> (%)	24 (34.3)	24 (34.3)	22 (31.4)	70 (76.1)
Chronic conditions, mean (SD)	2.0 (1.5)	2.5 (2.1)	1.6 (1.6)	2.0 (1.8)
Self-rated health, mean (SD)	3.4 (1.1)	3.1 (1.0)	3.6 (0.8)	3.4 (0.95)
Diastolic BP, mean (SD)*	84.9 (11.6)	77.1 (15.9)	77.5 (10.0)	79.9 (13.1)
Waist-hip ratio × 10, mean (SD)	9.3 (0.7)	9.1 (0.7)	9.3 (0.8)	9.2 (0.7)
Smoking status, <i>n</i> (%)				
Non-smoker	9 (32.1)	13 (46.4)	6 (21.4)	28 (30.4)
Current smoker	19 (38.0)	15 (30.0)	16 (32.0)	50 (54.4)
Former smoker	3 (21.4)	2 (14.3)	9 (64.3)	14 (15.2)

**p* < 0.05

We explored interactions between each of the SES variables—income, education, employment, and financial strain—adding them individually into models. The interaction between work status and educational attainment was significant in comparing the short versus long LTL tertile ($\chi^2 = 4.07$, 1 df, *p* = 0.044). Stratified analyses revealed that lower educational attainment was associated with greater odds of short versus long telomeres only among those not working (OR=0.10, 95% CI=0.01, 0.91, *p* = 0.040). Predicted probabilities of short and long LTL tertile by education level were calculated for those not working and graphed in Fig. 3.

Discussion

The results of the present study provide support for the link between socioeconomic factors and LTL, and extend this research by examining these relationships in a midlife sample of African American men. Controlling for demographic and health variables, lower income was associated with greater risk of having short LTL. As income increased, the probability of being in the medium LTL tertile increased, while the probability of being in the short LTL tertile decreased. A number of previous studies have reported associations between lower income and poorer health [e.g., 3–5]. This association may

Table 2 Multinomial logistic regression models examining leukocyte telomere length among African American men in the Bay Area Heart Health Study, 2010 (*n* = 92)

	Short vs. long OR (95% CI)	Medium vs. long OR (95% CI)	Short vs. medium OR (95% CI)
Yearly income in \$1000	1.01 (0.96, 1.06)	1.05 (1.00, 1.10)	0.97 (0.93, 1.00)*
Financial strain	1.37 (0.71, 2.66)	0.62 (0.30, 1.30)	2.21 (1.09, 4.51)*
Education level	0.92 (0.39, 2.18)	0.85 (0.36, 2.03)	1.08 (0.51, 2.30)
Working vs. not	1.32 (0.30, 5.90)	1.08 (0.23, 5.12)	1.22 (0.28, 5.44)
Age	1.23 (1.08, 1.41)*	1.16 (1.02, 1.31)*	1.07 (0.93, 1.22)
Single vs. not	2.15 (0.52, 8.88)	4.68 (0.94, 23.23)	0.46 (0.10, 2.04)
Chronic conditions	1.23 (0.81, 1.88)	1.77 (1.10, 2.86)*	0.70 (0.46, 1.05)
Self-rated health	0.52 (0.22, 1.27)	0.35 (0.14, 0.86)*	1.51 (0.73, 3.12)
Diastolic BP	1.09 (1.02, 1.16)*	1.03 (0.97, 1.08)	1.07 (1.00, 1.13)*
Waist-hip ratio × 10	0.34 (0.11, 1.10)	0.15 (0.04, 0.54)*	2.23 (0.81, 6.10)
Smoking status (ref, current)			
Never	1.33 (0.23, 7.66)	2.14 (0.37, 12.31)	0.62 (0.13, 3.00)
Former	0.08 (0.01, 0.66)*	0.07 (0.01, 0.67)*	1.07 (0.12, 9.61)

**p* < 0.05

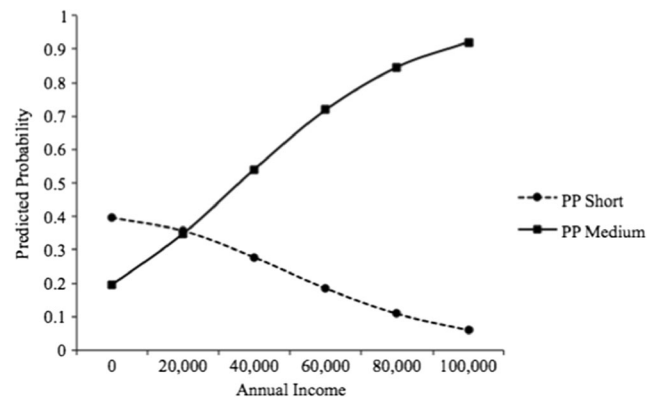
Table 3 Predicted probabilities of tertiles of leukocyte telomere length among African American men in the Bay Area Heart Health Study, 2010 ($n = 92$)

	Short	Medium	Long
Income			
\$20,000	0.36	0.35	0.29
\$40,000	0.28	0.54	0.18
\$60,000	0.18	0.72	0.10
\$80,000	0.11	0.85	0.05
\$100,000	0.06	0.92	0.02
Financial strain			
Not difficult (0)	0.18	0.53	0.29
Somewhat difficult (2)	0.41	0.25	0.34
Extremely difficult (4)	0.64	0.08	0.28
Chronological age			
Younger (38.1)	0.18	0.24	0.59
Mean (43.9)	0.34	0.32	0.34
Older (49.6)	0.51	0.33	0.16
Chronic conditions			
None	0.34	0.15	0.51
Moderate (3)	0.32	0.42	0.26
High (6 or more)	0.19	0.73	0.08
Self-rated health			
Poor (1)	0.27	0.67	0.06
Good (3)	0.35	0.38	0.27
Excellent (5)	0.23	0.11	0.66
Diastolic BP			
Lower (66.8)	0.16	0.34	0.5
Mean (79.9)	0.34	0.32	0.34
Higher (93.0)	0.58	0.24	0.18
Waist-hip ratio $\times 10$			
Lower (8.52)	0.32	0.53	0.15
Mean (9.2)	0.34	0.32	0.34
Higher (9.9)	0.27	0.14	0.58
Smoking status			
Never	0.35	0.46	0.19
Former	0.09	0.07	0.85
Current	0.39	0.32	0.29

Predicted probabilities are for variables significantly associated with tertiles of leukocyte telomere length in multinomial logistic regression models. The predicted probability for a specific variable was calculated with all other continuous variables being set constant to their mean, and other categorical variables being set to the proportion belonging to a group in order to demonstrate relationships for the average participant

be mediated by a range of factors such as access to material goods, social support, a sense of control, life stress, and relative social status [6]. Our results suggest that telomere attrition associated with lower income may be a pathway leading to poorer health in African American midlife men.

A novelty of this study was examining a subjective indicator of financial strain, which was associated with greater risk

**Fig. 1** Predicted probabilities (PP) of short and medium tertiles of leukocyte telomere length by annual income among African American men in the Bay Area Heart Health Study, 2010 ($n = 92$)

of short LTL. This is consistent with several studies reporting links between financial strain and various health outcomes independent of objective SES indicators [25–29]. One reason that financial strain is predictive of LTL category, above and beyond these objective measures, may be that financial strain reflects aspects of SES, such as quality of education or financial obligations to family members, that are not detected by measures such as personal income and educational attainment. Another possibility is that reports of financial strain may represent a cognitive averaging of various dimensions of one's socioeconomic context, thus forming a composite measure of SES. However, studies reporting that financial strain varies independently of objective measures of SES suggest that not all individuals appraise their socioeconomic circumstances in the same way [56]. In short, socioeconomic disadvantage may be a more powerful stressor for some than others. Given the evidence that various life stressors are associated with LTL [57–59], it may be that high levels of financial strain represent a stressor that accelerates biological aging. Our finding that financial strain is associated with increased odds of short LTL is consistent with previous work proposing that self-appraised success in fulfilling traditionally masculine gender roles, including that of economic provider, is a key aspect of identity for African American men [16, 21]. Difficulties in performing this socially important role may represent a stressor contributing to cellular aging.

In exploratory analyses, a significant interaction was found between employment status and educational attainment, with lower levels of educational attainment being associated with greater probability of short LTL, but only among those not working. This finding is consistent with the theory of resource substitution, which proposes that education is a more potent predictor of health for those who have fewer alternative resources. For example, one study found a stronger association between educational attainment and physical functioning among those whose parents were poorly educated [60]. Another study reported that

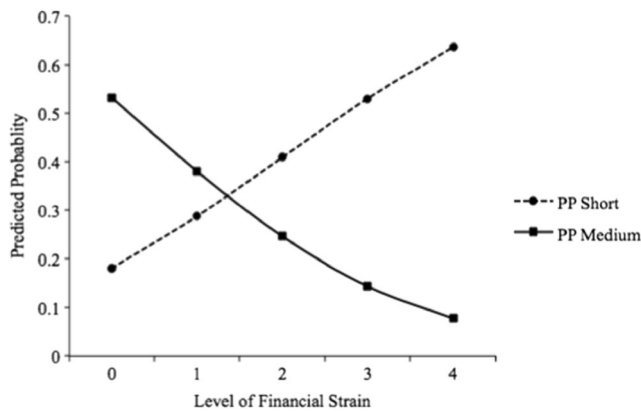


Fig. 2 Predicted probabilities of short and medium tertiles of leukocyte telomere length by financial strain among African American men in the Bay Area Heart Health Study, 2010 ($n = 92$). For financial strain measured as self-assessed difficulty in paying monthly bills, 0 = not difficult at all, 1 = slightly difficult, 2 = somewhat difficult, 3 = very difficult, and 4 = extremely difficult

education was a stronger predictor of depression among women than men [61]. In the case of the present study, the psychosocial benefits of higher levels of education may be particularly beneficial in protecting against accelerated telomeric aging among those who are out of work.

The strengths of this study lie in the multiple measures of SES examined, including measurement of financial strain and studying their relationships with LTL in a sample of African American midlife men, a group at particularly high risk for aging-related disease and disability. Nevertheless, there are several limitations present. The first is that the purposive sampling of African American midlife men precludes the generalization of results to other groups such as women, older adults, and other race groups. Another limitation is the cross-sectional nature of the study, which raises

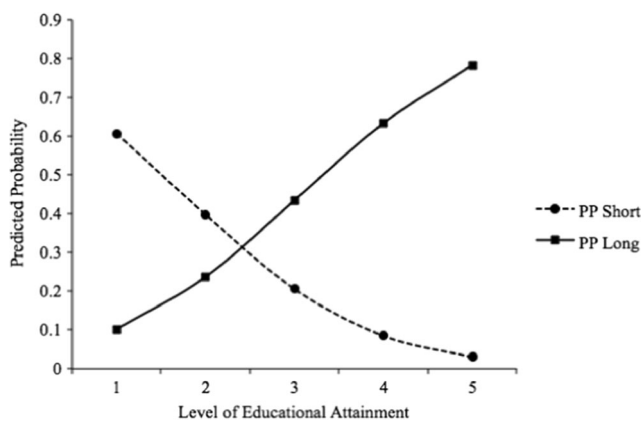


Fig. 3 Predicted probabilities of short and long tertiles of leukocyte telomere length by education level among African American men who are not working in the Bay Area Heart Health Study, 2010 ($n = 92$). 1 = no formal education, elementary or grade school, or junior high school; 2 = high school or GED/high school equivalent; 3 = some college but did not graduate or associate degree/community college; 4 = college degree; and 5 = graduate degree

questions regarding the directionality of the reported associations. For example, it is possible that poorer health associated with short LTL negatively impacts SES. However, to address this possible concern, statistical models were used that controlled for self-rated health, the number of self-reported chronic health conditions, blood pressure, and waist-hip ratio in our analyses. Another caveat to these findings is the relatively small sample size, which may have limited the ability to detect statistically significant associations. Given that our sample is relatively small and self-selected, replication of our findings in other samples is warranted. Furthermore, our restricted sample size may have limited our ability to detect meaningful associations. In addition, the finding of the significant interaction between education and working status should be viewed as preliminary. Because multiple interactions between SES variables were explored in post-hoc analyses, this finding may have been spurious. Future studies may examine this and other interactions, in addition to the main effects of objective and subjective measures of SES in relation to LTL.

The literature suggests that SES disparities partially account for well-documented racial disparities in health [7, 8]. Despite the limitations of this study, our findings suggest that lower SES among African Americans may contribute to poorer health in this population via its impact on the telomere maintenance system. The persistence of racial disparities across multiple health outcomes suggests that there may be common physiologic processes contributing to these inequities, and that the impact of lower SES on accelerated biological aging as reflected by LTL may be one such mechanism.

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Compliance with Ethical Standards

Disclosure Statement J.L. is a co-founder of Telomere Diagnostics Inc. and serves on its scientific advisory board. The company plays no role in the current study. No other financial disclosures were reported by the authors of this paper.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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