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Financial Strain is Associated with Increased Oxidative Stress Levels: The Women's Health and Aging Studies

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Abstract

Background—Elevated oxidative stress levels may be one underlying biological mechanism that contributes to poor health outcomes, including atherosclerosis and diabetes. Financial strain in adulthood is consistently associated with poor health. High oxidative stress and financial strain are each predictors of morbidity and mortality, but little research has investigated their relationship. This study investigated whether financial strain was associated with elevated oxidative stress levels.

Methods—A cross-sectional analysis was conducted on 728 community-dwelling older adult women from the Women's Health and Aging Studies I and II at the baseline visit. Linear regression was performed to quantify the relationship between financial strain and oxidative stress. Oxidative stress was measured using protein carbonyl concentrations obtained from serum samples. Financial strain was measured as three-level ordinal response to: "At the end of the month, do you have more than enough money left over, just enough, or not enough?"

Results—Those who reported high financial strain exhibited 13.4% higher protein carbonyl concentrations compared to individuals who reported low financial strain (p= 0.002).

Conclusions—Findings show that high financial strain among community-dwelling older adult women may be associated with increased oxidative stress, suggesting that oxidative stress could

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mediate the associations between financial strain and poor health outcomes. These results are of critical importance because individuals from lower SES backgrounds consistently exhibit poorer health outcomes.

Keywords

oxidative stress; financial strain; older adults

Introduction

With the United States' aging population, it is expected that by 2030, the number of individuals aged 65 and older will double to 70 million.[1] Thus, one in five Americans will be over the age of 65.[1] It is also expected that individuals will live roughly 15-20 years past age 65.[2] As our population ages, we can expect an increase in chronic conditions, geriatric syndromes, and disabilities.[3] Beyond the demographic shift towards an aging population, another concern is the potential for a growing number of older adults living in poverty. Based on the growing number of older adults, it has been projected that the current Social Security system may not be stable or secure enough to meet the demands of a growing older adult population.[4] The number of retired older adults using social security funds is increasing at a faster rate than employed persons paying into the social security fund.[5] The health implications of poverty in older adults is critical to understand as background to the potential re-design of social policies and of interventions to improve the quality of life and health outcomes for older adults.

Socioeconomic status (SES) can be defined as an individual's or household's access to desired resources.[6] SES is a broad concept that categorizes individuals within our societal structure.[6] Given the broad definition of SES, researchers have had a difficult time agreeing on the most appropriate way to measure SES.[6,7] The most common ways to date have been income, years of education achieved, occupation and wealth. Perceived financial strain is an SES measure that has received little attention.[8] However, it may be particularly appropriate among older adults, because it addresses the balance between income and necessary expenses.[9] Perceived financial strain measures account for the fact that people with similar incomes can have a wide variation in their financial experience.[10] This becomes especially important when assessing SES in older adults who may be living on limited incomes, but could have additional financial assets or wealth not accounted for in their annual household income.

Considerable research links low SES to poor functional and health outcomes from adolescence through adulthood.[10–15] Individuals in lower SES strata experience greater functional limitations,[10] and higher morbidity[16] and mortality[17] than their higher SES counterparts. These inequalities may not be completely explained by a lack of access to the healthcare system, greater exposure to adverse risk factors, and engagement in high-risk health behaviors.[10] It is important to explore other biological factors, which may partially explain the SES gradient in health.

Oxidative stress is a biological factor that may enhance the understanding of how SES leads to poor health. Oxidative stress is the imbalance of oxidant and antioxidant defenses.

Oxidant species are short-lived intermediates produced in the reduction-oxidation (redox) process of oxygen to water.[1819] They exist in all aerobic organisms and are primarily created in the mitochondria. When one's body has unequal levels of oxidant and antioxidant species, for example, more oxidative reactive species than antioxidants, oxidant species begin to breakdown proteins, lipids, and nucleic acids in the cell.[1820] The accumulation of these cellular damages in the presence of excess oxidant species can result in cell death, and can lead to poor health outcomes. Prior literature suggests that several factors may lead to elevated levels of oxidative stress. African-Americans have been shown to have higher levels of oxidative stress compared to their Caucasian counterparts.[21] Behavioral factors, such as, obesity[22] and smoking[23] are also associated with higher levels of oxidative stress. Intensity of physical activity has also been shown to effect oxidative stress levels.[24] Previous research has shown that high oxidative stress contributes to the onset and progression of diabetes[25], atherosclerosis[26], and most importantly, mortality.[18] Oxidative stress is a candidate biological factor that may mediate the associations between SES and poor health outcomes, namely mortality. Previous research has explored the relationship between psychological stressors and red blood cell oxidative stress.[27] Specifically, perceived racial discrimination was associated with red blood cell oxidative stress in a sample of older adults.[28] Therefore, we anticipate that there may be a similar association between oxidative stress and SES, a significant psychological stressor among older adults.

Financial strain and oxidative stress are both risk factors for morbidity[29,30] and mortality.[9,18] Although financial strain and oxidative stress are each predictors of disease and disability susceptibility, there has been little research examining their relationship. The mechanism through which financial strain may increase risk for poor health outcomes is still unknown. Identifying the relationship between financial strain and oxidative stress may provide evidence that oxidative stress mediates the associations between financial strain and poor health outcomes. Therefore, the objective of this study is to examine the association between financial strain and oxidative stress, specifically, the hypothesis that higher financial strain is associated with higher oxidative stress.

Materials and Methods

Study population and design

This was a secondary data analysis using data from the Women's Health and Aging Study (WHAS). The WHAS was a population-based cohort study that has followed community-dwelling older women in Baltimore, MD. The primary aim of the study was to identify the causes and courses of disability. The participants in WHAS I and WHAS II were identified and selected randomly from the Health Care Financing Administration's Medicare eligibility list for 12 zip codes of Eastern Baltimore City and County. WHAS I is representative of the one-third most disabled women and WHAS II is representative of the two-thirds least disabled women residing in Baltimore City and Baltimore County. Inclusion into WHAS I was limited to women aged 65 and older who had difficulty in two or more areas of physical functioning and had a Mini-Mental State Examination (MMSE) score of at least 18.[31] Inclusion into WHAS II was limited to women aged 70-79 who had difficulty in no or only one area of physical functioning and had a MMSE score of at least 24. Areas of functioning

assessed, in a standardized manner, in WHAS I and WHAS II included upper extremity function, mobility function, higher functioning, and basic self-care. Specifics regarding these two studies have been described elsewhere.[32–34]

Recruitment and baseline assessments were conducted between 1992-1995 in WHAS I and 1994-1996 in WHAS II. In 1992, of the 1,409 women who were screened and eligible for WHAS I, 71.0% agreed to participate. Compared to those participants that were eligible and enrolled, those who declined to participate exhibited no major differences in socio-demographic or reported health characteristics.[34] In 1994, of the 880 women who were screened and eligible for WHAS II, 49.5% agreed to participate. Compared to those participants that were eligible and enrolled, those who declined to participate had less education and fewer diseases, but did not significantly differ in race.[32] Follow-up questionnaires and physical performance measures were administered every six months for three years for WHAS I and every eighteen months for WHAS II. For the purposes of this cross-sectional analysis, data from the first round of data collection were pooled from WHAS I and WHAS II to obtain data from community-dwelling women of all socioeconomic backgrounds. Only participants who were between the ages of 70-79 years were included in this analysis since this age range was common in both WHAS studies. Fifteen participants did not complete the financial strain measure at the baseline visit and were excluded from the analyses. A total of 276 participants did not participate in the blood drawing, and were therefore missing data on oxidative stress at the baseline visit and were excluded from the analyses. Those individuals who did not participate in the blood draw at baseline were more likely to report high financial strain compared to those who participated in the blood draw (p=0.001). Of the 728 participants with complete financial strain and oxidative stress data, 323 subjects were from WHAS I and 405 were from WHAS II. The Johns Hopkins School of Medicine Institutional Review Board approved all protocols for these studies. Written informed consent was obtained from all participants.

Measures

Financial strain—Perceived financial strain was measured as a three-level ordinal response to the following question: “At the end of the month, do you have *more than enough money left over*, *just enough, or not enough*?” Based on prior literature[7] and due to small numbers in these categories of financial strain, individuals who reported having “not enough money left over at the end of the month” or “just enough money left over at the end of the month” were combined and categorized as high financial strain. Individuals who reported “more than enough money left over at the end of the month” were categorized as low financial strain.

Oxidative stress—Oxidative stress was measured using protein carbonyl concentrations obtained from serum samples. Protein carbonyl concentrations are one biomarker for protein oxidation and are used in this study due to their stability and ease of measurement through serum or plasma samples.[30] Following a standardized protocol, venipuncture was performed between 9AM and 2 PM to collect non-fasting blood samples. All processing, aliquoting, and freezing of samples was performed at the Core Genetics Laboratory of the Johns Hopkins University School of Medicine. Once processed, samples were transported to Quest

Diagnostics Laboratory (Teteboro, NJ) and stored until needed for analyses. To ensure long-term stability of protein carbonyls, samples were stored at −70°C.[35,36] Serum protein carbonyls were measured using a commercially available ELISA kit (Zentech PC Test, Protein Carbonyl Enzyme Immuno-Assay Kit, Biocell, Papatoetoe, NZ) in one of the co-investigator's lab (RDS). This assay has a minimum detectability of 0.02 nmol/mg protein.[18,30,36] Intra-assay and interassay coefficients of variation for the protein carbonyl measurements were 10.1% and 18.2%.[18,30,36] Log-transformations of serum protein carbonyls were performed to obtain a normal distribution.

Covariates—Based on a priori theory, prior literature and univariate analyses, covariates that were associated with both financial strain and oxidative stress were included in the analyses Age was measured in years and the analytic sample had an age range of 70-79 years. Race was dichotomized as Caucasian or African American. Smoking status was categorized into never, former, and current smoker. BMI was calculated using each participant's weight and height and categorized into <18.5 kg/m^2, 18.5-24.9 kg/m^2, 25.0-29.9 kg/m^2, and ≥ 30.0 kg/m^2.[37] Cardiovascular diseases included heart attack or myocardial infarction, angina, congestive heart failure, stroke, and peripheral artery disease. All diseases and conditions in the WHAS studies were adjudicated by two physicians based on examination, medication list, radiographs, blood tests, and medical records.[34] Physical activity was based on participant self-reports of how much they participated in certain activities in the week prior to the interview. Based on an algorithm developed in another study using WHAS data, participants were subsequently categorized into the following physical activity categories: extremely physically inactive, minimally physically active, and moderately physically active.[38] Disability was dichotomized as either disabled if individuals had difficulty in more than one activity of daily living (ADL) or not disabled if individuals had difficulty in no or only one ADL. To assess the independent association between financial strain and oxidative stress, education and income were included as covariates.

Statistical analyses

Chi-square tests and ANOVA tests were used to examine the proportional mean differences by financial strain level, respectively. Two linear regression analyses were performed to examine the cross-sectional associations between financial strain and log-transformed serum protein carbonyl concentrations. This method models the percent difference in log-transformed serum protein carbonyl concentrations comparing individuals who reported high versus low financial strain.

The first model examined the unadjusted association between financial strain and log-transformed serum protein carbonyl concentrations. The second model examined the associations between financial strain and log-transformed serum protein carbonyl concentrations, adjusting for age, race, smoking status, education, income, BMI, cardiovascular diseases, diabetes, physical activity, and disability.

A weighted analysis was performed to account for sampling design and non-participation. Weights were calculated based on each participant's probability of being selected into the study.[34] Probabilities varied by age and race. Performing a weighted analysis affords the

opportunity to generalize the results to the entire population of community-dwelling older women residing in and around Baltimore. All analyses were conducted using STATA 11.0 (Stata Corp, College Station, TX).

Results

Table 1 displays the baseline demographic and disease characteristics of the 728 participants from the WHAS I and II studies, by financial strain. The mean age of the sample was 73.9 years. Seventy-six percent of the sample was Caucasian. High financial strain was reported by 35% of the participants. More women with high financial strain were African American (n=98, 38.6%) versus low financial strain (n=79, 16.7%). More women with high financial strain were likely to be obese (n=90, 37.8%) when compared to women with low financial strain (n=117, 25.0%). Women with high financial strain were more commonly diagnosed with angina, congestive heart failure, peripheral artery disease, and diabetes. Women with low financial strain were more moderately physically active (n=369, 77.9%) compared to their higher financially strained counterparts (n=140, 55.1%). With regard to SES outcomes, women with high financial strain were more likely to self-report an annual household income less than $10,000 (n=170, 66.9%) compared to having an annual household income greater than $22,250 (n=38, 15.0%). These same women were also more likely to report lower achieved levels of education. The mean $\log_e$ serum protein carbonyl concentrations (SD) for the pooled sample were −2.4 (0.45). Mean $\log_e$ serum protein carbonyls were not significantly different between the two categories of financial strain (p=0.454).

In the unadjusted linear regression model, financial strain was not significantly related to oxidative stress (Table 2). Individual's self-reporting high financial strain had 13.4% higher protein carbonyl concentrations compared to individuals reporting low financial strain (p= 0.02) and the association was robust to adjustment for age, race, smoking status, BMI, cardiovascular diseases, diabetes, physical activity, disability, education and income.

Discussion

Several differences were observed among women with high compared to low financial strain. As hypothesized, we found that community-dwelling women ages 70-79 that report high financial strain exhibited higher oxidative stress, compared to women who report low financial strain. Further, we provided novel preliminary evidence for a relationship between financial strain and oxidative stress, controlling for age, race, smoking, education, income, BMI, cardiovascular diseases, diabetes, physical activity and disability. This finding suggests one pathway that may explain why individuals from lower SES backgrounds consistently exhibit poorer health outcomes compared to those of higher SES backgrounds; and, indicates that these mechanisms are impactful in changing health status at older ages. We anticipate that oxidative stress may mediate the associations between financial strain and poor health outcomes based on a biological pathway. Specifically, raised cortisol levels activated by the hypothalamic–pituitary–adrenal axis (HPA axis) in individuals with higher financial strain may be impacting oxidative stress through inflammation.[39] Increased cortisol levels may result in greater inflammation which has been found to be associated with oxidative stress.[40] Prior research has also supported this association in young adults. In this

study which used data from the Coronary Artery Risk Development in Young Adults (CARDIA), researchers examined whether SES, measured by education, income, and occupation, was associated with measures of oxidative damage, F(2)-isoprostanes and gamma-glutamyltransferase (GGT), in young adults.[41] They noted that measures of oxidative damage were lower among individuals of higher SES, as measured by education, income or occupation.[41] Financial strain used in our analysis is a perceived measure of SES. Among individuals with the same education and income, one person may perceive themselves to have high financial strain whereas another person may perceive themselves to have low financial strain. Alternatively, two individuals with high perceived financial strain may live in two different areas offering different levels of housing quality, access to services, and resources. The subjective nature of this measure is of value since perception about financial strain can influence actions, behaviors, possibly the HPA axis, and ultimately affects health outcomes. Therefore, it is important that we incorporate information on self-perception of financial strain, in addition to objective measures of socioeconomic position, when conceptualizing and designing policies to address health disparities.

Limitations

This study had several limitations by virtue of being a secondary data analysis. Few participants were missing data on perceived financial strain, but a number of women from both WHAS I and II did not participant in the blood draws and had no data on oxidative stress. Based on the exploratory analyses, it was assumed that this data was missing at random (MAR). Given our use of a maximum likelihood method in the analysis, our results are valid under the MAR assumption and provide us with robust results and unbiased estimates.

This study was a cross-sectional analysis looking at the relationship between perceived financial strain and oxidative stress. Therefore, temporality cannot be established. However, the data collection methods for WHAS I and WHAS II offer some built-in temporality. The financial strain measure conducted at baseline captured an individual's perception of financial strain "at the end of the month." The serum samples were collected at the same time that the baseline assessments were conducted; however, for an individual to answer the financial strain measure they needed to consider their finances at either the end of the past month or at the end of an average month both of which would be previous to the oxidative stress measurement.

Although women make up the majority of older adults living in poverty,[42] the fact that we included only women in this study limits our ability to generalize our findings. It is possible that the findings would differ for men. Likewise, this study included a relatively young population of older individuals. Future research should consider if these relationships are maintained among those in older age groups.

Conclusion

In summary, data from this analysis suggests that high financial strain among community dwelling older adult women is associated with higher oxidative stress. The identified

associations between financial strain and oxidative stress are possible precursors to poor health outcomes. These results are of critical importance given that individuals from low SES backgrounds consistently exhibit poorer health outcomes. It may helpful, therefore, to develop practical interventions to target underlying biological declines in lower SES older adults. Lifestyle and behavioral interventions have been found to reduce oxidative stress, and include, cessation of smoking,[43] maintaining a healthy Mediterranean diet high in fruits, vegetables, whole grains, nuts, and oils,[44–47] and increasing physical activity and exercise.[48,49]

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Table 1

Baseline Characteristics of Study Participants by Financial Strain: The Women's Health and Aging Studies I and II (*N=728)*

Characteristic	Total (n=728)	High Financial Strain* (n=254)	Low Financial Strain** (n=474)	p-value
	Mean ± SD	Mean ± SD	Mean ± SD	
Log_e serum protein carbonyls, nmol/mg	−2.4 ± 0.5	−2.4 ± 0.4	−2.4 ± 0.5	0.454
Age, years	73.9 ± 2.8	73.8 ± 2.8	74.0 ± 2.8	0.185
Education, years	11.5 ± 5.5	10.0 ± 6.1	12.3 ± 5.0	<0.001
Income, dollars	22,116.1 ± 22,149	14,485.6 ± 15,907	26,200.0 ± 24,166	<0.001
	N (%)	N (%)	N (%)	
Current smoking	88 (12.1)	38 (15.0)	50 (10.6)	0.025
Body Mass Index, kg/m^2				0.002
<18.5	30 (4.2)	10 (4.2)	20 (4.3)	
18.5-24.9	221 (31.3)	58 (24.4)	163 (34.8)	
≥ 25.0- 29.9	249 (35.2)	80 (33.6)	169 (36.0)	
≥ 30.0	207 (29.3)	90 (37.8)	117 (24.9)	
Cardiovascular disease	237 (32.6)	115 (45.3)	112 (23.6)	<0.001
Diabetes	96 (13.2)	51 (20.1)	45 (9.5)	<0.001
Cancer	67 (9.2)	25 (9.8)	42 (8.9)	0.662
Moderately Physically Active,	511 (70.2)	140 (55.1)	369 (77.9)	<0.001
Disability	323 (44.4)	183 (72.1)	140 (29.5)	<0.001

*High Financial Strain- Individuals who self-reported having "not enough money left over at the end of the month" or "just enough money left over at the end of the month."

**Low Financial Strain- Individuals who self-reported having "more than enough money left over at the end of the month."

Table 2

Unadjusted and Adjusted Linear Regression Models for the Relation between Financial Strain and Log_e Serum Protein Carbonyl concentrations (nmol/mg), the Women's Health and Aging Studies I and II *(N=728)*

	Model 1			Model 2		
Financial Strain	**Beta**	**Standard Error**	**p-value**	**Beta**	**Standard Error**	**p-value**
High Financial Strain	0.03	0.04	0.47	0.13	0.05	0.02
Low Financial Strain	(ref)	-----	-----	(ref)	-----	-----

Model 1: Unadjusted

Model 2: Adjusted for age, race, smoking, education, income, BMI, cardiovascular diseases, diabetes, physical activity and disability

Reference (ref): Low Financial Strain