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The Association between Flourishing and C-reactive protein Levels
Among Aging Adults: A Cross-Sectional Study

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B.S., Emory University, 2014

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Abstract

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By Misha N. Sharp

Background: The research available indicates that elderly populations display higher levels of C-reactive protein (CRP), increased prevalence of cardiovascular disease and higher levels of flourishing mental health. While the association between flourishing and CRP level has not yet been studied, research would suggest that constructs with overlapping measures, like positive affect, have positive correlations with successful aging and longevity for older adults. Flourishing may have important implications for increased positive psychological wellbeing, and in turn, lowered measures of inflammation like CRP that affect future risk of cardiovascular disease.

Objective: This study examines the association between flourishing and CRP in three different age groups, 20-39 year olds, 40-59 year olds and those 60 and older.

Methods: A secondary analysis of cross-sectional data from the Predictive Health Institute's Center for Health and Wellbeing 2009 cohort was used in order to conduct linear regression models to examine the association between flourishing and CRP. Models were stratified by age group and adjusted for demographic characteristics as well as biological variables and health behaviors.

Results: There was a significant association between flourishing and CRP for adults aged 60 and older, even after adjustment for education, income, race and gender. Associations for flourishing and CRP were non-significant for younger and middle-aged adults and the flourishing by age interaction was significant at $p= 0.0116$. Body mass index, physical activity and smoking status were important predictors of CRP regardless of levels of flourishing.

Discussion: These analyses found that flourishing is significantly associated with CRP for the oldest group in this cohort, those 60 and older. This suggests that the relationship between cardiovascular health and mental health may be more important for maintaining the physical health of senior adults.

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Introduction

Rationale

Between 2012 and 2050, the United States will see considerable growth in its elderly population aged 65 and over. By the year 2050, this population is expected to reach 83.7 million, as compared to 43.1 million in 2012 (1). The issue of aging and health is particularly salient for the decades immediately approaching, as the generation of baby boomers began turning 65 in the year 2011 (1). Surviving baby boomers will be approximately 85 years old by the year 2050 (1). The growing size of this population will largely be driven by improved mortality for elderly populations, especially with regard to behavioral interventions in the spheres of smoking cessation and obesity prevention (1).

Cardiovascular disorder and disease create a large burden of disease for all age groups, killing approximately 610,000 every year, or one in every four deaths in the United States (2). There is variation in risk according to demographic, genetic, behavioral and psychological factors, with senior adults at the highest risk of cardiovascular disease (2). Researchers have built a large body of literature focusing on predictive biomarkers of cardiovascular disease in order to better protect individuals from the onset of cardiovascular diseases.

C-reactive protein (CRP) is a sensitive marker of chronic inflammation and cardiovascular functioning in the body produced in the human liver that increases with age (3). Elevated levels of CRP are known to be a risk factor for the development of chronic diseases like diabetes, colorectal cancer and myocardial infarction (4, 5, 6). Certain behavioral attributes, including obesity, lack of physical activity and smoking, are associated with increased levels of CRP as well (5). In addition to the link between elevated CRP and unhealthy lifestyle behaviors, several genetic analyses have identified genomic patterns of risk for cell receptors that trigger CRP production in populations of African versus European descent (6,7).

Positive psychological wellbeing has consistently been associated with protective effects against CVD, suggesting that individuals who report high levels of mental health may also experience lower levels of CRP and inflammation (8). Researchers have identified the construct of optimism as having the most robust health effect in terms of reduced risk of cardiovascular event (8). Flourishing is a measure of emotional, social and psychological wellbeing that is defined as the presence of mental health versus the mere absence of mental illness. Flourishing scales positively correlate with multiple psychometric scales designed to assess positive psychological wellbeing, including positive affect, self-efficacy, satisfaction with life, coping, and sense of coherence (9). In a study of flourishing among people of different age groups in the United States, adults aged 45-74 were found to report higher levels of flourishing than adults who were below 45 years old (10).

This research will seek to investigate the cross-sectional effect of flourishing on levels of CRP, and the differing effects of flourishing on CRP for cohort members aged 20-39, 40-59 and 60 or older. The subjects in this study were obtained through the Predictive Health Institute and the Center for Health and Wellbeing, a collaborative cohort study of holistic health data on over 750 Southeastern subjects that has been collecting data annually since 2006. Flourishing was first assessed in 2009, thus these analyses will focus on cohort data collected during this year.

Purpose of Study

The purpose of this study is to examine the association of flourishing mental health with the inflammatory biomarker, CRP. Results from this study may be used to determine if higher levels of flourishing are associated with lower levels of CRP, and for which age groups the association is most pronounced. This will add to the body of literature on psychosocial predictors for cardiovascular health and inflammation, providing additional detail on the interaction of flourishing and age.

Objective and Research Questions

The objective of this research is to explore the association of flourishing with CRP levels, with particular interest in the interaction between flourishing and participant age. The research questions central to this analysis are:

1) Are higher levels of flourishing associated with lower levels of CRP?
2) Is the impact of flourishing on CRP stronger for older, compared to young or middle-aged adults?

Assumptions

Because of the self-reported nature of flourishing, this study requires the assumption that subjects in the cohort answered questions accurately and to the best of their ability. The study also assumes that participants fully understood the survey questions and had a literacy level appropriate for completion. Similar assumptions apply to all covariates that were self-reported through online surveys like measures of income, education, physical activity and smoking status. Lastly, the analysis assumes that laboratory testing for CRP was completed correctly and consistently to eliminate the potential for biased lab results.

Literature Review

This literature review will thoroughly explore the factors underlying the relationship between aging and mental health, further examining the potential for flourishing mental health to provide a protective effect towards cardiovascular events and chronic disease in the elderly. Because of the specific distribution of ages in this cohort, this review will primarily focus on psychosocial, behavioral and physical health differences between younger adults (20-39 years), middle-aged adults (40-59 years) and seniors (60 years or more) in order to better understand the relationship between flourishing and CRP levels.

Aging and Mental Health

Although elderly populations often experience a higher burden of disease and declining physical functioning, most aging individuals maintain a fairly high sense of subjective wellbeing despite adverse physical health. Lacruz and colleagues sought to identify predictors of "successful aging" in terms of bio-psychosocial mechanisms that maintain good mental health and adaptation to adversity in a 13-year follow-up study of 1,079 men and women aged 65 and older (11). The term, "successful aging," has many different definitions across the literature, including an absence of multiple morbidities, absence of mental health conditions, regular functioning and quality of life, presence of wellbeing, good self-perceptions of health, and optimal functioning (11).

Many other researchers have questioned the definitions and predictors of successful aging. Depp and Jeste identified quantitative studies of adults over 60 that included definitions of successful aging and found 28 studies with 29 different definitions, most of which concentrated on large samples of community-dwelling older adults (12). This study found that 26 of 29 definitions of successful aging included disability and physical functioning, with the most frequently significant correlates of successful aging being younger age, nonsmoking, and absence of a disability like arthritis or diabetes (12). Successful aging was also correlated with greater physical activity, more social connections, better self-rated health, absence of depression and cognitive impairment, and fewer medical conditions (12).

Various aspects of mental health, as well as the absence of mental illness, appear to have a positive impact on longevity and successful aging for older adults. MacLeod and colleagues studied the impact of high resilience among older adults and found associations with improved quality of life, happiness, wellbeing and reduced depression (13). They found additional positive outcomes of high resilience that included strong coping skills, optimism, positive emotions, a strong social support network and engagement in physical activity (13).

Positive Psychology

Positive psychology is an emerging field through which measures like flourishing have been developed. The intent of this recently developed field is to study positive subjective experience, positive individual traits and positive institutions in order to improve quality of life and prevent pathologies that arise with the subjective view that life has no meaning (14). Positive psychologists have added to the field of psychology by enhancing the understanding of how, why and under what conditions these positive experiences, traits and institutions flourish (15). The field as a whole strives to supplement a historical focus on treatment of psychological illness and disorder by focusing on a more holistic picture of the human experience – one that includes the predictors of happiness and health.

Flourishing

Flourishing indicates the presence of mental health versus the absence of mental illness. The concept of flourishing, created by Corey Keyes, was developed over the course of mounting evidence that measures of mental illness and mental health exist on two distinct continua instead of opposite ends of one continuum (16). According to Keyes' research, only a small proportion of those who are free of mental disorders are actually mentally healthy, or flourishing. Additionally, flourishing individuals who were free of mental disorder had higher levels of overall functioning when compared to individuals who were not flourishing and free of mental disorder, as measured by days of work missed and work productivity (16).

Using the longitudinal study of health and wellbeing, MIDUS (Midlife in the United States), the prevalence of five chronic physical conditions was stratified by flourishing status in addition to presence of absence of physician-diagnosed mental illness. This comparison revealed that the number of chronic physical conditions increased as the level of flourishing decreased, even after adjustment for variables like BMI, smoking status, and level of physical exercise (16). Individuals who were both languishing and had major depression (about 7% of the sample) had the largest average number of chronic conditions, whereas those who were flourishing with no mental illness (about 17% of the sample) had the lowest average (16).

Demographic Differences in Flourishing

There are documented demographic differences in flourishing. When age groups were compared, Keyes and colleagues found that rates of flourishing were highest among the oldest age groups in the MIDUS study, ages 45-54, 55-64 and 65-74 (10). Keyes also compared African American and Caucasian rates of flourishing, and found that African Americans had higher rates of flourishing than Caucasians, despite reporting higher rates of social inequality, discrimination and physical morbidity (17).

Cardiovascular Disease and Distribution

Heart disease is the foremost cause of death in the United States, killing nearly 610,000 people every year, with 735,000 heart attacks and 370,000 dying annually from coronary heart disease (18). In the United States, someone has a heart attack every 43 seconds and each minute an individual dies from a heart disease related event (19). Heart disease is the leading cause of death for adults 65 and older, and the second highest cause of death for adults 45-54 and 55-64 (20). By itself, coronary heart disease costs the United States $108.9 billion each year as a result of added health care services, medications and lost productivity (19).

Cardiovascular Biomarkers

For the last ten years, researchers have been searching for biomarkers to help predict the risk of heart disease, especially those that are highly accurate, easy to measure and that provide new predictive information. One of the most widely studied biomarkers is C-reactive protein (CRP). CRP is set of proteins made by the body when exposed to major infection or trauma that was discovered nearly 70 years ago by researchers investigating human inflammatory responses. CRP varies by genetics as well as lifestyle habits and higher CRP is typically associated with smoking, high blood pressure, excess body weight, and sedentary behaviors (21). Even though behavioral pathways account for a large portion of the variability in CRP, almost half of the variation is inherited and reflects family levels passed down through genes (21).

The most important use of CRP appears to be in primary prevention for high-risk individuals who do not yet know that they are at elevated risk for heart attack or stroke. At baseline levels, CRP is highly predictive of both future risk and recurring coronary events among patients who have already suffered from heart disease (21). In addition to cardiovascular disorders, CRP can also predict the risk of developing type 2 diabetes, since individuals who have CRP levels greater than 3 mg/L having a risk of diabetes four to six times greater than individuals with levels below one (21). Both of these chronic conditions are largely caused by inflammation as a result of excess fat around the stomach, or central obesity. In fact, it is the fat cells, or adipocytes, that produce the proteins that activate production of CRP (21).

There has been little evidence that lowering CRP will also lower cardiovascular risk, however, best practices for lowering CRP are the same for heart disease, including eating a healthy diet, exercising, controlling blood pressure and smoking cessation (22).

Statin drugs, like aspirin, are very effective at reducing the risk of first heart attack, and also reduce CRP levels in most patients as a part of their anti-inflammatory properties (22).

Several large cohort studies have confirmed the ability of baseline CRP level to predict myocardial infarction and stroke, especially when coupled with the predictive value of total and HDL cholesterol (5). Ridker et. al, studied CRP as a predictor for myocardial infarction in a cohort of 14,916 healthy men participating in the Physician's Health Study. Researchers found that models which incorporated baseline CRP and lipid parameters were significantly better at being able to predict risk than models that used lipids alone (5). Another study done by Ridker and colleagues looked at the predictive capabilities of CRP on risk of cardiovascular event in a cohort of 15,632 initially healthy U.S. women aged 45 and older, with follow-up after a 10-year period. This research found that high-sensitivity CRP added prognostic information beyond lipid measures after adjustment for obesity, diabetes, smoking, blood pressure and age (23).

Positive Psychological Wellbeing and Inflammation

Julia Boehm and colleagues have examined positive psychological wellbeing and cardiovascular events in work that focuses on the associations between emotional vitality, optimism and coronary heart disease (CHD) in a sample of 7,942 middle-aged men and women from the Whitehall II cohort (24). Boehm found that positive psychological wellbeing was associated with a consistent reduced risk of incident CHD that could not be explained by health-related behaviors or biological factors (24). In a meta-analysis of studies that focused on positive psychological wellbeing and cardiovascular health, Julia

Boehm and colleagues found that not all aspects of psychological wellbeing were associated with cardiovascular health, but that optimism was the construct most robustly associated with a reduced risk of cardiovascular events (8). This analysis also discussed the potential pathways through which positive psychological wellbeing might affect cardiovascular health, including the finding that positive psychological wellbeing was positively associated with restorative health behaviors (smoking cessation, physical activity, etc.) and biological functions (inflammatory and metabolic processes) and inversely associated with deleterious health behaviors and biological functions (8).

Several studies have examined constructs of positive psychological wellbeing in relation to their association with inflammatory markers like CRP. The Multi-Ethnic Study of Atherosclerosis (MESA), a cohort of 6,814 men and women aged 45-84, found that higher levels of positive disposition were related to lower levels of inflammatory markers like interleukin-6 (IL-6), fibrinogen and homocysteine (25). Additionally, researchers found that pessimism was significantly associated with higher levels of CRP, IL-6, fibrinogen and homocysteine (25). Rius-Ottenheim and colleagues studied 1,084 community-dwelling seniors (aged 60-85) and found that lower dispositional optimism was associated with increasing levels of CRP for participants that were obese (26).

Summary

This literature review provides an in-depth appraisal of both flourishing and CRP as affected by demographic characteristics, physical health, and behavioral pathways. The research available indicates that elderly populations display higher levels of CRP and prevalence of heart disease but alternatively, higher levels of flourishing and mental health. While the association between flourishing and CRP level has not yet been studied, research would suggest that constructs with overlapping measures, like positive affect, have positive correlations with successful aging and longevity for older adults. The three-factor construct of flourishing (including emotional, social and psychological wellbeing) may have important implications for increased positive psychological wellbeing, and in turn, lowered measures of inflammation like CRP that affect future risk of chronic disease.

Methods

Target Population and Sample Population

The following analyses were conducted using data collected by the Predictive Health Institute (PHI) through their Center for Health Discovery and Wellbeing (CHDWB) as a part of a collaborative cohort study initiated in 2006 by Emory University and the Georgia Institute of Technology in Atlanta, Georgia. Their primary objective in building this cohort was to describe health in social, cultural and biological terms, and to use these tools to understand and predict deviations from health and overall health prognosis (27).

The sample was drawn from the employees of the university and academic health center who were employed for at least two years and covered by the university-sponsored health insurance plan (N=6464) (28). Every tenth employee on an alphabetical list was invited by email to participate in the study. Of those invited, approximately 30% agreed to be screened by telephone, and 10% of those were enrolled based on the inclusion and exclusion criteria (28). Inclusion criteria for the study required that subjects be greater than 18 years of age, and have no history in the past year of: hospitalization due to acute or chronic disease, Axis I psychosocial disorder, significant changes in a chronic disease condition requiring new medication, substance abuse, or alcoholism (29). Participants were excluded if they were unable to give consent, if they had active, malignant neoplasms or a history of malignancies during the past five years, acute illness in the two weeks before baseline studies, or the inability to undergo study assessments over the course of follow-up (28).

Procedure

The University Institutional Review Board approved all protocols for this study. All subjects who agreed to participate in the study were asked to commit to five years of follow-up visits with an assessment at baseline and 6 months, with annual visits thereafter (28). All subject participants were required to provide informed consent via email after the telephone screening and signed a consent form at the first visit allowing investigators to perform all of the assessments and measurements necessary (29).

The cohort contains data on over 750 employees from the university and academic health centers who, each year, completed in-person medical testing and a range of self-reported online surveys including demographic, psychosocial and self-reported health measures. Examples of the online data elements included personal health history, tobacco and alcohol use, medication use, food intake, measures of stress, anxiety, depression, spirituality, social support and sleep quality. The in-person assessments included treadmill testing, body composition and bone density testing, measures of cardiovascular function and risk, blood chemistry and hormone profiles. Laboratory tests were also conducted to measure biomarkers like regenerative cell potential, oxidative stress and inflammation (27).

Measures

The cross-sectional cohort data used for these analyses were obtained from the year 2009, the first year that the flourishing measure was incorporated by PHI investigators. These data include values for flourishing, age, gender, race, income and education, BMI, physical activity, smoking status and the Beck Depression Inventory (BDI).

Mental Health Continuum-Short Form

The MHC-SF was used to measure flourishing mental health, the primary exposure of interest. This survey was derived from the long-form (MHC-LF), consisting of seven items that measure emotional wellbeing, 18 items that measure psychological wellbeing, and 15 items that measure social wellbeing (30). The MHC-SF consists of a total of 14 items that represent the most central constructs for each sector of wellbeing. Three items investigate questions of emotional wellbeing, six items investigate psychological wellbeing and five items investigate the social wellbeing domain. The MHC-SF has shown excellent internal consistency and discriminant validity in adults in the United States, the Netherlands and South Africa, and the three-factor structure of the survey has been confirmed in population-based samples both internationally and domestically (30).

The MHC-SF was assessed using a Likert scale, asking participants to report how often they experience each statement (i.e. how often do you feel happy, interested in life, etc.). There are six possible response options ranging from never to every day, with each response receiving a numeric score from zero to five. Lower scores indicate a lower frequency of each experience and higher scores indicating a higher frequency of each experience.

For these analyses, continuous MHC-SF scores were calculated for each individual instead of using flourishing, moderate and languishing categorizations because of the skewed nature of the cohort towards flourishing categorizations and high scores on the MHC-SF. To calculate each participant's continuous MHC-SF score, each response was given a numeric value from zero to five and added cumulatively for a total possible range of 0-70. The continuous scores were also split into tertiles (7-50, 51-59, and 60-70) of three equal groups in the distribution of MHC-SF total scores in order to examine differences in CRP and covariates by equal groupings of MHC-SF score.

Beck Depression Inventory

These analyses use the Beck Depression Inventory (BDI) to measure the level of depressive symptoms present for each participant (31). These symptoms and attitudes included qualities like mood, pessimism, sense of failure, lack of satisfaction, guilt feelings, sense of punishment, self-dislike, self-accusation, suicidal wishes, crying, irritability, social withdrawal and more (31). In this cohort, the scale was self-administered and results are divided into four categories by total score, with less than 10 points indicating minimal depression, 10-18 indicating mild depression, 19-29 indicating moderate depression and 30-63 indicating severe depression (31). These scores were calculated by summing the item ratings (0-3 in terms of intensity of feeling) given to each of the 21 items.

Demographics

Information on age, gender, race/ethnicity, income and education was self-reported by participants. Age and education were used as categorical variables, with age group cut-points occurring at ages 20-39, 40-59, and 60 or older. Education was divided into those who had attained a college degree or more (16 or more years of education reported) versus those who had not (less than 16 years of education reported). Gender was categorized as male or female, and race/ethnicity was split into groups of Caucasian, non-Hispanic versus African American, non-Hispanic. Income was defined by annual income per family before taxes and was classified into four different groups, less than $50,000, $50,000 to $99,000, $100,000 to $199,999 and $200,000 or more.

Body Mass Index

Individual body mass index (BMI) was measured during in-person visits using the Tanita Body Composition Analyzer, which includes full-body and segmental analysis models that are within 5% of the gold standard measurement tool for BMI, the Dual-energy X-ray absorptiometry (28). In these analyses, individuals were grouped by standard BMI categorization values, meaning underweight participants had a BMI under 18.5, normal weight was in between 18.5 and below 25, and those over 25 were defined as overweight (28).

Physical Activity

Physical activity was a self-reported measure of whether or not the participant met CDC guidelines for weekly vigorous activity, defined as one hour and fifteen minutes of high intensity aerobic activity (i.e. jogging or running) every week (32). Participants were coded as reporting that they met this guideline or that they did not meet this guideline.

Smoking Status

Smoking status among cohort participants was classified as ever having smoked tobacco or never having smoked tobacco. Because of the small number of cohort members who reported smoking daily, life course tobacco use was also assessed. Participants were categorized as ever having used tobacco, or never having used tobacco.

C-Reactive Protein

C-reactive protein was measured during standard blood tests by a high-sensitivity C-reactive protein test (hs-CRP) or an ultra-sensitive C-reactive protein test (us-CRP). High levels of CRP indicate that an inflammatory process is occurring in the body, which can act as an alert for other health problems like kidney failure or infection (5). Providers generally agree that numeric values of CRP less than one indicate low risk for chronic disease or infection, with values between one and three indicating moderate risk and values over three indicating high risk (5). In this cohort, CRP was assigned a numeric value above zero based on results from the hs-CRP test. Because the cohort CRP values were heavily right-skewed, CRP values were log-transformed in order to restore normality. The variable was analyzed continuously in all analyses for this study.

Data Analysis

All data were entered using RedCAP and exported into password-encrypted SAS, SPSS and Excel files. SAS Version 9.4 was used for all secondary data cleaning and analyses completed in this study. Exploratory analyses were conducted for all variables of interest in order to check for normality, outliers and missing values. Subjects who had not completed the MHC-SF or did not have a measurement for CRP were excluded from the study, resulting in a cohort of 694 participants for analysis.

Univariate analyses were conducted for the MHC-SF, CRP and each of the covariates to determine the frequency of each categorical variable (age, education, income, gender, BMI, physical activity, smoking status and depression) as well as the distribution of all continuous variables (MHC-SF and CRP). Bivariate associations were then calculated by examining chi-square values between groups of CRP (split into two groups by median value of cohort distribution) and MHC-SF (median split by cohort distribution), as well as all study covariates. Multivariable linear regression was performed in order to analyze crude and adjusted associations of MHC-SF and CRP. Demographic covariates were added to the models first, followed by physical and behavioral health variables (BMI, physical activity, smoking status), as well as depressive symptoms. An interaction term between MHC-SF and age was added in order to test for effect modification in the relationship between flourishing and CRP levels. Because the interaction between flourishing and age was a significant interaction term, the final linear regression models were stratified by age group.

Results

As seen in Table 1, the sample for this study contained 694 participants in the 2009 cohort, and among these, 450 had a recorded measurement for CRP. Out of the total number of cohort members, 65.3% were female, 71.5% were Caucasian, non-Hispanic and 22.6% were African American, non-Hispanic. Most participants were highly educated, with 82.1% reporting a college degree or more (16 or more years of education). In addition, 37.5% of the sample made less than $50,000 in annual family income before taxes, 34% made between $50,000 and $99,999, and 22.5% made $100,000 or more.

Demographic characteristics differed moderately by age group (Table 1). The youngest portion of the cohort (ages 20-39) contained more variation with respect to demographic characteristics, on average, than the middle-aged (40-59) and senior age groups (60+). Younger cohort members were comprised of 64.3% females, 62.5% Caucasian participants, 73.2% having attained a college degree or more, and 75% making less than $50,000 per year in total family income before taxes. The middle-aged sample, on average, had more women than men (70.5% and 29.5%, respectively), 66.1% Caucasian subjects, had completed more years of education (83.2% had a college degree or more) and had a higher annual income before taxes (only 40.3% made less than $50,000 per year). The oldest group was made up of 58.6% female participants and 81% Caucasian subjects. They had a similar education distribution to the middle-aged group, with 82.5% attaining a college degree or more, and a slightly more wealthy income distribution, with only 32.7% of members making less than $50,000 annually.

The sample was primarily overweight and obese, with 65.2% having a BMI of 25 or greater and categorized as overweight (50.9% for younger adults, 65.5% for middle-aged adults and 67.7% for seniors). There were 24.4% (41.1% of young adults, 25.2% for middle-aged adults and 19.8% for seniors) of participants who met the recommendations for vigorous activity set forth by the CDC and 5.6% of the cohort who reported ever using tobacco (similar distribution for all age groups). Five percent of the overall baseline sample had values of CRP that put them at moderate to high risk for chronic disease or a cardiovascular event (CRP of one or more), with 6.9% at higher risk among younger adults, 11.3% at higher risk for middle-aged adults and 2.9% at higher risk for seniors (Table 1).

On average, cohort participants reported high scores on the flourishing scale, with over two-thirds of the sample reporting 51 points out of a possible 70. Oldest adults had the largest proportion of participants with high scores, with 39.2% reporting scores in the range of 60-70 points. Middle-aged adults and younger adults had 29.5% and 21.5% that scored in the highest tertile, respectively (Table 1). Most of the sample scored quite low on the Beck Depression Inventory, with 79.2% reporting minimum depression overall. Among the various age groups, younger adults fared the worst, with a 10.7% prevalence of moderate to severe depression. Middle-aged and senior adults had a 3.6% and 3.0% prevalence of moderate to severe depression, respectively.

Bivariate analyses were conducted to analyze significant differences in CRP based on demographic and psychosocial characteristics of the cohort (Table 2). Based on these unadjusted results, there appeared to be significant ($p < 0.05$) differences in the higher half of CRP values versus the lower half of CRP values (median split) based on gender, race/ethnicity, education, income, BMI and physical activity status (Table 2). There were significant ($p < 0.05$) differences between the higher half of flourishing scores versus the lower half of flourishing scores (median split) based on age group, race/ethnicity, income group, and category of BDI (Table 3).

Multivariable linear regression models were stratified by each age group, 20-39 years, 40-59 years and 60 years or more. For participants ages 20-39, flourishing was not significantly associated with CRP level in crude or adjusted models. Similar findings were observed in middle-aged participants. However, for the oldest participants in the study, higher levels of flourishing were associated with lower levels of CRP at the 90% confidence level without adjustment for covariates. When adjusted for education, gender, race and income, higher levels of flourishing were significantly associated with lower levels of CRP at the 95% confidence level. When BMI, physical activity and smoking status were added to linear regression models, the association between higher levels of flourishing and lower levels of CRP remained significant at the 90% confidence level, and also remained when models controlled for depressive symptoms. According to these results, higher levels of flourishing are most significantly associated with lower levels CRP for the oldest age group, even when adjusted for demographics, BMI, physical activity, smoking status and depressive symptoms. For those 60 years and older, higher CRP was significantly associated with being a woman and/or having a higher BMI.

Discussion

These analyses examined the association between flourishing and CRP level, a measure of bodily inflammation that helps to predict cardiovascular risk. Results from this study support the notion that flourishing provides a protective effect on CRP levels for participants that are 60 years old and older, but not for participants that are 20-39 years old, or 40-59 years old. Higher levels of flourishing were significantly associated with lower levels of CRP for adults 60 years or older, even when adjusted for education, income, race and gender. The association was slightly diminished when biological and behavioral health variables are introduced, which indicates that BMI, physical activity and smoking status are important predictors of CRP that may be on the causal pathway between flourishing and CRP.

Existing literature establishes that individuals over 60 are more likely to have both increased levels of CRP and increased levels of flourishing (5, 10). Although the relationship between flourishing and inflammation has not been studied extensively, previous literature cites that components of flourishing (like positive affect) are consistently associated with protective effects on cardiovascular health and inflammatory biomarkers (33, 34, 35). In elderly populations, the relationship between mental health (as measured by constructs like positive affect, purpose in life, etc.) and physical health appears to hold more weight (36).

These results suggest that CRP is more strongly impacted by flourishing level in adults over 60, even when adjusted for other demographic characteristics like education, income, race and gender. The concept of socio-emotional selectivity may be helpful in explaining why adults over 60 have higher rates of flourishing and receive a significant protective effect from flourishing on levels of CRP. In the socioemotional selectivity theory, there are two social motives, relating to the acquisition of knowledge and the regulation of emotion (36). When time is perceived as limited (when adults age), emotional goals take priority over knowledge acquisition, meaning that there are notable differences in social goals as individuals age (36). Older individuals may experience a greater degree of positive emotion, purpose in life, and overall positive psychological wellbeing that increases the importance of flourishing on indicators of physical health and inflammatory markers like CRP.

Strengths and Limitations

A key strength of this analysis is the ability to investigate associations between psychosocial and biological indicators of health. The MHC-SF, a tool used to measure flourishing, has not been extensively researched as a predictor for physical and behavioral pathways. This study adds significant findings to a small body of literature linking the potential protective effects of flourishing mental health to physical health outcomes. In addition, this study uses participant demographics to differentiate between those who may benefit most from flourishing mental health in order to appropriately target and develop interventions focusing on risk of cardiovascular and chronic disease.

Limitations of this study include the narrow level of variation found in the cohort demographically. Because the cohort was primarily Caucasian, highly educated, had high incomes, and were reasonably healthy, it was difficult to see associations between flourishing and CRP for different subgroups of participants. In addition, because the cohort was drawn from a working population, the association between flourishing and

CRP levels seen in the senior population may have been affected by a "healthy worker effect," meaning that those individuals who have been able to stay in the workforce past the age of 60 were particularly physically and mentally healthy. In order to remedy this issue, future studies should consider analyzing these associations in a more representative, population-based sample.

Future Research

Further examination of the association between flourishing and CRP should use longitudinal data in order to establish the temporality of the relationship between flourishing and CRP. It would also be useful to analyze baseline levels of flourishing and their effect on individual trajectories of CRP levels over time in order to establish directionality between the exposure and outcome of interest. Additionally, future studies could consider controlling for additional factors related to CRP levels, such as statin medication use, oral contraceptive use, or behavioral pathways like alcohol use and nutrition.

Conclusions

Among separate age groups in this cohort, significant associations between higher levels of flourishing and lower levels of CRP occur only for the group of participants that is 60 years or older. This relationship indicates that it may be more important, with declining physical health and functioning, for older adults to prioritize mental wellbeing in order to prevent unnecessary upswings in the body's inflammatory pathways, ultimately preventing chronic disease and cardiovascular disorder. Future research needs to examine this relationship longitudinally in order to establish temporality and directionality in the association between flourishing and CRP for aging adults.

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Appendix

Table 1. Demographic, positive psychology and cardiovascular health characteristics among all participants, 2009 (n=694).

Characteristic	n (%)
Gender	
Female	453 (65.3)
Male	240 (34.6)
Age	
20-39	56 (8.1)
40-59	369 (53.2)
60 +	268 (38.7)
Race/Ethnicity	
White non-Hispanic	496 (71.5)
Black non-Hispanic	157 (22.6)
Other	40 (5.8)
Education	
Less than College	124 (17.9)
College Degree or More	569 (82.1)
Income	
< $50,000	260 (37.5)
$50,000 - $99,999	236 (34.0)
$100,000 - $199,999	71 (10.2)
$200,000 or more	85 (12.3)
Mental Health Continuum	
Lowest Tertile (7-50)	234 (33.7)
Middle Tertile (51-59)	234 (33.7)
Highest Tertile (60-70)	226 (32.6)
Beck Depression Inventory	
Minimum Depression (0-9)	549 (79.2)
Mild Depression (10-18)	117 (16.9)
Moderate Depression (19-29)	25 (3.6)
Severe Depression (30-63)	2 (0.3)
Body Mass Index	
<18.5	10 (1.5)
18.5 - 24.9	230 (33.4)
25+	449 (65.2)

Physical Activity	
Meets Guideline	169 (24.4)
Does Not	524 (75.6)
Ever Smoked Tobacco	
Yes	39 (5.6)
No	652 (94.0)
C-reactive Protein	
1+	35 (5.0)
< 1	415 (59.8)

Table 1a. Demographic, positive psychology and cardiovascular health characteristics among subjects 20-39 years old (n = 56).

Characteristic	n (%)
Gender	
Female	36 (64.3)
Male	20 (35.7)
Race/Ethnicity	
White non-Hispanic	35 (62.5)
Black non-Hispanic	14 (25.0)
Other	7 (12.5)
Education	
Less than College	15 (26.8)
College Degree or More	41 (73.2)
Income	
< $50,000	36 (75.0)
$50,000 - $99,999	8 (16.7)
$100,000 - $199,999	1 (2.1)
$200,000 or more	3 (6.3)
Mental Health Continuum	
Lowest Tertile (7-50)	28 (50.0)
Middle Tertile (51-59)	16 (28.6)
Highest Tertile (60-70)	12 (21.4)
Beck Depression Inventory	
Minimum Depression (0-9)	39 (69.6)
Mild Depression (10-18)	11 (19.6)
Moderate Depression (19-29)	5 (8.9)
Severe Depression (30-63)	1 (1.8)
Body Mass Index	
< 18.5	3 (5.5)
18.5 - 24.9	24 (43.6)

25+	28 (50.9)
Physical Activity	
Meets Guideline	23 (41.1)
Does Not	33 (58.9)
Ever Smoked Tobacco	
Yes	3 (5.4)
No	53 (94.6)
C-Reactive Protein	
Moderate to High Risk (1+)	2 (6.9)
Low Risk (< 1)	27 (93.1)

Table 1b. Demographic, positive psychology and cardiovascular health characteristics among subjects 40-59 years old (n = 369).

Characteristic	n (%)
Gender	
Female	260 (70.5)
Male	109 (29.5)
Race/Ethnicity	
White non-Hispanic	244 (66.1)
Black non-Hispanic	104 (28.2)
Other	21 (5.7)
Education	
Less than College	62 (16.8)
College Degree or More	307 (83.2)
Income	
< $50,000	141 (40.3)
$50,000 - $99,999	131 (37.4)
$100,000 - $199,999	39 (11.1)
$200,000 or more	39 (11.1)
Mental Health Continuum	
Lowest Tertile (7-50)	125 (33.9)
Middle Tertile (51-59)	135 (36.6)
Highest Tertile (60-70)	109 (29.5)
Beck Depression Inventory	
Minimum Depression (0-9)	292 (79.1)
Mild Depression (10-18)	64 (17.3)
Moderate Depression (19-29)	12 (3.3)
Severe Depression (30-63)	1 (0.3)
Body Mass Index	
<18.5	3 (0.8)

18.5 - 24.9	124 (33.7)
25+	241 (65.5)
Physical Activity	
Meets Guideline	93 (25.2)
Does Not	276 (74.8)
Ever Smoked Tobacco	
Yes	21 (5.7)
No	346 (94.3)
C-Reactive Protein	
Moderate to High Risk (1+)	28 (11.3)
Low Risk (< 1)	220 (88.7)

Table 1c. Demographic, positive psychology and cardiovascular health characteristics among subjects 60 years old or more (n = 268).

Characteristic	n (%)
Gender	
Female	157 (58.6)
Male	111 (41.4)
Race/Ethnicity	
White non-Hispanic	217 (81.0)
Black non-Hispanic	39 (14.6)
Other	12 (4.5)
Education	
Less than College	47 (17.5)
College Degree or More	221 (82.5)
Income	
< $50,000	83 (32.7)
$50,000 - $99,999	97 (38.2)
$100,000 - $199,999	31 (12.2)
$200,000 or more	43 (16.9)
Mental Health Continuum	
Lowest Tertile (7-50)	80 (29.9)
Middle Tertile (51-59)	83 (31.0)
Highest Tertile (60-70)	105 (39.2)
Beck Depression Inventory	
Minimum Depression (0-9)	218 (81.3)
Mild Depression (10-18)	42 (15.7)
Moderate Depression (19-29)	8 (3.0)
Severe Depression (30-63)	0 (0.0)
Body Mass Index	

< 18.5	4 (1.5)
18.5 - 24.9	82 (30.8)
25+	180 (67.7)
Physical Activity	
Meets Guideline	53 (19.8)
Does Not	215 (80.2)
Ever Smoked Tobacco	
Yes	15 (5.6)
No	253 (94.4)
C-Reactive Protein	
Moderate to High Risk (1+)	5 (2.9)
Low Risk (< 1)	168 (97.1)

Table 2. Differences in CRP by demographic and psychosocial characteristics among all participants with CRP measurement, 2009 (n= 450).

Characteristic	C-reactive Protein[1] < 0.26 (%)	≥ 0.26 (%)	Chi-Square	Effect Size (Phi/Cramer's V)
Total Sample	229 (50.9)	221 (49.1)		
Gender				
Female	138 (43.3)	181 (56.7)	$\chi^2 = 25.52$, $p < 0.0001$	$\varphi = 0.2381$
Male	91 (69.5)	40 (30.5)		
Age				
20-39 years	15 (51.7)	14 (48.3)	$\chi^2 = 3.98$, $p = 0.1365$	$V= 0.0941$
40-59 years	116 (46.8)	132 (53.2)		
60-79 years	98 (56.7)	75 (43.4)		
Race/Ethnicity				
White, Non-Hispanic	174 (56.1)	136 (43.9)	$\chi2 = 13.3$, $p = 0.0003$	$\varphi = 0.1750$
Black, Non-Hispanic	46 (36.8)	79 (63.2)		
Education[2]				
Less than College	37 (39.8)	56 (60.2)	$\chi^2 = 5.78$, $p = 0.0162$	$\varphi = 0.1134$
College or More	192 (53.8)	165 (46.2)		
Income				
< $50,000	82 (43.6)	106 (56.4)	$\chi2 = 8.34$, $p = 0.0395$	$V= 0.1391$
$50,000 - $99,999	80 (53.0)	71 (47.0)		
$100,000 - $199,999	27 (57.5)	20 (42.6)		
$200,000 or more	29 (64.4)	16 (35.6)		
Body Mass Index				
Underweight (< 18.5)	2 (100.0)	0 (0.0)	$\chi^2 = 23.36$, $p < 0.0001$	V= 0.2286
Normal Weight (18.5-24.9)	72 (70.6)	30 (29.4)		
Overweight (≥ 25)	153 (44.5)	191 (55.5)		

Physical Activity[3]				
Meets Guideline	60 (63.2)	35 (36.8)	$\chi^2 = 7.25$, $p = 0.0071$	$\varphi = 0.1270$
Does Not Meet Guideline	169 (47.6)	186 (52.4)		
Tobacco Use				
Never Used Tobacco	218 (51.9)	202 (48.1)	$\chi^2 = 2.11$, $p = 0.1459$	$\varphi = 0.0687$
Ever Used Tobacco	11 (37.9)	18 (62.1)		
Mental Health Continuum				
Lower Tertile (7-50)	79 (51.0)	76 (49.0)	$\chi 2 = 3.29$, $p = 0.1934$	$V = 0.0855$
Middle Tertile (51-59)	69 (45.7)	82 (54.3)		
Highest Tertile (60-70)	81 (56.3)	63 (43.8)		
Beck Depression Inventory				
Minimum Depression (0-9)	183 (51.8)	170 (48.2)	$\chi 2 = 2.01$, $p = 0.1562$	$V = 0.0949$
Mild Depression (10-18)	41 (51.3)	39 (48.8)		
High Depression (19-29)	5 (33.3)	10 (66.7)		
Severe Depression (30-63)	0 (0.0)	2 (100.0)		

[1] CRP split by median values in the baseline population

[2] Education measured by years of education, with < 16 years considered less than college, and 16+ years considered college or more

[3] Physical activity guidelines measured as meeting the guidelines for vigorous activity recommended by the CDC

Table 3. Differences in flourishing by demographic and psychosocial characteristics among all participants with MHC-SF scores, 2009 (n=694).

Characteristic	Mental Health Continuum[1] < 55 (%)	≥ 55 (%)	Chi-Square	Effect Size (Phi/Cramer's V)
Total Sample	325 (46.8)	369 (53.2)		
Gender				
Female	217 (47.9)	236 (52.1)	$\chi^2 = 0.6944$, $p = 0.4047$	$\varphi = 0.0317$
Male	107 (44.6)	133 (55.4)		
Age				
20-39 years	35 (62.5)	21 (37.5)	$\chi^2 = 9.54$, $p = 0.0085$	$V = 0.1173$
40-59 years	179 (48.5)	190 (51.5)		
60-79 years	110 (41.0)	158 (59.0)		
Race/Ethnicity				
White, Non-Hispanic	246 (49.6)	250 (50.4)	$\chi 2 = 6.20$, $p = 0.0128$	$\varphi = 0.0975$
Black, Non-Hispanic	60 (38.2)	97 (61.8)		
Education[2]				
Less than College	60 (48.4)	64 (51.6)	$\chi^2 = 0.1619$, $p = 0.6874$	$\varphi = 0.0153$
College or More	264 (46.4)	305 (53.6)		
Income				

< $50,000	138 (53.1)	122 (46.9)	$\chi2 = 17.23$, $p = 0.0006$	*V*= 0.1626
$50,000 - $99,999	115 (48.7)	121 (51.3)		
$100,000 - $199,999	29 (40.9)	42 (59.2)		
$200,000 or more	24 (28.2)	61 (71.8)		
Body Mass Index				
Underweight (< 18.5)	6 (60.0)	4 (40.0)	$\chi^2 = 1.03$, $p = 0.3091$	V= 0.0429
Normal Weight (18.5-24.9)	112 (48.7)	118 (51.3)		
Overweight (≥ 25)	205 (45.7)	244 (54.3)		
Physical Activity[3]				
Meets Guideline	70 (41.4)	99 (58.6)	$\chi^2 = 2.55$, $p = 0.1100$	φ = 0.0607
Does Not Meet Guideline	254 (48.5)	270 (51.5)		
Tobacco Use				
Never Used Tobacco	300 (46.0)	352 (54.0)	$\chi^2 = 2.48$, $p = 0.1150$	φ = 0.0600
Ever Used Tobacco	23 (59.0)	16 (41.0)		
C-reactive Protein				
< 1	104 (45.4)	125 (54.6)	$\chi2 = 1.04$, $p = 0.3070$	φ = 0.0482
≥ 1	111 (50.2)	110 (49.8)		
Beck Depression Inventory				
Minimum Depression (0-9)	205 (37.3)	344 (62.7)	$\chi2 = 91.42$, $p < 0.0001$	*V*= 0.3732
Mild Depression (10-18)	93 (79.5)	24 (20.5)		
High Depression (19-29)	24 (96.0)	1 (4.0)		
Severe Depression (30-63)	2 (100.0)	0 (0.0)		

[1] MHC-SF split by median values in the population

[2] Education measured by years of education, with < 16 years considered less than college, and 16+ years considered college or more

[3] Physical activity guidelines measured as meeting the guidelines for vigorous activity recommended by the CDC

Table 5a. Results of linear regressions for participants 20-39 years

	Model 1	Model 2	Model 3	Model 4
Characteristic	Beta (p-value)	Beta (p-value)	Beta (p-value)	Beta (p-value)
Intercept	-2.0661 (0.0003)	-2.3086 (0.0002)	-1.0119 (0.3968)	-2.1605 (0.1022)
MHC-SF Score	0.0163 (0.1055)	0.0150 (0.1392)	0.0081 (0.4656)	0.0222 (0.0980)
Education		0.4723 (0.1847)	0.5706 (0.1157)	0.4130 (0.2329)
Gender		0.2854 (0.4091)	-0.0110 (0.9766)	0.1482 (0.6828)
Race		0.2534 (0.4191)	0.3980 (0.2456)	0.2620 (0.4224)
Income		-0.1854 (0.3299)	-0.2493 (0.2201)	-0.1656 (0.3931)
Body Mass Index			-0.1938 (0.5196)	-0.1357 (0.6316)
Physical Activity			-0.7133 (0.0856)	-0.4457 (0.2734)

Smoking Status			0.3052 (0.6165)	0.1636 (0.7759)
Depression				0.4346 (0.0772)

Table 5b. Results of linear regressions for participants 40-59 years

	Model 1	Model 2	Model 3	Model 4
Characteristic	Beta (p-value)	Beta (p-value)	Beta (p-value)	Beta (p-value)
Intercept	-0.8954 (0.0004)	-0.8540 (0.0012)	-2.3466 (< .0001)	-2.1756 (< .0001)
MHC-SF Score	-0.0052 (0.2632)	-0.0053 (0.2673)	-0.0038 (0.4133)	-0.0073 (0.1694)
Education		-0.0156 (0.9157)	-0.0417 (0.7707)	-0.0337 (0.8139)
Gender		-0.5024 (0.0002)	-0.5427 (< .0001)	-0.5505 (< .0001)
Race		0.3482 (0.0086)	0.2630 (0.0448)	0.2462 (0.0607)
Income		-0.0416 (0.5322)	-0.0247 (0.7004)	-0.257 (0.6889)
Body Mass Index			0.4248 (0.0009)	0.4440 (0.0006)
Physical Activity			0.3444 (0.0058)	0.3518 (0.0048)
Smoking Status			0.2631 (0.2686)	0.2725 (0.2514)
Depression				-0.1571 (0.1795)

Table 5c. Results of linear regressions for participants 60 years and older

	Model 1	Model 2	Model 3	Model 4
Characteristic	Beta (p-value)	Beta (p-value)	Beta (p-value)	Beta (p-value)
Intercept	-0.8745 (0.0012)	-0.7377 (0.0059)	-2.1174 (< .0001)	-2.0998 (< .0001)
MHC-SF Score	-0.0084 (0.0830)	-0.0105 (0.0352)	-0.0085 (0.0783)	-0.0089 (0.0936)
Education		0.0115 (0.3852)	0.0696 (0.5910)	-0.0711 (0.5851)
Gender		-0.2418 (0.0305)	-0.3605 (0.0015)	-0.3618 (0.0016)
Race		0.2658 (0.0751)	0.2129 (0.1467)	0.2116 (0.1512)
Income		-0.0081 (0.8876)	0.0002 (0.9971)	-0.00003 (0.9996)
Body Mass Index			0.4819 (0.0002)	0.4835 (0.0002)
Physical Activity			-0.0738 (0.5998)	-0.0725 (0.6079)
Smoking Status			0.3342 (0.0687)	0.3343 (0.0695)
Depression				-0.0168 (0.8711)