2013

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Recommended Citation
Boehm, Julia K., et al. (2013). "The Association between Optimism and Serum Antioxidants in the Midlife in the United States Study." *Psychosomatic medicine* 75(1), 2-10. DOI: 10.1097/PSY.0b013e31827c08a9

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Comments
This is a pre-copy-editing, author-produced PDF of an article accepted for publication in *Psychosomatic Medicine*, volume 75, issue 1, 2013 following peer review. The definitive publisher-authenticated version is available online at DOI:10.1097/PSY.0b013e31827c08a9.

Published in final edited form as:
Psychosom Med. 2013 January ; 75(1): 2–10. doi:10.1097/PSY.0b013e31827c08a9.

The Association between Optimism and Serum Antioxidants in the Midlife in the United States Study

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Abstract

Objective—Psychological and physical health are often conceptualized as the absence of disease, but less research addresses positive psychological and physical functioning. For example, optimism has been linked with reduced disease risk and biological dysfunction, but very little research has examined associations with markers of healthy biological functioning. Thus, we investigated the association between two indicators of positive health: optimism and serum antioxidants.

Methods—The cross-sectional association between optimism and antioxidant concentrations was examined in 982 men and women from the Midlife in the United States study. Primary measures included self-reported optimism (assessed with the revised Life Orientation Test) and serum concentrations of nine different antioxidants (carotenoids and Vitamin E). Regression analyses examined the relationship between optimism and antioxidant concentrations in models adjusted for demographics, health status, and health behaviors.

Results—For every standard deviation increase in optimism, carotenoid concentrations increased by 3–13% in age-adjusted models. Controlling for demographic characteristics and health status attenuated this association. Fruit and vegetable consumption and smoking status were identified as potential pathways underlying the association between optimism and serum carotenoids. Optimism was not significantly associated with Vitamin E.

Conclusions—Optimism was associated with greater carotenoid concentrations and this association was partially explained by diet and smoking status. The direction of effects cannot be conclusively determined. Effects may be bidirectional given that optimists are likely to engage in

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health behaviors associated with more serum antioxidants, and more serum antioxidants are likely associated with better physical health that enhances optimism.

Keywords

optimism; antioxidants; carotenoids; vitamin E

INTRODUCTION

Although the World Health Organization defines health as "a state of… well-being and not merely the absence of disease or infirmity" (1), most empirical research has characterized both psychological and physical health in terms of the presence or absence of disease. For example, psychological health has typically been assessed with indicators such as depression and anxiety while physical health has been assessed with indicators such as hypertension and cardiovascular disease. However, health can only be understood comprehensively if the full spectrum of human functioning is considered. Therefore, characterizations of health need to include markers of enhanced psychological and biological processes that indicate the presence of well-being, rather than only its absence. Indeed, researchers are increasingly recognizing that psychological well-being (including constructs like optimism, happiness, and life purpose) is not the direct opposite of psychological ill-being, and that psychological well-being may have unique effects separate from psychological ill-being (2, 3). Thus far, research that defines physical well-being in terms of positive biological functioning remains scarce.

Antioxidants such as carotenoids (e.g., β-carotene) and vitamin E (e.g., α-tocopherol) constitute well-recognized markers of biological health. Antioxidants help to inhibit other molecules from oxidizing or producing free radicals that damage cells and contribute to disease pathophysiology (4). Dietary antioxidants are often assessed through self-reported inventories of food consumption, and have been linked with reduced risk of cardiovascular disease (5, 6). Objectively assessed serum antioxidants are also inversely associated with inflammation, atherosclerosis, diabetes, hypertension, coronary heart disease, and cancer (7–12). Although a substantial amount of work has examined how diet is associated with psychosocial factors (e.g., 13, 14, 15), less work has considered the association between serum antioxidants and psychosocial factors. To date, inverse associations have been reported for serum antioxidants and psychosocial factors such as socioeconomic status (16–18), poor cognitive function (19), depression (20, 21), hostility (22), and job stress (23). However, no empirical research has investigated the association between psychological well-being and serum antioxidants.

Therefore, we investigated the cross-sectional association between optimism – an indicator of adaptive psychological functioning characterized by positive expectations for the future (24) – and serum carotenoids and Vitamin E. We hypothesized that more optimistic individuals within a sample of aging adults would have greater concentrations of antioxidants than less optimistic individuals. We also investigated whether the association between optimism and antioxidant status was altered by potential confounders (i.e., demographic characteristics and health status). In addition, because of the strong link between antioxidant status and health behaviors such as fruit and vegetable consumption (19, 25, 26) and multivitamin supplementation (27), we separately examined whether health behaviors play a role in the pathway linking optimism and antioxidant concentrations.

METHODS

Participants

Participants were men and women drawn from the Midlife in the United States (MIDUS) study, initiated to understand a range of factors that influence the mental and physical health of Americans as they age. The first phase of MIDUS took place in 1994–1995 and comprised a national sample of 7,108 individuals aged 25 to 74. Participants were recruited via random digit dialing and included siblings and twin pairs for some individuals (28).

A second phase of MIDUS began 9–10 years later (2004–2005) and involved five distinct projects (psychosocial assessment, daily diary study, cognitive function assessment, biomarker assessment, and neuroscience assessment). The current investigation included a subset of participants from Phase 2 who completed both the survey assessments of psychosocial function and the biomarker project. If individuals were healthy enough to travel to the research clinic, all living participants who completed the Phase 2 psychosocial assessment (n = 5,895) were eligible to participate in the biomarker project (29). Of the 3,191 individuals eligible to participate in the biomarker project, 39.3% (n = 1,255) did so (29). After accounting for those individuals who could not be contacted, the response rate for the biomarker project was 43.1% (29). Notably, past work has demonstrated that participants in the biomarker project did not differ from participants in the psychosocial assessment in terms of age, sex, race, marital status, income, chronic conditions, or body mass index; however, participants in the biomarker project were more highly educated than participants in the psychosocial assessment (29).

The analytic sample for the present study comprised 982 individuals with complete data on optimism, antioxidants, and covariates (of those, 365 were members of a sibling or twin set). Participants provided informed consent and the research was approved by Institutional Review Boards at participating institutions.

Measures

Because the current investigation combined data from two separate projects that took place during Phase 2 of MIDUS, not all of the variables were assessed at the same point in time. Optimism and demographic characteristics were assessed prior to the measurement of antioxidants, health status, and health behaviors. On average, the latter set of variables was measured 830.62 days (a little over 2 years) after the optimism and demographic characteristics were measured (SD = 451.71; range 115 to 1,893 days).

Optimism—Optimism (i.e., the general expectation that the future will be favorable) was assessed with the well-validated 6-item Life Orientation Test-Revised (30). Example items include the positively worded “I expect more good things to happen to me than bad” and the negatively-worded “I hardly ever expect things to go my way.” Participants responded to each item with the following scale: 1 = *agree a lot*, 2 = *agree a little*, 3 = *neither agree nor disagree*, 4 = *disagree a little*, and 5 = *disagree a lot*. A total optimism score was computed by first reverse-scoring the three positively-worded items, then summing the responses of all six items, and finally standardizing the score (M = 0, SD = 1). Larger scores indicated higher levels of optimism and internal consistency reliability was good in this sample (α = 0.81). Prior work with other participants has reported comparable internal consistency reliabilities (e.g., α = 0.79) and test-retest reliabilities that range from 0.56 to 0.79 across 4 to 28 months (30). The Life Orientation Test-Revised has also previously demonstrated acceptable convergent and discriminant validity (30).

According to MIDUS data conventions, missing values were imputed from the mean of completed items if at least three of the six items were available. In addition to a continuous measure of optimism, we assessed potential discontinuities in effects by creating tertiles based on the distribution of scores. Standardized scores from ≤ −0.40 were categorized as low (33.95%), scores > −0.40 and < 0.50 as moderate (30.27%), and scores ≥ 0.50 as high (35.79%).

Although researchers have sometimes split the Life Orientation Test-Revised into subscales based on the valence of items (positively-worded vs. negatively-worded), we opted not to do this for several reasons. It is increasingly apparent that this practice may be at odds with the goal of controlling for acquiescence response bias in the measurement of psychological constructs. Moreover, comprehensive assessment of optimism requires not only that respondents endorse positively-worded items, but also disagree with negatively-worded items (31). Finally, valenced-based subscales compromised the internal consistency of the optimism scale ($\alpha_{\text{optimism subscale}} = 0.66$; $\alpha_{\text{pessimism subscale}} = 0.82$).

Antioxidants—After traveling to one of three clinical research centers (University of California, Los Angeles; University of Wisconsin; Georgetown University) for a 2 day visit, participants provided a fasting blood sample on the second morning of their visit. Blood samples were processed with standardized procedures at each research center and stored in a freezer between −60° C and −80° C. Assays of the frozen samples were conducted at the Antioxidants Research Laboratory at Tufts University. In accordance with previous methodology (31, 32), a reverse-phase gradient high pressure liquid chromatography system was used with ultraviolet visible and fluorescence detection.

Measures of the following nine antioxidants (in μmol/l) were obtained: carotenoids included trans-β-carotene, 13-cis-β-carotene, α-carotene, β-cryptoxanthin, lutein, zeaxanthin, and lycopene; vitamin E included α-tocopherol and γ-tocopherol. We created a composite of total carotenoids that was composed of trans-β-carotene, α-carotene, β-cryptoxanthin, lutein, and zeaxanthin, but excluded lycopene because it has demonstrated inconsistent associations with health-related variables (12, 16, 22). Serum concentrations of each carotenoid were first standardized (M = 0, SD = 1) and then summed to represent total carotenoid levels. One outlier was removed to maintain a normal distribution for the carotenoid composite, yielding a sample size of 981 in relevant statistical analyses.

For carotenoids, the minimum assay range was 0.01–0.03 μM, the inter-assay coefficient of variability ranged from 1–16%, and the intra-assay coefficient of variability ranged from 6–13%. The minimum assay range for α-tocopherol was 1.18 μM and 0.11 μM for γ-tocopherol. The inter-assay coefficient of variability for the tocopherols ranged from 2–6% and the intra-assay coefficient of variability ranged from 6–10%.

Potential confounders—Self-reported confounders included demographic characteristics and health status. Demographic factors were age (in standardized years), sex (male, female), race/ethnicity (white, non-white), education (less than high school, high school degree, some college, 4-year college degree or higher), and household income (in standardized United States dollars). Health status factors included chronic conditions of heart disease, hypertension, stroke, high cholesterol, diabetes, or cancer (none, presence of one or more), and body mass index (in standardized kg/m^2). Categorical variables were dummy-coded and continuous variables were standardized (M = 0, SD = 1) prior to inclusion in the models.

Potential pathways—The health behaviors of fruit and vegetable consumption, multivitamin supplementation, exercise, and smoking status were investigated as possible pathways by which optimism and antioxidant status may be associated.[1] Participants reported the average number of fruit and vegetable servings they consumed in a typical day (2 or fewer, 3–4, 5 or more) and their consumption of multivitamin supplements (no, yes). Participants also indicated whether they had engaged in regular exercise at least three times each week for 20 minutes (no, yes) and their smoking status (current smoker, past smoker, never smoker). All behavior-related variables were dummy coded.

Statistical Analyses

Statistical analyses were conducted in SAS 9.2. Individual antioxidant concentrations were log transformed (base e) prior to inclusion in the analyses to improve distributional properties.[2] The log transformed variables had approximately normal distributions. For each antioxidant and the total carotenoid score, the primary analyses that were conducted included a series of hierarchical linear regressions with the continuous optimism score. We first fit age-adjusted models with optimism as a predictor of each antioxidant concentration. A second minimally adjusted model contained all demographic characteristics (age, sex, race/ethnicity, education, and income). Because the amount of time between the assessments of optimism and serum antioxidants differed for each participant, we also included a covariate to account for this in the minimally adjusted model. Although optimism and antioxidant levels are considered to be largely stable over time (30, 33), instability in either measure would likely bias any observed associations towards the null; thus, these analyses may provide a conservative test of our hypothesis. The third model added health status (chronic conditions and body mass index) to the second model.

Additional models tested whether health behaviors independently accounted for any part of the association between optimism and antioxidant concentrations in models minimally adjusted for demographics (age, sex, race, education, income, and time between assessments). To this end, we compared the regression coefficients for optimism when a potential pathway variable was either excluded from or included in the model. When the regression coefficient for optimism was reduced with the inclusion of a potential pathway variable (as indicated by the percent change), this was taken to suggest that the potential pathway variable accounted for part of the association between optimism and antioxidant concentrations.

Secondary analyses tested for potential discontinuities in effects by including tertiles of optimism in models that were age-adjusted and minimally adjusted. We then repeated the primary statistical analyses with generalized estimating equations (GEE) to account for the data clustering of the sibling and twin sets. Results were virtually unchanged in GEE analyses, which suggests that clustering of families did not bias parameter estimates or standard errors. Findings from the non-GEE analyses are presented in the text for ease of interpretation, but see Supplementary Tables 1 and 2 for the primary analyses with GEE.

RESULTS

Sample characteristics

The analytic sample was comprised of men (45.21%) and women (54.79%) with an average age of 55.30 years (SD = 11.81; ages ranged from 34 to 84 years old). The majority of participants were white (93.28%) and 46.64 % had a 4-year college degree or higher (29.23% had some college, 20.67% had a high school degree, and 3.46% had less than a

[1]Alcohol consumption was also considered as a potential pathway variable, but made no difference in regression models and will not be discussed further. In addition, findings that controlled for depressed affect are discussed in the supplementary text (Supplemental Digital Content 1).

[2]One participant with 13-cis-β-carotene concentration = 0 and one participant with zeaxanthin concentration = 0 were set to missing because values were either an aberrant finding or below the detection level of the methodology.

high school degree). Table 1 shows the sample characteristics according to level of optimism. Individuals with low optimism levels were significantly younger and reported less income and education than those with higher optimism levels. In addition, less optimistic individuals tended to be current smokers, engage in less regular exercise, and consume fewer fruits and vegetables.

The unadjusted mean (in μmol/l) for each antioxidant was as follows: $M_{trans\text{-}\beta\text{-}carotene}$ = 0.63 (SD = 0.75), $M_{13\text{-}cis\text{-}\beta\text{-}carotene}$ = 0.08 (SD = 0.08), $M_{\alpha\text{-}carotene}$ = 0.10 (SD = 0.11), $M_{\beta\text{-}cryptoxanthin}$ = 0.21 (SD = 0.18), M_{lutein} = 0.30 (SD = 0.21), $M_{zeaxanthin}$ = 0.07 (SD = 0.05), $M_{lycopene}$ = 0.46 (SD = 0.23), $M_{\alpha\text{-}tocopherol}$ = 29.36 (SD = 13.67), and $M_{\gamma\text{-}tocopherol}$ = 3.48 (SD = 2.73). The mean for the total carotenoid composite of the individual standardized carotenoids was −0.03 (SD = 3.12).

The association between optimism and antioxidants

Individuals with greater optimism were generally more likely to have higher concentrations of carotenoids (Table 2). That is, for trans-β-carotene, α-carotene, β-cryptoxanthin, lutein, zeaxanthin, and lycopene, age-adjusted and minimally adjusted regression models indicated that one standard deviation higher in optimism was associated with 3–13% higher carotenoid concentrations. Although these findings were sometimes attenuated to marginal statistical significance or non-significance with the addition of health status, the magnitude of the regression coefficients remained similar and 3–7% higher carotenoid concentrations were still evident. Findings for the total carotenoid composite had a similar pattern in age-adjusted models, minimally adjusted models, and models adjusted for health status (Table 2). Namely, optimism was positively and significantly associated with total carotenoid concentrations. Optimism was not significantly associated with α-tocopherol and γ-tocopherol. Given optimism's null association with tocopherols in these and subsequent analyses, we do not discuss results for vitamin E further.

Health behaviors as potential pathways linking optimism and total carotenoids

Given that carotenoid concentrations demonstrated the most robust association with optimism, we investigated whether the association was potentially accounted for by health behaviors. To start, we examined the association between the total carotenoid composite and each health behavior. Individuals who consumed five or more servings of fruit and vegetables each day had higher carotenoid concentrations (M = 1.25, SD = 3.40) relative to those who consumed three or four servings (M = 0.17, SD = 3.02) or two or fewer servings (M = −0.89, SD = 2.79), $F(2, 978) = 34.77$, $p < .001$. Similarly, individuals who consumed multivitamins had higher carotenoid concentrations (M = 0.30, SD = 3.06) than those who did not (M = −0.40, SD = 3.15), $t(979) = 3.51$, $p < .001$, and individuals who exercised had higher carotenoid concentrations (M = 0.14, SD = 3.17) than those who did not (M = −0.70, SD = 2.85), $t(979) = 3.44$, $p < .001$. Current smokers had the lowest carotenoid concentrations (M = −1.60, SD = 2.30) relative to past smokers (M = −0.006, SD = 3.10) and never smokers (M = 0.26, SD = 3.18), $F(2, 978) = 16.77$, $p < .001$.

We next determined how the association between optimism and total carotenoids changed when controlling for each potential pathway variable as well as demographic characteristics. As shown in Table 3, fruit and vegetable consumption substantially reduced the association between optimism and total carotenoids, as did smoking status. In both cases, the initially statistically significant regression coefficient for optimism was reduced by 25% or more and became marginally significant when the potential pathway variable was included. Exercise also explained part of the association, but multivitamin supplementation did not. All of the health behaviors combined accounted for nearly half of the association between optimism and total carotenoid concentrations, and reduced the association to non-significance.

Secondary analyses

Findings for tertiles of optimism were consistent with those described previously (Table 4). Many of the same carotenoids that were associated with optimism continuously were associated with high levels of optimism in age-adjusted models and, to a lesser extent, in minimally adjusted models. That is, relative to the lowest levels of optimism, the highest levels of optimism were associated with 9–20% higher concentrations of trans-β-carotene, α-carotene, β-cryptoxanthin, lutein, zeaxanthin, and lycopene in age-adjusted models. In addition, for the total carotenoid composite, the highest level of optimism was significantly associated with greater total carotenoids in age-adjusted and minimally adjusted models. Thus, compared with the lowest optimism levels, the highest levels were positively associated with carotenoid concentrations. Evidence for an association between moderate relative to low levels was less strong. However, because statistical power is reduced in tertiled analyses, these findings warrant cautious interpretation.

DISCUSSION

This is the first study to investigate the association between self-reported optimism and serum antioxidants. Whereas previous health research has mostly emphasized problematic psychological and physical functioning (i.e., the presence of ill-being or disease), we used a positive definition of health by focusing on psychological and biological processes that indicate the presence of restorative processes rather than the absence of deteriorative processes. Findings suggest that optimism is positively associated with greater concentrations of one group of antioxidants – namely, carotenoids. This relationship held for both continuous and categorical measures of optimism. The relationship also remained mostly statistically significant after controlling for demographic characteristics (e.g., socioeconomic status) and health status (e.g., body mass index), although effect sizes were somewhat attenuated with the addition of these factors. Although optimism was not associated with vitamin E, previous research has also reported null associations between psychosocial factors and tocopherols (22, 34). Tocopherols may be more strongly dependent on other factors (e.g., lipids), which may make it difficult to detect direct effects of psychosocial variables.

One of the major strengths of the current study is the objective assessment of serum antioxidants, which alleviates concerns that optimism's observed associations are due to a reporting bias. Moreover, including health behaviors individually in regression models allowed investigation of the potential pathways linking optimism and carotenoids. Exploring the role of health behaviors – in particular, diet and vitamin consumption – has rarely been done in previous research. Findings indicated that the consumption of fruits and vegetables, along with smoking status, explained the greatest variation in the association between optimism and total carotenoid concentrations. Indeed, individuals who ate two or fewer servings of fruits and vegetables a day were significantly less optimistic than individuals who ate three or more servings a day. These findings are consistent with research suggesting that optimism is linked with consuming a healthy diet, exercising regularly, and not smoking cigarettes (35–38). The favorable expectations that optimistic individuals hold for the future may provide them with the resources to better manage challenge and stress (39), particularly in the context of health behaviors. Although most people want to lead a healthy lifestyle, daily constraints often thwart such intentions. Because optimists tend to persist at their goals, use successful coping strategies, and know when to pursue achievable versus unachievable goals (39), they may be better able to maintain the healthy behaviors that are associated with improved antioxidant status. Of course, the reverse may also be true; that is, individuals who engage in healthier behaviors and enjoy better health may also be more optimistic about life.

Although this study confirms that that the association between optimism and serum antioxidants can be partially explained by the health behaviors of fruit and vegetable consumption and cigarette smoking, it is also interesting to note that including health behaviors did not completely explain all the variance in the relationship. Although this may suggest that measurement error was present in the assessment of self-reported health behaviors, we note that these are commonly used measures and including them is a unique strength of the study. Thus, assuming there is limited residual confounding, such findings could also indicate that other pathways may be operating. For example, one possibility is that optimism and antioxidant concentrations are associated because positive psychological factors enhance the bodily processes that encourage antioxidant absorption. Although the present research cannot address this issue, early studies regarding positive psychological states like love and comfort suggest that digestion may vary based on the psychological context (40). Moreover, recent evidence indicates that numerous factors influence the bioavailability of antioxidants, and that patterns of bioavailability can vary by type of antioxidant (41, 42). Another possibility comes from work suggesting that levels of serum antioxidants are lower in the presence of greater inflammation (12, 43). In fact, this explanation has been proposed for why smoking is associated with reduced antioxidant levels (44, 45). Given prior work suggesting that higher levels of optimism are associated with reduced inflammation (46, 47), mitigating inflammatory processes may be another pathway by which optimism is associated with higher antioxidant concentrations. Thus, it is feasible that optimism and serum antioxidants may be linked by as yet unidentified physiological processes.

It is also worth noting evidence that antioxidant supplementation alone does not improve disease or mortality outcomes (e.g., 48). Although a conservative interpretation of this evidence might suggest that serum antioxidants serve primarily as a marker of health habits, prior research has not ruled out the possibility that antioxidant supplementation may have limited effects on health outcomes because effects are influenced by interactions with other biological substrates. Thus, antioxidants may yet emerge as a marker of biological health rather than merely a marker of healthy behaviors such as eating a balanced diet.

One of the major limitations of the current study is the cross-sectional design. This prevents conclusions about the causal direction of the optimism-antioxidant association. We suspect that it is likely bi-directional (i.e., optimistic individuals are likely to engage in health behaviors associated with greater concentrations of antioxidants; greater concentrations of antioxidants are associated with better physical health that may enhance optimism), but the time between assessments reduces the likelihood that serum antioxidants were driving optimism levels. Furthermore, health behaviors may confound the association between optimism and carotenoids rather than be on the pathway; however, the current data cannot resolve such issues. It is also possible that other unexamined third variables could explain the association between optimism and antioxidant concentrations. For example, some evidence suggests that different concentrations of antioxidants may be associated with genetic variation (49), and levels of optimism could similarly have a genetic basis.

In addition, there was an approximately 2 year lag between the assessment of optimism and serum antioxidants. Although concurrent assessment would have been preferable, both optimism and serum antioxidant measurements are relatively stable within periods of several years (30, 33). Antioxidant concentrations were also measured on a single occasion, which may be susceptible to within-person variability. Future research with repeated measures of antioxidant concentrations may provide a better understanding of typical concentrations, although research also suggests that single assessments of antioxidant status reliably characterize longer term concentrations (33). Another caveat concerns the use of a predominantly white, middle-aged sample, which limits the generalizability of the findings.

We cannot be certain that the association between optimism and carotenoids is present in other ethnic groups or even at other stages of the lifespan.

Despite these limitations, this study is one of the first of its kind to investigate how positive indicators of psychological health (i.e., optimism) and physical health (i.e., serum antioxidants) might be associated. This study also adds to the relatively small literature regarding psychosocial factors and serum antioxidant status. Additional strengths include a relatively large sample size, a comprehensive set of covariates, and objectively-assessed antioxidant concentrations. Taken together, results suggest that optimism was associated with higher carotenoids concentrations. Moreover, health behaviors like fruit and vegetable consumption seemed to explain a large proportion of the optimism and antioxidant relationship. Future research would benefit from the use of prospective study designs, diverse samples, and other measures that capture adaptive psychological functioning. Moreover, researchers could examine whether adaptive psychological functioning protects against challenges that are known to be associated with diminished antioxidant status such as racial inequality and low socioeconomic status. Additional research might examine whether manipulating or enhancing optimism could increase serum antioxidants or the likelihood of engaging in health behaviors. Replication of these findings and a more nuanced understanding of relevant pathways may indicate that enhancing psychosocial assets like optimism could provide effective strategies for promoting health.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Support for this research was provided by the Robert Wood Johnson Foundation's Pioneer Portfolio through the grant “Exploring Concepts of Positive Health.” The original Midlife in the United States study was supported by the John D. and Catherine T. MacArthur Foundation Research Network on Successful Midlife Development. Follow-up data collection was supported by the National Institute on Aging (P01-AG020166). We thank the staff of the clinical research centers at Georgetown University, University of Wisconsin-Madison, and University of California, Los Angeles for their support in conducting this study.

Acronyms

GEE	generalized estimating equations
M	mean
MIDUS	Midlife in the United States
SD	standard deviation
SE	standard error

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TABLE 1

Distribution of participant characteristics according to level of optimism

Characteristic	Optimism			*p*-value
	Low *n* = 332	Moderate *n* = 298	High *n* = 352	
Mean age (SD), years	53.43 (11.71)	56.55 (12.32)	56.01 (11.28)	.002
Sex				.27
Men	48.49%	44.97%	42.33%	
Women	51.51%	55.03%	57.67%	
Race				.23
White	91.57%	94.97%	93.47%	
Non-white	8.43%	5.03%	6.53%	
Education				< .001
Less than high school	5.42%	2.35%	2.56%	
High school degree	26.51%	20.81%	15.06%	
Some college	32.23%	29.87%	25.85%	
4-year college degree or higher	35.84%	46.98%	56.53%	
Mean household income (SD), US dollars	68,006.96 (54,411.13)	75,354.99 (58,081.43)	84,756.40 (64,189.53)	.001
Mean time between assessments (SD), days	828.87 (452.58)	831.31 (452.71)	831.69 (451.33)	.996
Chronic conditions[a]				.90
Yes	64.16%	64.77%	63.07%	
No	35.84%	35.23%	36.93%	
Mean body mass index (SD), kg/m^2	29.74 (6.48)	28.73 (5.51)	28.78 (5.67)	.049
Fruit and vegetable consumption				< .001
2 or fewer servings per day	49.70%	39.93%	32.95%	
3–4 servings per day	34.04%	37.58%	42.33%	
5 or more servings per day	16.27%	22.48%	24.72%	
Multivitamin supplementation				.51
Yes	51.20%	55.70%	52.56%	
No	48.80%	44.30%	47.44%	
Regular exercise				.009
Yes	74.10%	83.89%	80.11%	
No	25.90%	16.11%	19.89%	
Smoking status				< .001
Current smoker	17.77%	8.72%	6.82%	
Past smoker	30.72%	36.58%	32.67%	
Never smoker	51.51%	54.70%	60.51%	

Note: Percentages refer to the column percent of individuals within each optimism category with that characteristic, *p*-value comes from χ^2 or analysis of variance tests.

[a]Because our measure of chronic conditions included high blood pressure and high cholesterol, the proportion of participants with chronic conditions may appear relatively large; however, the prevalence in our sample is consistent with the prevalence of such conditions in middle-age to older adults living in the United States (50).

TABLE 2

Unstandardized parameter estimates (standard error) for the association between one standard deviation increase in optimism and serum antioxidants (*N* = 982)

Log Antioxidants (μmol/l)[a]	Optimism		
	Model 1[b]	**Model 2[c]**	**Model 3[d]**
Carotenoids			
Trans-β-carotene	**0.10*** (0.03)**	**0.06* (0.03)**	0.04 (0.03)
13-cis-β-carotene	0.02 (0.02)	−0.004 (0.02)	−0.01 (0.02)
α-carotene	**0.13*** (0.03)**	**0.08** (0.03)**	**0.07* (0.03)**
β-cryptoxanthin	**0.07*** (0.02)**	**0.05* (0.02)**	**0.04* (0.02)**
Lutein	**0.05** (0.02)**	**0.04* (0.02)**	0.03~ (0.02)
Zeaxanthin	**0.04* (0.02)**	0.03~ (0.02)	0.03 (0.02)
Lycopene	0.03~ (0.02)	**0.04* (0.02)**	**0.04* (0.02)**
Total Carotenoids	**0.39*** (0.10)**	**0.24* (0.10)**	**0.19* (0.10)**
Vitamin E			
α-tocopherol	0.001 (0.02)	−0.002 (0.02)	0.0003 (0.02)
γ-tocopherol	−0.02 (0.02)	−0.007 (0.02)	−0.003 (0.02)

[a]Each individual antioxidant was log transformed; the composite of total carotenoids was not

[b]Adjusted for age

[c]Adjusted for demographics (age, sex, race, education, income, time between assessments)

[d]Adjusted for demographics and health status (chronic conditions, body mass index)

~ $p \leq .10$,

* $p \leq .05$,

** $p \leq .01$,

*** $p \leq .001$

TABLE 3

Change in the association between optimism and total carotenoid concentrations when potential pathway variables are included (*N* = 981)

	Association with Total Carotenoid Concentrations[a]		
Predictors	***b***	**SE**	**% Δ**
Optimism	0.24*	0.10	–
Demographic covariates[b]			
Optimism	0.17~	0.10	−29%
Demographic covariates[b]			
Fruit and vegetable consumption			
Optimism	0.24*	0.10	0%
Demographic covariates[b]			
Multivitamin supplementation			
Optimism	0.22*	0.10	−8%
Demographic covariates[b]			
Exercise			
Optimism	0.18~	0.10	−25%
Demographic covariates[b]			
Smoking status			
Optimism	0.13	0.10	−46%
Demographic covariates[b]			
All behaviors[c]			

Note: The *p*-value symbolized in the second column from the left indicates the association between optimism and total carotenoid concentrations in the presence of demographic covariates or demographic covariates plus potential pathway variable(s).

[a]Total carotenoid concentrations was composed of trans-β-carotene, α-carotene, β-cryptoxanthin, lutein, and zeaxanthin

[b]Adjusted for age, sex, race, education, income, and time between assessments

[c]Adjusted for fruit and vegetable consumption, multivitamin supplementation, exercise, and smoking status

~$p \leq .10$,

*$p \leq .05$

TABLE 4

Unstandardized parameter estimates (standard error) for the association between tertiled optimism and serum carotenoids in age-adjusted and minimally adjusted models[a] ($N = 982$)[b]

	Optimism		
Log Carotenoids (µmol/l)[c]	**Low (n = 332)**	**Moderate (n = 298)**	**High (n = 352)**
Trans-β-carotene			
Age-Adjusted	reference	0.08 (0.07)	0.20** (0.07)
Minimally Adjusted	reference	0.02 (0.07)	0.11 (0.07)
13-cis-β-carotene			
Age-Adjusted	reference	−0.008 (0.06)	0.07 (0.06)
Minimally –Adjusted	reference	−0.05 (0.06)	−0.003 (0.06)
α-carotene			
Age-Adjusted	reference	0.14~ (0.08)	0.20** (0.07)
Minimally Adjusted	reference	0.07 (0.08)	0.10 (0.07)
β-cryptoxanthin			
Age-Adjusted	reference	0.10* (0.05)	0.17*** (0.05)
Minimally Adjusted	reference	0.09~ (0.05)	0.14** (0.05)
Lutein			
Age-Adjusted	reference	0.04 (0.05)	0.12** (0.05)
Minimally Adjusted	reference	0.03 (0.04)	0.09* (0.04)
Zeaxanthin			
Age-Adjusted	reference	0.04 (0.05)	0.10* (0.04)
Minimally Adjusted	reference	0.03 (0.05)	0.08~ (0.04)
Lycopene			
Age-Adjusted	reference	0.03 (0.04)	0.09* (0.04)
Minimally Adjusted	reference	0.04 (0.04)	0.10** (0.04)
Total Carotenoids			
Age-Adjusted	reference	0.37 (0.25)	0.85*** (0.24)
Minimally Adjusted	reference	0.19 (0.24)	0.51* (0.24)

[a]Adjusted for demographics (age, sex, race, education, income, time between assessments)

[b]Analyses for total carotenoids were based on $N = 981$ due to one excluded outlier

[c]Each individual carotenoid was log transformed; the composite of total carotenoids was not

~ $p \leq .10$,

* $p \leq .05$,

** $p \leq .01$,

*** $p \leq .001$