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Daily positive events and inflammation: Findings from the National Study of Daily Experiences

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ABSTRACT

Background: Inflammation is implicated in the development of chronic diseases and increases the risk of mortality. People who experience more daily stressors than others have higher levels of inflammation, but it is unknown whether daily positive events are linked to inflammation.
Objective: To examine the association of daily positive events with 3 inflammatory markers, interleukin-6 (IL-6), C-reactive protein (CRP), and fibrinogen.
Method: A cross-sectional sample of 969 adults aged 35–86 from the Midlife in the United States Study completed telephone interviews for 8 consecutive evenings. Participants reported positive experiences that occurred over the past 24 h. Blood samples were obtained at a separate clinic visit and later assayed for inflammatory markers. Regression analyses evaluated the frequency of daily positive events (defined as the percent of study days with at least 1 positive event) as a predictor of each inflammatory marker. Covariates included information on demographics, physical health, depressive symptoms, dispositional and behavioral factors, and daily positive and negative affect.
Results: On average, participants experienced positive events on 73% of days (SD = 27%). The frequency of daily positive events was associated with lower IL-6 ($p < 0.001$) and CRP ($p = 0.02$) in the overall sample, and lower fibrinogen among women ($p = 0.01$). The association remained for IL-6 in the fully adjusted model, but was no longer significant for CRP and fibrinogen after controlling for household income and race. Effects were more pronounced for participants in the lowest quartile of positive event frequency than for those in the top 3 quartiles, suggesting that lack of positivity in daily life may be particularly consequential for inflammation. Furthermore, interpersonal positive events were more predictive of lower IL-6 overall and lower fibrinogen in women than non-interpersonal positive events.
Conclusion: Daily positive events may serve a protective role against inflammation.

1. Introduction

Elevated inflammation is implicated in the development of chronic diseases and is a risk factor for mortality in both clinical and population-based samples (Harris et al., 1999; Reuben et al., 2002; Volpato et al., 2001). Negative psychological factors—including depression, hostility, and stress—are consistently linked with elevations in inflammatory markers, including the cytokine interleukin-6 (IL-6) and the acute phase proteins C-reactive protein (CRP) and fibrinogen (Duivis et al., 2011; Glaser et al., 2003; Howren et al., 2009; Kiecolt-Glaser et al., 2003; Steptoe et al., 2007). Inflammation has bidirectional relationships with psychological distress (Miller et al., 2002; Dantzer et al., 2008) and is therefore likely to play a core mechanistic role linking negative psychological factors to subsequent mental and physical health outcomes.

Although the associations between negative emotions and physiological dysregulation are well-documented, the links between positive psychological factors and inflammation have received less attention. Emerging evidence suggests that indicators of well-being—such as positive affect, purpose in life, and positive social relations—are associated with lower inflammation (Brouwers et al., 2013; Deverts et al., 2010; Friedman and Ryff, 2012; Friedman et al., 2005, 2007; Prather et al., 2007; Steptoe et al., 2008; Von Känel et al., 2012) and less inflammatory reactivity during acute stress tasks (Aschbacher et al., 2012; Steptoe et al.,

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2005). These associations are independent of, and sometimes stronger than, the effects of negative emotions. For example, trait positive affect, but not negative affect, has been linked to lower production of stimulated cytokines in a middle-aged community sample (Prather et al., 2007). Prospective data from a large cohort of healthy adults showed that, among Black participants, low positive affect uniquely predicted higher CRP five years later but depressive affect did not (Deverts et al., 2010).

Existing studies related to positivity and inflammation have largely relied on trait measures of affect or laboratory tasks that may not fully reflect emotional and stress processes in everyday life. Daily experiences and routine challenges—such as arguments, work deadlines, and family obligations—have immediate effects on emotional and physical functioning, as well as cumulative influences on health. Recent prospective studies have shown that heightened emotional responses to daily stressors are associated with critical outcomes across a decade of follow-up, including increased risks of psychological distress or an affective disorder (Charles et al., 2013), developing a chronic medical condition (Piazza et al., 2013), and mortality (Mroczek et al., 2013). Inflammatory processes are likely to be a key pathway whereby daily experiences influence subsequent health. Indeed, several studies have linked daily stressors to elevated IL-6 and CRP (Gouin et al., 2012a, 2012b; Fuligni et al., 2009). Interpersonal events may be especially important for inflammation; for example, daily interpersonal stress is associated with greater stimulated IL-6 production and glucocorticoid resistance among patients with rheumatoid arthritis (Davis et al., 2008), as well as higher CRP among healthy adolescents (Fuligni et al., 2009).

Less is known regarding the potential salutary benefits of minor positive events (also called *uplifts*) in day-to-day life. Daily positive events, such as having dinner with a friend or taking a leisurely walk, occur more frequently than daily stressors and have differential effects on mood in comparison to daily negative events (Zautra et al., 2005; Zautra and Reich, 1983). These experiences may influence health over and above the effects of trait positive and negative affect, although this has yet to be empirically tested. Whereas trait affect represents endogenous psychological processes, daily events are exogenous and reflect an individual's transactions with his or her environment.

In the only existing study of minor positive events and inflammation to our knowledge, the perceived intensity of uplifts was marginally associated with lower IL-6 in a sample of 108 healthy adults (Jain et al., 2007). The study measured uplifts using a questionnaire that required participants to report on whether specific events had occurred in the past month. However, retrospective measures are susceptible to recall biases and lack the ecological validity of naturalistic methods (e.g., momentary assessments or daily diaries). The question of whether naturally-occurring positive events (assessed in the context of daily life) might influence inflammation remains unanswered.

The primary objective of the current study was to examine the associations between the occurrence of daily positive events and inflammatory markers in a large national sample of midlife and older adults. Daily experiences were measured using daily diary methodology, which assesses events closer to their natural contexts and is better able to capture the richness of everyday life, relative to traditional survey approaches. We utilized 3 markers of inflammation as outcomes: IL-6, CRP, and fibrinogen. Although IL-6 has many anti-inflammatory actions in certain contexts, such as exercise and as a modulator of inflammation in infection (for reviews, see Hawkley et al., 2007; Woods et al., 2009), it is widely considered proinflammatory in the context of psychological stress; IL-6 as well as CRP and fibrinogen have been robustly linked to cardiovascular disease (Danesh et al., 2004; Pearson et al., 2003; Yudkin et al., 2000) and all have been associated with psychological stress (e.g., Gouin et al., 2012a; Wium-Andersen et al., 2013).

Our secondary objective was to describe the associations of inflammatory markers with various aspects of daily positive events (i.e., frequency, type of event, independence from affect). Specifically, we explored non-linear associations among quartiles of positive event frequency, compared the relative contributions of interpersonal versus non-interpersonal daily positive events, and disentangled the inflammatory correlates of daily positive events from those of daily positive affect (PA) and daily negative affect (NA). Our study is the first to report that inflammatory markers are associated with daily positive events, utilizes a large sample using naturalistic methods, and highlights the important role of seemingly minor daily experiences for health and well-being.

2. Methods

2.1. Participants and design

This study uses cross-sectional data from a subset of participants in the second wave of the Midlife in the United States Study (MIDUS II), conducted between 2004 and 2006. The purpose of MIDUS II was to investigate health and well-being in a national sample of non-institutionalized, English-speaking adults aged 35–86 ($N = 4963$). An additional 592 African Americans from Milwaukee were recruited to increase the diversity of the study.

A representative subsample of respondents from MIDUS II ($N = 2022$) were invited to participate in the National Study of Daily Experiences, which consisted of short telephone interviews about daily experiences for 8 consecutive evenings (Almeida et al., 2009). Of these, 1001 respondents participated in the MIDUS Biomarker Project. The Biomarker Project required an overnight stay at one of three General Clinical Research Centers (UCLA, Georgetown, and the University of Wisconsin, Madison), where participants provided blood samples and were assessed for physical health and psychophysiological function (Love et al., 2010). The order and timing of data collection varied among participants. Data collection for the daily diary and biomarkers were separated by a median of 6 months, with some participants completing the daily diaries before the biomarker assessment and others after. Of the 1001 participants with biomarker assessments, 19 were missing income data and 13 were missing personality or depressive symptoms data. Thus, the current analyses were conducted on a final sample of 969 adults, including 129 participants from the Milwaukee cohort. Procedures were approved by Institutional Review Boards at participating institutions, and all participants provided informed consent.

2.2. Measures

2.2.1. Predictor: daily positive events

During telephone interviews for 8 days, participants were asked whether they had experiences that most people would consider particularly positive in the past 24 h. Five items inquired about events in each of the following life domains: positive interaction, positive experience at work/volunteer position, positive experience at home, network positive event (i.e., positive event experienced by close friend or relative), and any other positive event (Charles et al., 2010). For instance, positive interactions were assessed by asking, "Did you have an interaction with someone that most people would consider particularly positive (for example, sharing a good laugh with someone, or having a good conversation) since we spoke yesterday?" Participants reported who else was involved in each event (e.g., spouse, child, friend); events where participants were not alone were coded as *interpersonal events*.

The *frequency of positive events* was defined as the percent of study days in which at least 1 positive event occurred, based on the number of daily interviews completed (Seltzer et al., 2009). There was no difference in the frequency of positive events between those who completed all 8 interviews ($N = 684$) and those with less than 8 interviews ($N = 285$). We analyzed the frequency of positive events as both a continuous variable and split into quartiles: Q1: positive events on <57% of days, Q2: 57–79%, Q3: 80–99%, Q4: 100%. We did not use the raw total number of positive events as the predictor because it does not account for the number of interview days; results were comparable to those reported when the raw number of positive events was entered as a predictor.

2.2.2. Outcome: inflammatory markers IL-6, CRP, and fibrinogen

Venous blood samples were collected from participants following overnight fasting. Samples were stored in a −65 °C freezer until assayed. IL-6 was assayed at the MIDUS Biocore Lab using the Quantikine® high-sensitivity enzyme-linked immunosorbent assay kit (R&D Systems, Minneapolis, MN). Intra-assay and inter-assay coefficients of variation (CV) were <10%. CRP and fibrinogen were assayed at the Laboratory for Clinical Biochemistry Research (University of Vermont, Burlington, VT). CRP was measured using a BN II nephelometer with a particle enhanced immunonephelometric assay. Intra-assay CV was 2.3–4.4% and inter-assay CV was 2.1–5.7%. Fibrinogen was assayed using the Clauss method on a BN II nephelometer (N Antiserum to Human Fibrinogen; Dade Behring Inc., Deerfield, IL). Intra-assay CV for fibrinogen was 2.7% and inter-assay CV was 2.6%. Values of all three biomarkers were natural log-transformed to normalize the distributions.

2.2.3. Covariates

Data on demographics and personality were obtained by telephone and mail surveys, respectively; these surveys were conducted separately from the daily diary and biomarker protocols. The demographic covariates were age, gender, and race (White vs. non-White). Previous research using MIDUS data found that household income (i.e., income from wages, pension, Social Security, and government assistance), but not education level, was independently associated with inflammation (Friedman and Herd, 2010). Thus, we controlled for household income quintile using the following ranges: Q1: <$24,950; Q2: $24,950–$47,249; Q3: $47,250–$70,499; Q4: $70,500–$105,499; Q5: ⩾$105,500.

Prior studies have shown that both negative and positive dispositional factors are linked with inflammatory markers (Marsland et al., 2008; Roy et al., 2010; Ikeda et al., 2011); therefore, we included neuroticism and optimism as covariates. Participants rated themselves on 4 items for neuroticism (*moody, nervous, worrying, calm* [reversed]) using a 1-to-4 scale. Ratings were averaged, with higher scores indicating more neuroticism. Optimism was assessed with the 6-item Life Orientation Test-Revised, of which 3 items were positively-worded to measure optimism and 3 items were negatively-worded to measure pessimism (Scheier et al., 1994). Ratings were summed across the 6 items to produce an overall optimism score, with higher scores indicating more optimism (scores ranged from 6 to 30).

As part of the clinic visit for the Biomarker Project, participants provided information on their health status and completed self-reported questionnaires. Height and weight were measured and used to calculate body mass index (BMI); values were natural log-transformed to normalize the distribution. Medical comorbidity was assessed using a checklist of 20 physician-diagnosed chronic conditions (e.g., depression, heart disease, high blood pressure, asthma, diabetes); the total number of chronic conditions was included in the analyses as a continuous variable. Due to the effects of certain medications on inflammatory levels, we controlled for the use of blood pressure, cholesterol-lowering (e.g., statins), corticosteroid, and antidepressant medications. Dummy-coded variables were included to control for current smoking and for regular exercise (defined as engagement in regular exercise or physical activity of any intensity for 20 min or more at least 3 times per week). Depressive symptoms were assessed using the 20-item Center for Epidemiological Studies Depression Scale, with higher scores (maximum of 60 points) indicating greater severity (Radloff, 1977).

We controlled for daily PA and NA, assessed at the end of each day, to reduce the possibility that any association between daily positive events and inflammation were attributable to affect. Daily affect was assessed using scales developed for the MIDUS study (Kessler et al., 2002; Mroczek and Kolarz, 1998). Participants reported the frequency of 13 positive emotions (e.g., cheerful, enthusiastic, calm and peaceful) and 14 negative emotions (e.g., nervous, upset, frustrated) using the following 5-point scale: 0 = *none of the time*, 1 = *a little of the time*, 2 = *some of the time*, 3 = *most of the time*, 4 = *all of the time*. Daily PA and NA were calculated by averaging the respective items. Across the 8 days, Cronbach's alpha ranged from 0.93 to 0.95 for daily PA and from 0.84 to 0.88 for daily NA. The mean levels of daily PA and NA were obtained by aggregating scores across all 8 interview days.

2.3. Data analysis

For descriptive purposes, we computed correlations between positive event frequency (i.e., percent of days with ⩾1 positive event) and participant demographics, physical health, medication use, and psychological covariates. For our primary analyses, multivariate regression models were run to test positive event frequency as a predictor of each inflammatory marker. The models sequentially controlled for the following covariates: (1) age and gender; (2) household income quintile and White race; (3) log BMI, number of chronic conditions, medication use, smoking status, and regular exercise; and (4) neuroticism, optimism, depressive symptoms, and mean daily PA and NA. We tested interactions between positive event frequency and demographics, BMI, and psychological variables.

We conducted 3 sets of follow-up analyses; these analyses were run using multivariate regression models that controlled for age and gender. First, non-linear associations between positive events and inflammation were evaluated using dummy-coded variables for quartiles of positive event frequency. Second, the percent of days with interpersonal positive events and with non-interpersonal positive events were tested as simultaneous predictors of each inflammatory marker. Finally, mean daily PA and NA were tested separately as predictors of inflammatory markers. Analyses were conducted using SAS version 9.3 (SAS Institute Inc., Cary, NC).

3. Results

3.1. Descriptive findings

Collectively, 969 participants provided 7212 daily interviews. Participants completed an average of 7.4 interviews (SD = 1.2); 71% of the sample completed all 8 interviews. Participants experienced approximately 1 positive event per day, with a sample median of 8 events across the 8 days of interviewing (range: 0–28 total events across 8 days). On average, participants experienced at least 1 positive event on 73% of days (SD = 27%; range: 0–100%).

Sample characteristics and their correlations with daily positive events are shown in Table 1. Fifty-seven percent of the participants were female, and the average age was 58. The racial composition of the sample was 81% White, 15% Black and/or African American, and 4% Native American, Asian American, or other race. Participants had an average of 4 chronic medical conditions, and 40% were

Table 1
Participant characteristics by positive event frequency ($N = 969$).

Participant characteristics	Mean (SD) or *N* (%)	Correlation *r* with positive event frequency[a]
Demographics		
Age	58 (11.5)	0.17***
Female	548 (56.6%)	−0.05
White race	789 (81.4%)	0.16***
Household income, median (IQR)	$58,750 ($64,763)	0.11***
Physical health, medications, and health behaviors		
No. of chronic conditions	4 (2.9)	0.05
Body mass index	29.66 (6.47)	−0.07*
Blood pressure medication use	348 (36%)	−0.01
Cholesterol medication use	271 (28%)	0.03
Corticosteroid medication use	41 (4%)	−0.05
Antidepressant medication use	137 (14%)	0.04
Current smoker	129 (13%)	−0.09**
Regular exercise	747 (77%)	0.02
Psychological covariates		
Depressive symptoms (range: 0–60)	8.53 (8.19)	−0.18***
Neuroticism (range: 1–4)	2.03 (0.64)	−0.11***
Optimism (range: 6–30)	23.87 (4.71)	0.26***
Daily positive affect (range: 0–4)	2.71 (0.70)	0.15***
Daily negative affect (range: 0–4)	0.21 (0.27)	−0.04

*** $p \leqslant .001$.
** $p \leqslant .01$.
* $p \leqslant .05$.
[a] Positive event frequency was defined as the percent of days in which the participant experienced at least one positive event.

obese (i.e., BMI $\geqslant$ 30). Those who had a greater frequency of positive events (i.e., percent of days with at least 1 positive event) tended to be older, White, and had higher income and lower BMI. Participants who experienced more frequent daily positive events also had fewer depressive symptoms, less neuroticism, more optimism, higher daily PA, and were less likely to smoke.

3.2. Daily positive events and inflammation

The median non-transformed levels of inflammatory markers were 2.08 pg/mL for IL-6 (Quartile 1, Quartile 3 [Q1, Q3] = 1.33, 3.38), 1.36 mg/L for CRP (Q1, Q3 = 0.68, 3.39), and 337.00 mg/dL for fibrinogen (Q1, Q3 = 286.00, 394.00). The inflammatory markers had non-normal distributions and were natural log-transformed for the following analyses.

3.2.1. IL-6

As shown in Table 2, higher positive event frequency predicted lower log IL-6 after controlling for age and gender. The inverse association between the frequency of daily positive events and IL-6 persisted after sequential adjustment for household income and race, physical health (BMI, number of chronic conditions, medication use, smoking, and regular exercise), and psychological covariates (neuroticism, optimism, depressive symptoms, and mean daily PA and NA).

There was a significant interaction between positive event frequency and household income quintile in predicting IL-6 ($p = 0.02$ for interaction in fully adjusted model). IL-6 did not differ based on positive event frequency among participants with higher income; however, more frequent daily positive events were associated with relatively lower IL-6 among participants with lower income. Positive event frequency did not interact with mean levels of daily PA or daily NA (fully adjusted $p = 0.79$ and $p = 0.37$, respectively), nor did it interact with BMI or other demographic and psychological characteristics to predict IL-6.

3.2.2. CRP

Greater frequency of daily positive events predicted lower log CRP, controlling for age and gender (Table 2). This association was reduced to non-significance after controlling for household income and race. Positive event frequency interacted with mean levels of daily NA in determining CRP, such that more frequent positive events was associated with lower CRP only among participants with lower NA but not for participants with higher NA ($p = 0.01$ for interaction in fully adjusted model). Positive event frequency did not interact with mean levels of daily PA in predicting CRP (fully adjusted $p = 0.39$), nor did it interact with demographics, BMI, or other psychological characteristics.

3.2.3. Fibrinogen

Positive event frequency did not predict log fibrinogen in an age- and gender-adjusted model ($b = -0.04$, $SE = 0.03$, $p = 0.19$). However, there was a significant interaction between positive event frequency and gender ($b = 0.15$, $SE = 0.06$, $p = 0.02$), such that higher frequency of daily positive events was associated with lower fibrinogen among women ($n = 547$; $p = 0.01$) but not men ($n = 419$; $p = 0.41$). Table 2 shows the results of multivariate models for women only. After controlling for household income and race, positive event frequency was no longer associated with fibrinogen among women. No interaction effects were significant after controlling for covariates, either in gender-stratified models or as 3-way interactions in the sample as a whole (i.e., positive event frequency $\times$ gender $\times$ participant characteristic).

3.3. Secondary analyses

3.3.1. Non-linear associations

In regression models testing quartiles of positive event frequency as predictors, participants in the lowest quartile (positive events on <57% of days) had marginally higher log IL-6 than the second quartile (positive events on 57–79% of days; $b = -0.12$, $SE = 0.06$, $p = 0.055$) and significantly higher IL-6 than the third quartile (positive events on 80–99% of days; $b = -0.20$, $SE = 0.07$, $p = 0.003$) and the fourth quartile (positive events every day; $b = -0.23$, $SE = 0.06$, $p < 0.001$), controlling for age and gender (Fig. 1). The top three positive event quartiles did not differ significantly from one another in IL-6. Compared to the highest quartile, log CRP was elevated among participants in the lowest quartile

Table 2
Positive event frequency predicting inflammatory markers.

	Log IL-6 (pg/mL, $N = 969$) unstandardized B (*SE*)				Log CRP (mg/L, $N = 966$) unstandardized B (*SE*)				Log fibrinogen in women (mg/dL, $N = 547$) unstandardized B (*SE*)			
Variable	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
Intercept	.82 (.03)***	1.14 (.06)***	1.06 (.07)***	1.07 (.07)***	.57 (.05)***	.99 (.10)***	.84 (.11)***	.85 (.11)***	5.85 (.01)***	5.95 (.03)***	5.91 (.03)***	5.90 (.03)***
Positive events	**−.33 (.09)*****	**−.23 (.09)****	**−.19 (.08)***	**−.19 (.08)***	**−.33 (.14)***	−.21 (.14)	−.14 (.13)	−.18 (.13)	**−.11 (.04)****	−.07 (.04)	−.05 (.04)	−.04 (.04)
Age	.02 (.00)***	.02 (.00)***	.01 (.00)***	.01 (.00)***	.01 (.00)	.01 (.00)	.01 (.00)	.01 (.00)	.00 (.00)**	.00 (.00)**	.00 (.00)**	.00 (.00)**
Gender (Ref: Male)	−.10 (.05)*	−.07 (.05)	−.07 (.04)†	−.08 (.04)*	−.44 (.07)***	−.40 (.07)***	−.40 (.07)***	−.39 (.07)***	___	___	___	___
Household income		−.05 (.02)**	−.03 (.02)*	−.04 (.02)*		−.05 (.03)†	−.02 (.02)	−.03 (.03)		−.01 (.01)	−.00 (.01)	.00 (.01)
White race		−.30 (.06)***	−.15 (.06)*	−.15 (.06)**		−.41 (.10)***	−.10 (.09)	−.10 (.09)		−.11 (.03)***	−.08 (.03)**	−.07 (.03)*
Log BMI			1.07 (.11)***	1.05 (.11)***			2.29 (.17)***	2.31 (.17)***			.34 (.05)***	.33 (.05)***
Chronic conditions			.01 (.01)	.01 (.01)			.01 (.01)	.01 (.01)			.00 (.00)	.00 (.00)
Blood pressure med.			.10 (.05)†	.10 (.05)†			.18 (.08)*	.18 (.08)*			−.01 (.03)	−.01 (.03)
Cholesterol med.			−.04 (.05)	−.04 (.05)			−.26 (.08)**	−.27 (.08)***			−.02 (.03)	−.01 (.03)
Corticosteroid med.			−.01 (.10)	−.01 (.10)			−.03 (.16)	−.04 (.16)			−.04 (.05)	−.05 (.05)
Antidepressant med.			.13 (.06)*	.13 (.06)*			.15 (.10)	.15 (.10)			.03 (.03)	.02 (.03)
Current smoker			.13 (.06)*	.14 (.06)*			.17 (.10)†	.19 (.10)†			.04 (.03)	.04 (.03)
Regular exercise			−.16 (.05)**	−.16 (.05)**			−.23 (.08)**	−.24 (.08)**			.00 (.03)	.01 (.03)
Neuroticism				−.04 (.04)				.05 (.07)				−.03 (.02)
Optimism				.00 (.01)				.02 (.01)†				.00 (.00)
Depressive symptoms				.00 (.00)				.00 (.01)				.00 (.00)
Mean daily PA				−.02 (.04)				.02 (.06)				.01 (.02)
Mean daily NA				−.10 (.10)				.01 (.15)				.04 (.05)

*** $p \leqslant .001$.
** $p \leqslant .01$.
* $p \leqslant .05$.
† $p \leqslant .10$.
[a] Model 1 contains age and gender as covariates.
[b] Model 2 includes additional covariates for race and household income quintile.
[c] Model 3 includes additional covariates for physical health, medication use, and health behaviors.
[d] Model 4 includes additional covariates for psychological factors and mean daily affect.

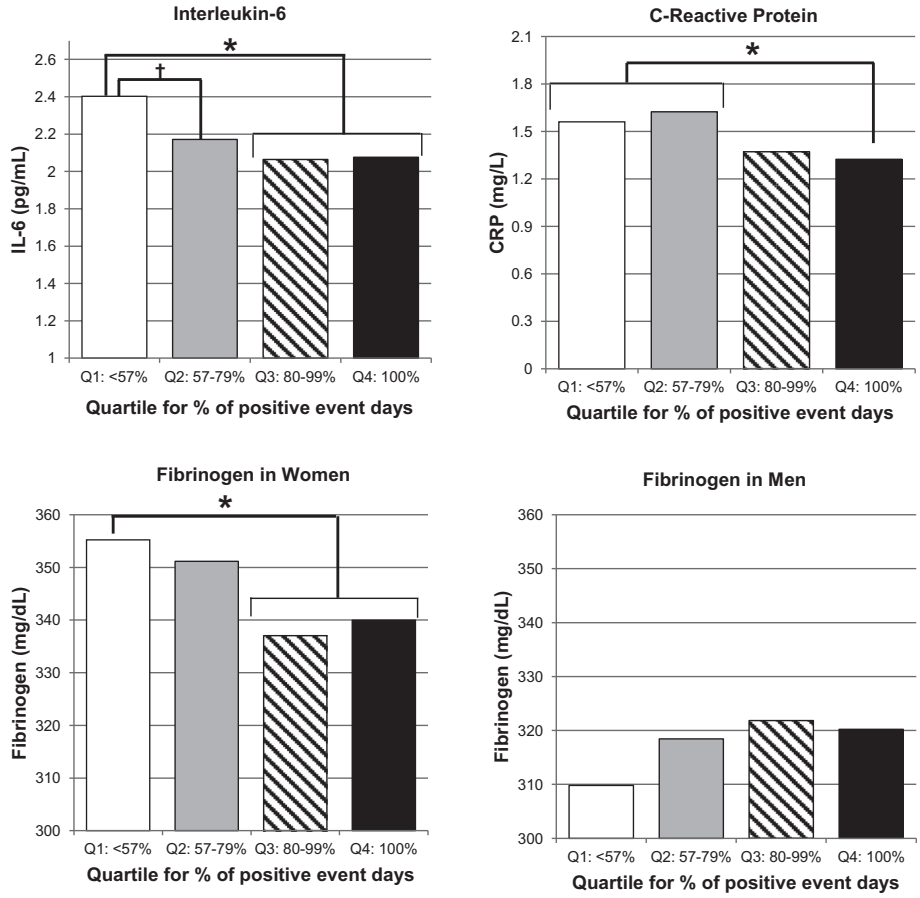

Fig. 1. *Quartiles of positive event frequency as predictors of inflammatory markers, controlling for age and gender.* Participants who experienced fewer daily positive events had the highest levels of inflammation. Those in the 1st quartile (i.e., positive events on <57% of days) had marginally elevated IL-6 compared to the 2nd quartile ($p = 0.055$) and significantly elevated IL-6 compared to the 3rd and 4th quartiles (p values $\leqslant 0.003$). The 1st and 2nd quartiles had higher CRP than the 4th quartile (p values < 0.05). Among women only, fibrinogen was significantly elevated for those in the lowest quartile of positive event frequency, compared to the 3rd and 4th quartiles (p values < 0.05); positive event frequency was not associated with fibrinogen in men. $^{*}p \leqslant .05$, $^{\dagger}p \leqslant .10$.

($b = 0.21$, $SE = 0.10$, $p = 0.04$) and in the second quartile ($b = 0.23$, $SE = 0.10$, $p = 0.02$), but no different for the third quartile ($b = 0.06$, $SE = 0.11$, $p = 0.59$), controlling for age and gender. Fibrinogen did not differ among quartiles for the sample as a whole; however, in women only, the lowest quartile of positive event frequency had higher log fibrinogen than the third quartile (age-adjusted $b = -0.07$, $SE = 0.03$, $p = 0.045$) and the fourth quartile (age-adjusted $b = -0.07$, $SE = 0.03$, $p = 0.04$).

3.3.2. Interpersonal versus non-interpersonal positive events

On average, participants experienced interpersonal positive events on 71% of days (SD = 27%) and non-interpersonal positive events on 9% of days (SD = 15%). The frequency of interpersonal positive events was associated with lower log IL-6 ($b = -0.28$, $SE = 0.09$, $p = 0.001$) but this association did not reach significance for CRP ($b = -0.26$, $SE = 0.14$, $p = 0.066$), controlling for age, gender, and non-interpersonal events. Among women only, frequency of interpersonal positive events predicted lower fibrinogen, independent of age and non-interpersonal events ($b = -0.10$, $SE = 0.04$, $p = 0.02$). The associations of daily interpersonal positive events with IL-6 and with fibrinogen in women were no longer significant in fully adjusted models. Non-interpersonal positive events were not associated with any inflammatory markers, either alone or after controlling for interpersonal positive events.

3.3.3. Affect

Daily PA and NA were not associated with any of the 3 inflammatory markers in unadjusted or adjusted models.

4. Discussion

This study is the first to show that daily positive events, assessed in the context of day-to-day life, are associated with inflammatory markers. In a national sample of 969 midlife and older adults, those who experienced frequent minor positive events tended to have relatively lower IL-6 and CRP, as well as lower fibrinogen among women. The association between frequency of daily positive events and IL-6 persisted after accounting for a range of potential confounding variables, suggesting that even seemingly minor daily experiences are consequential for health.

Our study adds to the growing evidence base linking positive psychological factors to lower levels of inflammation (Brouwers et al., 2013; Friedman and Ryff, 2012; Friedman et al., 2005, 2007; Prather et al., 2007; Steptoe et al., 2008, 2005; Von Känel et al., 2012; Aschbacher et al., 2012). Previous studies have focused on stable psychological characteristics and psychosocial resources (e.g., positive affect and social relations); our study extends these findings by demonstrating the importance of daily events on inflammation. Indeed, recent studies suggest that daily stressors accumulate over time to influence physical and mental health outcomes (Charles et al., 2013; Piazza et al., 2013; Mroczek et al., 2013; Gouin et al., 2012a, 2012b; Fuligni et al., 2009). One previous study of 108 healthy younger adults (mean age of 36) showed that daily positive experiences were marginally associated with lower IL-6 (Jain et al., 2007). In contrast, our study may have found significant effects due to the larger sample size, inclusion of participants regardless of medical comorbidities, greater age-related variability

in inflammation, and use of daily diary methodology for assessing daily events.

The links between daily positive events and inflammatory markers were explained or moderated by socioeconomic status and gender. Specifically, the findings for CRP and fibrinogen were accounted for by race and household income. In line with previous research on health disparities, White participants had significantly lower BMI and lower levels of all 3 inflammatory markers relative to non-White (primarily African American or Black) participants. White participants in our sample had more positive experiences in their daily lives; they reported positive events on 75% of days, compared to 64% for non-White participants. Yet, daily positive events may have represented a source of resilience that protected against the influence of economic disadvantage on IL-6. High-income participants did not differ in IL-6 based on their frequency of positive events, whereas low-income participants who experienced more frequent positive events had lower IL-6 than their counterparts who had fewer positive events. Prior studies have uncovered similar trends, in which positive aspects of psychological well-being (e.g., purpose in life, social relations) buffered against the detrimental effects of low educational attainment and medical comorbidities on inflammation (Friedman and Ryff, 2012; Morozink et al., 2010). Furthermore, there were gender differences in the association between daily positive events and fibrinogen. Our finding that positive event frequency was associated with lower fibrinogen only among women was consistent with a study of the Whitehall II cohort, in which positive affect was inversely associated with inflammatory markers among women but not men (Steptoe et al., 2008). Further work is needed to understand racial, socioeconomic, and gender differences in the role of daily experiences on health.

Notably, there was not a clear dose–response relationship between daily positive events and inflammatory markers. The effects were most pronounced among participants in the lowest quartile of positive event frequency (<57% of days), whose average anti-logged IL-6 level was 0.30 pg/mL higher than those in the top 3 quartiles of positive event frequency. In contrast, average IL-6 levels only varied by 0.01–0.11 pg/mL among the top 3 quartiles. Thus, consistent with past research (Deverts et al., 2010), lack of positivity appears to be particularly important for inflammation.

Prior research has found that social support and interpersonal interactions are important for health and well-being. As expected, we found that interpersonal positive events predicted lower IL-6 in the entire sample and lower fibrinogen in women, but non-interpersonal positive events were not associated with inflammatory markers. However, the findings for daily positive events as a whole were stronger than those for interpersonal events alone, indicating that interpersonal events are not the only type of positive experiences that are important for inflammation. The potential health effects of different types of positive experiences, their intensity, and subjective appraisals, are all topics that deserve further study.

Unlike previous research, positive and negative affect did not predict inflammation in the current study. Prior studies have primarily used measures of stable, recollected affect, in which participants rated their affect in general or over a specified period (e.g., past 2 weeks), whereas the present research used an aggregate measure of daily affect across 8 days. Recollected affect may differ from actual experience of affect because it is susceptible to memory biases and global evaluations of one's life (Kahneman and Riis, 2005). Few studies have compared momentary or daily measures of affect versus recollected measures for predicting physiological functioning (Daly, 2012; Steptoe et al., 2007). There was a moderating effect of daily NA in our study, whereby positive event frequency was associated with lower CRP only among participants with lower NA but not for those with higher NA. The positive events reported by participants were minor and common in daily life, such as gardening, spending time with family, or having a pleasant conversation; these experiences were perhaps not potent enough to counteract the inflammatory effects of frequent negative emotions (which occurred independent of trait neuroticism, optimism/pessimism, and depressive symptoms).

The mechanisms linking daily positive events to inflammation are unclear. The association was not explained by mean daily affect, suggesting that the findings were not merely driven by overall levels of affect. However, participants' perceptions of the events were not obtained. Our measures of end-of-day affect (aggregated across interview days) may have lacked the temporal sensitivity for capturing small changes in affect in response to the positive events. Momentary assessments would be ideal for examining affective reactions, perceptions, and contexts surrounding minor positive events in everyday life. Alternatively, positive psychological factors have been linked to better health behaviors that are consequential for inflammation, including non-smoking, physical activity, moderate alcohol consumption, and prudent dietary choices (Grant et al., 2009; Steptoe et al., 2006). Our measures of smoking and exercise were associated with inflammatory markers in the predicted directions, but they were not precise enough to examine the momentary coupling of positive experiences and health behaviors. Finally, daily positive events may be linked to lower inflammation via its role in stress processes. Daily stress elicits secretion of glucocorticoids, including cortisol (Stawski et al., 2013); persistently high cortisol output can lead to down-regulation of glucocorticoid receptors that subsequently diminishes the sensitivity of the immune system to cortisol's anti-inflammatory effects (Miller et al., 2002). Positive psychological factors have been shown to undo the physiological effects of stress (Fredrickson et al., 2000), enhance cognitive flexibility (e.g., creative problem-solving) and psychosocial resources for coping with stress (Fredrickson, 1998), and reduce physiological reactivity to stressors (Aschbacher et al., 2012; Steptoe et al., 2005).

Our study was limited in several ways. First, the MIDUS sample is more affluent and educated than the general population. Caution should be taken in generalizing the results to other samples. Second, this study was cross-sectional and therefore causal conclusions cannot be drawn regarding the directionality of the association between daily positive events and inflammation. Laboratory studies suggest that positive affect predicts lower inflammatory responses to stress tasks (Aschbacher et al., 2012; Steptoe et al., 2005); yet, other research has shown that elevated inflammation induces depressed mood and sickness behaviors that may subsequently impair daily functioning (Dantzer et al., 2008). Future studies using a longitudinal design and multiple assessments of inflammation are needed to better understand the role of daily experiences in inflammation.

In summary, the current study is the first to provide evidence that daily positive experiences are associated with lower levels of inflammation among midlife and older adults. Our study expands upon the literature on positivity and health, by demonstrating that exogenous positive experiences may be just as consequential for physiological functioning as trait positive affect and other positive psychological factors. These findings underscore the importance of examining positive aspects of day-to-day life, which are far more common than negative events and may accumulate over time to influence long-term health.

Conflict of interest

The authors have no conflicts of interest to disclose.

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