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BRIEF REPORT

Activity Mediates Conscientiousness' Relationship to Diurnal Cortisol Slope in a National Sample

Tim Bogg and Richard B. Slatcher
Wayne State University

Objective: The present study explored pathways from the personality traits of neuroticism and conscientiousness through health-related behaviors to diurnal patterns of the stress hormone cortisol using data from a large national study. ***Method:*** Using prospective data from the Midlife in the United States (MIDUS II) study and the National Study of Daily Experiences (NSDE II, a MIDUS substudy), hierarchical linear modeling (HLM) and Monte Carlo estimation for multilevel model mediation were used to test direct and indirect effects (via general activity level, moderate and vigorous physical activity, lifetime history of regular smoking, and alcohol consumption) of neuroticism and conscientiousness on cortisol at wakeup, diurnal cortisol slope, and cortisol awakening response ($N = 960$). ***Results:*** Initial HLM models showed greater levels of conscientiousness were associated with steeper (i.e., healthier) diurnal cortisol slope. Consistent with a hypothesized indirect biobehavioral pathway, when controlling for demographic factors, cortisol-related medications, daily stressors, and positive affect, HLM models showed the relationship between conscientiousness and diurnal cortisol slope was mediated by general activity levels. Lifetime history of smoking was associated with flatter diurnal cortisol slope, but did not mediate the effect of conscientiousness on diurnal cortisol slope. No effects were found for neuroticism. ***Conclusions:*** The results support a psychophysiological model of resilience—one that provides a more complete rendering of the health-protective mechanisms of conscientiousness via hypothalamic-pituitary-adrenal axis functioning. Specifically, the mediated pathway suggests greater engagement in the activities of day-to-day life are an instrumental means by which conscientious individuals experience healthier patterns of stress hormone secretion.

Keywords: personality, conscientiousness, cortisol, activity, stress

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The Big Five personality traits of Neuroticism (stable vs. anxious) and Conscientiousness (industrious vs. irresponsible) demonstrate consistent relations with significant health-related behaviors and outcomes, including physical activity, coping, and mortality (Bogg & Roberts, 2013; Lahey, 2009). However, to date, a limited number of the possible pathways from these traits to physiological indicators of health have been identified, some of which relate to immune system functioning (e.g., Turiano, Thorsteinsson, Rooke, & Schutte, 2013). Although the relationships between neuroticism and conscientiousness and immunity are noteworthy, the expression of these markers is regulated, in part, by the hypothalamic-pituitary-adrenal (HPA) axis. As the system primarily responsible for orchestrating biological responses to perceived stressors, the HPA axis—and its hormonal product, cortisol, in particular—has shown links to several health problems, including insulin resistance and compromised immune functioning (Cacioppo et al., 2002; Rosmond, 2005).

Recent research investigating associations between neuroticism and conscientiousness and diurnal cortisol secretion has not shown consistent associations between these traits and area under the curve, wakeup, and cortisol awakening response (CAR) measures of cortisol secretion (Laceulle, Nederhof, van Aken, & Ormel, 2014; Nater, Hoppmann, & Klumb, 2010; van Santen et al., 2011). However, these studies did not examine associations between neuroticism and conscientiousness and diurnal cortisol slope—a marker of HPA axis functioning shown to be associated with Type II diabetes status, preclinical atherosclerosis, and increased mortality risk (Hackett, Steptoe, & Kumari, 2014; Hajat et al., 2013; Kumari, Shipley, Stafford, & Kivimaki, 2011).

Meta-analytic research has shown conscientious and emotionally stable (inverse of neuroticism) individuals tend to perceive, manage, and cope with stressors better than their less conscientious and more neurotic counterparts (Connor-Smith & Flachsbart, 2007). To the extent that greater levels of conscientiousness and

Tim Bogg and Richard B. Slatcher, Department of Psychology, Wayne State University.

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Correspondence concerning this article should be addressed to Tim Bogg, Department of Psychology, Wayne State University, 5057 Woodward Avenue, 7th Floor, Detroit, MI 48202. E-mail: tdbogg@gmail.com

emotional stability represent aspects of psychological resilience to stressors (cf. Connor & Davidson, 2003), then higher standing on these traits should be associated with steeper diurnal cortisol slopes.

In addition to the direct associations anticipated between conscientiousness and neuroticism and diurnal cortisol slopes, the accumulated research suggests the possibility of indirect biobehavioral pathways from these traits to individual differences in diurnal cortisol slopes. Consistent with meta-analytic findings of associations between greater conscientiousness and emotional stability and greater activity levels, less (or no) cigarette smoking, and less alcohol consumption (Bogg & Roberts, 2004; Malouff, Thorsteinsson, Rooke, & Schutte, 2007; Malouff, Thorsteinsson, & Schutte, 2006; Rhodes & Smith, 2006), as well as research showing relationships between greater activity, less (or no) smoking, and less alcohol consumption and healthier diurnal cortisol patterns (King, Munisamy, de Wit, & Lin, 2006; Vreeburg et al., 2009), a mediated relationship is expected between neuroticism and conscientiousness and diurnal cortisol slopes.

In this way, emotional stability (i.e., low neuroticism), conscientiousness, activity, not smoking, and lower alcohol consumption can be viewed as components of positive psychological resilience. An examination of standing on neuroticism and conscientiousness in isolation (i.e., without a consideration of behavioral mediators) could only show that a set of general tendencies has an effect on subsequent patterns of HPA axis function, but would do little to explain *how* the effect occurs. To the extent that individual differences in neuroticism and conscientiousness are made manifest through these health-related behaviors, then such behaviors may act as pathways linking neuroticism and conscientiousness to diurnal cortisol secretion.

Using a large national sample, a prospective design, and multiple cortisol parameters—including diurnal slope—the current study provides a strong test of these direct and indirect pathways from neuroticism and conscientiousness to diurnal cortisol secretion.

Method

The online supplemental materials provide complete details and descriptions for the measures, protocols, and analytic strategy, including descriptive statistics for the study variables (see Supplemental Table 1).

The data for this study were drawn from the second wave of the National Study of Daily Experiences (NSDE II), a subsample of Midlife in the United States (MIDUS) II—the second wave of data collection for MIDUS I, a large panel survey of adults between the ages of 25 and 74 years. For the current study, the sample consisted of 960 adults.

Measures

Measures of neuroticism and conscientiousness were administered during the MIDUS II assessment. On Days 2 through 5 of the 8-day NSDE II study period (which occurred, on average, 20.54 months [$SD = 13.57$] after the MIDUS II assessment), participants self-collected saliva samples at four time points each day: immediately upon waking, 30 min later to assess CAR, before lunch, and at bedtime. Cortisol values were natural log-transformed to correct for positive skew in the cortisol distribution (Adam & Kumari, 2009), and a constant of 1 was added prior to transformation so that all transformed scores were positive. Age, sex, education, race/ethnicity, average wake time, the use of any cortisol-related medications, daily stressors during the 8-day NSDE II study period, waist circumference (in inches) assessed during MIDUS II, and a nine-item Positive Affect scale assessed during MIDUS II were included as covariates. During the MIDUS II assessment, the reported frequencies of both moderate and vigorous leisure time physical activity during summer and winter were assessed. For analytic purposes, the moderate and vigorous frequencies were first summed for summer and winter. In turn, the means of summer and winter moderate and vigorous scores were calculated to provide average scores of both moderate and vigorous leisure time physical activity across summer and winter (these scores were Blom-transformed to reduce skew and kurtosis). During the MIDUS II assessment, general activity level was measured with a single item. Using data from both MIDUS I and MIDUS II (to help account for missing data), lifetime history of regular smoking was assessed. During MIDUS II, the past-month weekly frequency of consuming at least one alcoholic beverage was assessed.

Data Analysis

Hierarchical linear modeling (HLM) was used to estimate cortisol parameters (cortisol at wakeup, slope, and CAR) and predict individual differences in cortisol profiles.

Results

The online supplemental materials provide additional details pertaining to the analyses and results.

When entering conscientiousness and neuroticism together as predictors of diurnal cortisol parameters in an HLM model without any covariates, neuroticism did not predict wakeup cortisol, cortisol slope, or CAR. Conscientiousness was associated with a steeper (healthier) cortisol slope (see Table 1, Model 1),[1] but was unrelated to either wakeup cortisol levels or CAR. Figure 1 depicts the differences in diurnal cortisol slope at high (1 *SD* above the mean) and low (1 *SD* below the mean) levels of conscientiousness.

Testing Direct Effects of Candidate Mediators

Model 2 in Table 1 tests the direct effects of general activity level, moderate and vigorous physical activity, and lifetime history of regular smoking (because there was no simple effect of alcohol consumption frequency on any of the cortisol parameters, it was excluded from the models). Activity and moderate and vigorous physical activity were associated with a steeper (healthier) cortisol slope. Lifetime history of regular smoking was associated with a flatter (less healthy) slope. None of the candidate mediators predicted wakeup cortisol or CAR.

[1] When conscientiousness was used as the only predictor of cortisol parameters, it was associated with a steeper cortisol slope ($\beta 11 = -0.008$, $SE = 0.003$, $p = .016$). Thus, the association between conscientiousness and cortisol slope was significant whether or not neuroticism was included in the model as a predictor.

Table 1
Multilevel Growth-Curve Models of Diurnal Cortisol Parameters

Fixed effect (independent variable)	Model 1 Estimate (*SE*)	Model 1 *p*	Model 2 Estimate (*SE*)	Model 2 *p*	Model 3 Estimate (*SE*)	Model 3 *p*
			Wakeup cortisol, π0			
Average wakeup cortisol (intercept), β00	2.676 (0.020)	<.001	2.678 (0.024)	<.001	2.848 (0.060)	<.001
Neuroticism, β04	.002 (0.026)	.940	.012 (0.030)	.660	.044 (0.027)	.106
Conscientiousness, β05	.024 (0.040)	.539	.011 (0.041)	.799	.054 (0.046)	.231
General activity level, β010	—	—	.022 (0.024)	.367	.013 (0.027)	.613
Moderate and vigorous physical activity, β012	—	—	.026 (0.018)	.148	.024 (0.020)	.226
Lifetime history of regular smoking, β014	—	—	−.003 (0.032)	.930	−.011 (0.031)	.719
Age, β01	—	—	—	—	.006 (0.002)	<.001
Female, β02	—	—	—	—	−.124 (0.034)	.001
Ethnicity, β07	—	—	—	—	−.114 (0.075)	.128
Education, β08	—	—	—	—	.095 (0.034)	.005
Average wake time, β09	—	—	—	—	−.014 (0.017)	.412
Taking cortisol medications, β013	—	—	—	—	−.072 (0.032)	.026
Waist circumference, β03	—	—	—	—	−.001 (0.001)	.533
Positive affect, β011	—	—	—	—	−.030 (0.028)	.278
Number of daily stressors, β06	—	—	—	—	.003 (0.005)	.601
			Time since waking, π1			
Average linear slope, β10	−.135 (0.004)	<.001	−.141 (0.004)	<.001	−.140 (0.006)	<.001
Neuroticism, β14	.001 (0.002)	.743	−.001 (0.002)	.578	.001 (0.002)	.820
Conscientiousness, β15	−.007 (0.003)	.022	−.005 (0.003)	.144	−.006 (0.002)	.083
General activity level, β110	—	—	−.003 (0.002)	.045	−.006 (0.002)	.003
Moderate and vigorous physical activity, β112	—	—	−.003 (0.001)	.042	−.001 (0.001)	.398
Lifetime history of regular smoking, β114	—	—	.010 (.003)	<.001	.008 (0.003)	.001
Age, β11	—	—	—	—	.000 (0.000)	.054
Female, β12	—	—	—	—	−.002 (0.004)	.601
Ethnicity, β17	—	—	—	—	.026 (0.007)	<.001
Education, β18	—	—	—	—	−.008 (0.003)	.005
Average wake time, β19	—	—	—	—	−.002 (0.001)	.224
Taking cortisol medications, β113	—	—	—	—	.006 (0.003)	.026
Waist circumference, β13	—	—	—	—	−.000 (0.000)	.354
Positive affect, β111	—	—	—	—	.004 (0.002)	.076
Number of daily stressors, β16	—	—	—	—	.000 (0.000)	.848
			Time since waking–squared, π2			
Average curvature, β20	.003 (0.000)	<.001	.003 (0.000)	<.001	.003 (0.000)	<.001
			Cortisol awaking response, π3			
Average CAR, β30	.414 (0.012)	<.001	.393 (0.019)	<.001	.267 (0.047)	<.001
Neuroticism, β34	.012 (0.018)	.505	.016 (0.019)	.407	.006 (0.021)	.771
Conscientiousness, β35	.008 (0.030)	.774	.007 (0.029)	.815	−.005 (0.030)	.873
General activity level, β310	—	—	.013 (0.016)	.423	.006 (0.018)	.743
Moderate and vigorous physical activity, β312	—	—	−.023 (0.013)	.088	−.017 (0.014)	.215
Lifetime history of regular smoking, β314	—	—	.035 (0.024)	.147	.039 (0.025)	.117
Age, β31	—	—	—	—	.002 (0.001)	.083
Female, β32	—	—	—	—	.073 (0.026)	.004
Ethnicity, β37	—	—	—	—	.040 (0.058)	.486
Education, β38	—	—	—	—	−.017 (0.025)	.515
Average wake time, β39	—	—	—	—	−.022 (0.009)	.013
Taking cortisol medications, β313	—	—	—	—	.049 (0.025)	.053
Waist circumference, β33	—	—	—	—	−.001 (0.001)	.196
Positive affect, β311	—	—	—	—	.010 (0.025)	.677
Number of daily stressors, β36	—	—	—	—	.011 (0.005)	.021

Note. Intercepts indicate average log-transformed cortisol values at wakeup; average slopes of time since waking indicate change in log-transformed cortisol per 1-hr change in time; average slopes of time since waking-squared indicate change in log-transformed cortisol per 1-hr change in time-squared. Because cortisol values were subjected to a natural log transformation, the reported betas can be interpreted as percent change in the cortisol parameter per unit change in the predictor variable, after applying the following transformation: $\beta_{\%change} = [\exp \beta_{raw}] - 1$ (cf. Adam et al., 2006). For example, in Model 1, the beta for conscientiousness in the prediction of the time since waking parameter is –.007. This means there is a predicted .7 % steepening of the slope per unit increase in conscientiousness. For lifetime history of regular smoking, 0 = no history, 1 = history reported at Midlife in the United States study I or II; for sex, male = 1, female = 2; for ethnicity, 0 = White, 1 = non-White; for education, 0 = high school or less, 1 = some college or more; for cortisol medications, 0 = none, 1 = one or more. CAR = cortisol awakening response.

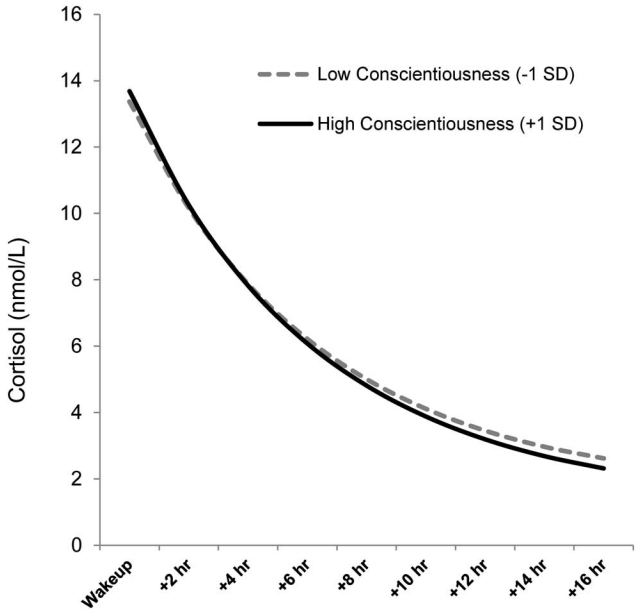

Figure 1. Association between conscientiousness and predicted cortisol values. Because cortisol values were natural-log transformed, the inverse of that transformation (the exponential function) was applied to return predicted cortisol values to the original scale of measurement. High values for conscientiousness are plotted at +1 standard deviation from the mean, and low values are plotted at −1 standard deviation from the mean.

Testing Mediation by General Activity Level, Moderate and Vigorous Physical Activity, or Lifetime Smoking History

Regression and HLM analyses were used to test whether the association between conscientiousness and steeper diurnal cortisol slopes could be explained by people high in conscientiousness generally being more active, engaging in more moderate and vigorous physical activity, and/or not having a lifetime history of regular smoking.

Simple regression analyses showed conscientiousness significantly predicted general activity levels ($b = .588$, $SE = .065$, $p < .001$, 95% CI [.461, .716]) and moderate and vigorous physical activity ($b = .138$, $SE = 0.069$, $p = .046$, 95% CI [0.003, .274]), but did not significantly predict lifetime smoking history ($b = -.071$, $SE = .037$, $p = .054$, 95% CI [−.143, .001]). As shown in Model 2 of Table 1, the effect of conscientiousness on cortisol slope was no longer significant with general activity, moderate and vigorous activity, and lifetime smoking history in the model. The small/marginal effects for conscientiousness on moderate and vigorous activity and lifetime smoking history in the simple regression analyses precluded tests of mediation for these variables.

We next tested the indirect effect of conscientiousness via general activity on cortisol slope. To evaluate this, Model 3 was used to examine the direct effect of general activity on cortisol slope when controlling for demographic factors, cortisol-related medications, smoking history, daily stressors, and positive affect, as well as moderate and vigorous physical activity, lifetime smoking history, and neuroticism. As shown in Model 3 of Table 1, general activity remained a significant predictor of cortisol slope. Monte Carlo estimation analyses showed the indirect effect of conscientiousness on cortisol slope via general activity was significant (95% CI [−0.009, −0.002]).

Discussion

To our knowledge, this is the first study to examine prospective relationships between the Big Five personality domains of Neuroticism and Conscientiousness and diurnal cortisol slopes. Using data from a large national sample, the results showed individuals with greater levels of conscientiousness tended to have healthier diurnal cortisol slopes compared with individuals with lower levels of conscientiousness. Consistent with the hypothesized relevance of activity levels as a behavioral route by which the relationship between conscientiousness and diurnal cortisol levels might be maintained, the results showed general activity levels mediated the association between conscientiousness and diurnal cortisol slopes, even when controlling for a host of other factors. Other research using MIDUS data has shown associations between conscientiousness and interleukin-6, a marker of inflammation (Turiano et al., 2013). The current findings extend this work by showing how conscientiousness is associated with HPA axis regulation—the system that is partly responsible for the expression of markers of chronic inflammation.

The mediating effect by general activity suggests the importance of greater engagement in day-to-day life as an instrumental means by which middle-aged conscientious individuals experience healthier diurnal cortisol slopes. Moreover, although physical activity and general activity were associated with each other (as would be expected), as well as with conscientiousness and diurnal cortisol slope, the mediated effect only held for general activity levels. This differentiated pattern of effects suggests that it is through the broader pattern of activity, rather than through the narrower form of leisure-time physical activity per se, that conscientious individuals experience healthier diurnal cortisol slopes. Future research is required to replicate and probe this finding to determine the conscientiousness- and cortisol-related components of life engagement. It is likely to be a multifaceted mixture of cognitive/intellectual (e.g., vocational or avocational), social (e.g., scheduled outings, meetings, or dates), and physical (e.g., leisure or nonleisure exertion) engagement that explains the mediated effect for general activity found in the present study.

Although the results of the current study are noteworthy, it is important to emphasize that only brief omnibus measures of the Big Five were available for analysis, possibly obscuring effects that might be present at the facet levels of Neuroticism and Conscientiousness. Moreover, a more thorough assessment of general activity levels via multi-item scale and/or a diary-based account of daily activity patterns is required to advance an understanding of the specific forms and/or intensities of activities that mediate the association between conscientiousness and diurnal cortisol slope. Similarly, future research should assess cigarette smoking with greater specificity.

The findings of the present study (a) add to a growing body of research linking conscientiousness to markers of physical health, and (b) illuminate a novel pathway by which this broad disposition

confers protective effects against forms of morbidity and reduced longevity via neuroendocrine functioning.[2]

[2] Please see the online supplemental materials for an expanded discussion of measurement limitations, implications regarding the cross-temporal stability of diurnal cortisol slope, and future directions related to possible personality-informed interventions for fostering greater activity and engagement in day-to-day life.

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