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Self-esteem change and diurnal cortisol secretion in older adulthood

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Summary

Objective: Research suggests that self-esteem can decline in older adulthood. This process could remove a buffer that normally protects individuals against distress-related changes in cortisol secretion. We examined this possibility by testing whether change in self-esteem would predict alterations in cortisol secretion, particularly among older adults who reported high levels of depressive symptoms or perceived stress.

Methods: 147 older adults (aged 60+) completed three days of diurnal cortisol measurements at three different time points, namely every two years over a total period of four years. Measures of self-esteem, depressive symptoms, and perceived stress were assessed at T1 and T2. Potential demographic and health-related confounds were measured at baseline (partnership status, SES, mortality risk index, and medication).

Results: Linear regression models indicated that a decline in self-esteem from T1 to T2 predicted elevated cortisol output (AUC_G) from T2 to T3, F (1, 137) = 8.09, $\beta = -.25$, $R^2 = .05$, $p = .005$. Interaction analyses revealed that this association was particularly strong among participants who experienced higher T1 or T2 levels of depressive symptoms or perceived stress, +1 *SD*: $\beta s = -.34$ to $-.51$, $ps < .001$, but not significant among their counterparts who reported relatively lower levels of depressive symptoms or perceived stress, -1 *SD*: $\beta s = .03$ to 11, $ps > .43$.

Conclusions: Declines in self-esteem represent a mechanism that contributes to higher levels of diurnal cortisol secretion if older adults experience psychological distress. Increases in self-esteem, by contrast, can ameliorate older adults' cortisol regulation in stressful circumstances.

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1. Introduction

Self-esteem is a psychological variable reflecting a person's general feelings of self-worth across different areas of life (Rosenberg, 1986). Research has identified self-esteem as an adaptive personality dimension that can be associated with subjective well-being, effective biological regulation, and physical health (Pruessner et al., 1999; Orth et al., 2012). Such effects of self-esteem may occur because it ameliorates the psychological consequences of difficult life circumstances (Greenberg et al., 1992) and has adaptive downstream implications for stress-related biological processes (Pruessner et al., 1999). Here we examine whether longitudinal changes in self-esteem can also be associated with stress-related alterations in the regulation of cortisol produced by the hypothalamic-pituitary-adrenocortical (HPA) axis.

1.1. Self-esteem and cortisol in the context of distress

Psychological theories suggest that sustained perceptions of stress and associated depressive symptoms can elicit changes in the functioning of individuals' hormonal system (Folkman and Lazarus, 1986; Cohen et al., 2007). A large number of studies have supported this assumption by showing that stress and negative emotions activate the HPA axis to release cortisol into the circulation. This process has been documented in laboratory studies that examine the hormonal effects of induced stress, as well as in field studies that observe the biological consequences of naturally occurring problems and emotions (Kirschbaum et al., 1993, 1995; Dickerson and Kemeny, 2004; Miller et al., 2007).

The release of cortisol is thought to be an important process because it can mediate a variety of behavioral and physiological responses to stressful life circumstances. On the one hand, cortisol is likely to facilitate effective behaviors in the context of pressing demands (Taylor et al., 2000). On the other hand, cortisol can have damaging effects on health-relevant biological processes when it is overproduced or dysregulated. Particularly, prolonged activation of the HPA axis may interfere with the regulation of other physiological systems, such as immune function, and has been associated with markers of systemic inflammation, physical health problems, and mortality (Sephton et al., 2000; Wrosch et al., 2009; Rueggeberg et al., 2012). However, blunted forms of cortisol dysregulation, may also predict health-related problems, perhaps as a consequence of a depletion of the system (Heim et al., 2000; Fries et al., 2005).

Despite its general occurrence, there is much variability in the effect of stressful experiences on cortisol secretion (Kudielka et al., 2009), which may in part be due to psychological characteristics that are involved in the adjustment to stress (Wrosch et al., 2007; O'Donnell et al., 2008). One factor that could facilitate adjustment to stressful situations relates to individual differences in self-esteem. Research suggests that self-esteem can promote effective coping (Baumeister et al., 2003) and is associated with less threatening appraisals of problematic situations (Orth et al., 2009; Ford and Collins, 2010). Such benefits of self-esteem, in turn, could prevent stress-related disturbances of the HPA axis. In support of this assumption, Pruessner and colleagues (1999) demonstrated that participants with low self-esteem secreted higher levels of cortisol in response to a stressor than their high self-esteem counterparts. Other research showed conceptually comparable findings by documenting that self-esteem modulates neuroendocrine responses to age-related challenges, experiences of shame, and threats to the social self (Seeman et al., 1995; Gruenewald et al., 2004; Ford and Collins, 2010).

1.2. Self-esteem change in older adulthood

The documented effects of self-esteem on levels of cortisol secretion may become particularly important in older adulthood, when many individuals encounter increasing age-related stressors (e.g., onset of physical disease or social network declines; Lang and Carstensen, 1994; Heckhausen et al., 2010) and secrete enhanced levels of cortisol (Sapolsky et al., 1986; Sapolsky, 1992; Lupien et al., 2005). In addition, age-comparative research suggests that levels of self-esteem can change in older adulthood. For example, there is evidence for an increasing variability in self-esteem at progressively older ages (Trzesniewski et al., 2003). Moreover, research has documented age-related declines in older adults' self-esteem, which could derive from a loss of social roles or an increase in physical health problems (Robins et al., 2002; Shaw et al., 2010; Orth et al., 2010). Other research, however, indicates that levels of self-esteem can remain fairly stable in old age or gradually increase throughout adulthood (Gove et al., 1989; Collins and Smyer, 2005; Wagner et al., 2013), which suggests that effective personality functioning could also be preserved into old age (Haase et al., 2013).

Although this mixed pattern of findings implies that there is inconsistency regarding the direction of change in older adults' self-esteem, it makes it likely that self-esteem could change for different older adults in different directions. Further, such inter-individual differences in the direction of change in self-esteem could play a role in determining older adults' diurnal cortisol secretion. In particular, if older adults perceive high levels of stress or depressive symptoms, longitudinal declines in self-esteem could put them at an enhanced risk of exhibiting an increase in cortisol secretion. The maintenance or increase of self-esteem, by contrast, could buffer cortisol increases in stressful circumstances.

1.3. The present study

We analyzed associations between self-esteem, psychological distress, and diurnal cortisol in three waves of data, collected over four years, from a heterogeneous sample of community-dwelling older adults. We expected that declines, as compared to increases, in self-esteem over the first two years of study would predict concurrent and subsequent increases in participants' diurnal cortisol volume. In addition, we hypothesized that such effects would become paramount if older adults perceive high, as compared to low, levels of stress or depressive symptomatology.

2. Methods

2.1. Participants

Data were collected as part of a larger longitudinal project with community-dwelling older adults known as the "Montreal Aging and Health Study" (MAHS).[1] Participants were recruited through newspaper advertisements from the greater Montreal area. The population of interest was older adults, thus the only eligibility criteria was a minimum age of 60 years.

The baseline assessment of the MAHS included 215 participants (T1) and subsequent waves of the study were conducted every two years. This study reports data from the first three waves of the MAHS, which included 181 and 164 participants in the two-year (T2) and four-year (T3) follow-ups, respectively. Study attrition from T1 to T3 was attributable to death ($n = 13$), refusal in study participation ($n = 8$), lost contact ($n = 13$), or withdrawal due to personal reasons ($n = 17$). Of the 164 participants at T3, 17 participants were further excluded because they either did not provide data on cortisol ($n = 13$) or self-esteem ($n = 4$).[2] Thus, the final analytic sample consisted of 147 participants. Study attrition was not significantly associated with baseline measures of the study variables, except for participants' age. Older participants were more likely than younger participants to discontinue the study over the three waves ($t[129.14] = 2.49$, $p = .01$) (for distribution of study variables, see Table 1). The Concordia University Research Ethics Board approved all procedures.

2.2. Procedure

Participants were scheduled for study visits during each wave of assessment. If they were unable to visit the laboratory, they were assessed in their homes. After obtaining informed consent, participants were asked to respond to a larger questionnaire that included all reported study measures. At each visit, they were further instructed to collect saliva samples over the course of three non-consecutive typical days. After completion of study measures at each visit, all materials were collected and participants were compensated with $50.

2.3. Materials

The main study variables included measures of participants' diurnal cortisol volume, self-esteem, perceived stress, and depressive symptoms. To minimize the possibility of confounding associations with the main study constructs, the analysis included sociodemographic and health-related covariates (i.e., partnership status, socioeconomic status [SES], mortality index, and cortisol-related medication usage).

Table 1 Means, standard deviations, and frequencies of main study variables ($N = 147$).

Constructs	*M* (*SD*) or percentage [a]	Range
Diurnal cortisol volume (AUC_G) (log nmol/l h)		
T1	12.18 (2.49)	6.16–18.70
T2	12.77 (2.38)	5.72–24.25
T3	12.93 (2.57)	5.97–19.96
Self-esteem (T1)	22.61 (4.13)	12–30
Self-esteem (T2)	22.31 (4.40)	9–30
Depressive symptoms (T1)	5.74 (4.32)	0–18
Depressive symptoms (T2)	6.62 (5.44)	0–23
Perceived stress (T1)	2.44 (0.65)	1–4.90
Perceived stress (T2)	2.44 (0.66)	1–4.30
Mortality risk index (T1)	5.66 (2.35)	2–13
Age (y)	71.44 (5.22)	64–90
Male (%)	49.70	
Diabetes (%)	15.00	
Cancer (%)	2.70	
Lung or other respiratory disease (%)	11.60	
Heart condition (%)	18.40	
BMI < 25 (%)	40.70	
Current smoker (%)	11.00	
Difficulty bathing (%)	2.00	
Difficulty walking around the home (%)	2.00	
Difficulty managing finances (%)	2.70	
Difficulty doing heavy housework (%)	18.40	
Married/living with partner (T1) (%)	53.70	
Socioeconomic status (T1)	−.01 (.82)	−1.83–2.12
Education [b]	2.09 (1.08)	0–4
Yearly family income [c]	1.54 (1.28)	0–5
Perceived social status	6.20 (1.76)	0–10
Cortisol-related medication (T1) (%)	82.30	

Notes: *M*, mean; *SD*, standard deviation; AUC, area under the curve.

[a] *M* and *SD* are presented for continuous variables.

[b] Education was indexed as 0 = no education, 1 = high school, 2 = trade or collegiate, 3 = bachelors, and 4 = masters or doctorate.

[c] Yearly family income was indexed as 0 = less than $17,000, 1 = up to $34,000, 2 = up to $51,000, 3 = up to $68,000, 4 = up to $85,000, and 5 = more than $85,000.

Diurnal cortisol volume (AUC_G) was measured at all three waves. Participants were asked to collect saliva samples (using cotton swabs in sterile plastic containers called salivettes, Sarstedt, Quebec City, Canada) across three non-consecutive typical days, at specific times of the day (awakening, 30-min, 2 PM, 4 PM, and bedtime). They collected the first sample when they woke up, and were

[1] Note that the MAHS is an ongoing longitudinal study and data on cortisol secretion have been reported in other manuscripts (e.g., Wrosch et al., 2007; Jobin et al., 2013). However, none of the previously published studies examined the effects of self-esteem on participants' cortisol secretion.

[2] Missing data for other variables were replaced with the respective sample mean prior to conducting the analyses and were related to BMI (2 missing), smoking (2 missing), and T2 depressive symptoms (1 missing).

provided with a timer to collect the 30-min measure. The research assistant subsequently reminded the participants by phone to collect the afternoon samples at 2 and 4 PM. The participants collected the last sample of the day themselves, at bedtime. Time of day was recorded for all samples. To prevent contamination with food or blood, participants were asked to refrain from eating or brushing their teeth before saliva collection. They were instructed to insert a salivette into their mouths for a period of 30 s, to collect saliva. The salivettes were stored in participants' home refrigerators until they were returned to the laboratory. Upon collection of the salivettes, samples were frozen until completion of the wave and analyzed at the University of Trier, Germany. The analysis involved the use of a time-resolved fluorescence immunoassay with a cortisol—biotin conjugate as a tracer. Cortisol analysis from this laboratory typically shows intra-assay coefficients of variation that are less than 10%.

All raw cortisol values were log transformed to stabilize variance. Levels of daily cortisol secretion exhibited a typical diurnal pattern. Cortisol values were high at awakening (*M*s [*SD*s] = 1.06—1.13 [.19—.22]), peaked 30 min after awakening (*Ms* [*SDs*] = 1.17—1.22 [.22—.24]), and continuously declined for the remainder of the day (2 PM: *M*s [*SD*s] = .77—.84 [.17—.18]; 4 PM: *M*s [*SD*s] = .72—.76 [.17—.18]), with lowest cortisol output at bedtime (*M*s [*SD*s] = .57—.60 [.17—.19]). Total diurnal cortisol volume was calculated by computing the area-under-the-curve with respect to ground (AUC_G; Pruessner et al., 2003). We analyzed AUC_G because it represents a reliable measure of individuals' overall cortisol output across a day (for associations with cortisol slope and awakening response, see Section 4.1). AUC_G was calculated separately for each of the three assessment days across waves, based on hours after awakening. Because of potential contamination with blood or food, cortisol values that were more than three SDs above the sample mean for a certain time of day were excluded. Subsequently, we calculated AUC_G only if participants had at least four of five possible cortisol values for a given day (1300 out of 1323 potential days; 98.26%). On days where a single cortisol value was missing, cortisol values were replaced by the respective sample mean before AUC_G calculation (for the 1300 days, 1.83% of cortisol values were replaced). The 30-min samples were excluded from the calculation of AUC_G because the awakening response has been shown to be relatively independent from other aspects of the diurnal cortisol rhythm (Pruessner et al., 2003; Chida and Steptoe, 2009). Change scores for AUC_G from T1 to T2 (and from T2 to T3) were obtained in separate regression analyses by predicting T2 levels of AUC_G from T1 AUC_G (and T3 levels of AUC_G from T2 AUC_G), and saving the standardized residuals for further analysis.

Self-esteem was measured at T1 and T2 by administering the Rosenberg self-esteem scale (Rosenberg, 1986), which is a 10-item self-report questionnaire using 4-point Likert-type scales (*strongly disagree* = 0 to *strongly agree* = 3). Sample items include statements such as "I feel that I have a number of good qualities" or "All in all, I am inclined to feel that I am a failure." Indicators of participants' self-esteem were obtained at T1 and T2 by computing a sum score of the 10 items, after reverse coding of negatively formulated items (αs = .79 and .82). Individual differences in change of self-esteem from T1 to T2 were obtained in a regression analyses, predicting T2 self-esteem scores from T1 self-esteem scores, and saving the standardized residuals for further analysis.

Depressive symptoms were measured at T1 and T2. Participants responded to a 10-item version of the Center for Epidemiologic Studies Depression Scale (CES-D; Andresen et al., 1994). They were asked to rate how frequently they experienced 10 depressive symptoms during the past week, using 4-point Likert-type scales (*rarely or none of the time* = 0 to *most or all of the time* = 3). Items included, "I could not get going" and "I was bothered by things that usually don't bother me." Scale scores for depressive symptoms were obtained at T1 and T2 by computing the sum of the 10 items (αs = .72 and .82).

Perceived stress was measured at T1 and T2. Participants were asked to respond to the 10-item version of the Perceived Stress Scale (Cohen et al., 1983). They rated how frequently they experienced 10 different situations over the past month by using 5-point Likert-type scales (*never* = 1 to *very often* = 5). Items included, "How often have you felt that things were going your way?" and "How often have you felt nervous and stressed?" Positively formulated items were reversed coded and indicators of perceived stress at T1 and T2 were obtained by averaging the ratings of the 10 items (αs = .87 and .87).

Covariates were measured at baseline (see Table 1). A previously validated risk index for predicting older adults' mortality was computed by counting participants' weighted risk factors: age, being male, presence of diabetes, cancer, lung or other respiratory disease, heart condition, body mass index < 25, smoking and functional aspects of aging such as, bathing, walking around the home, managing finances, and heavy housework (for further details, see Lee et al., 2006). SES was indexed by averaging the standardized scores of participants' reported annual family income, highest level of education, and perceived social status (*r*s = .40—.56, *p*s < .001). Self-reported partnership status was measured by categorizing participants into two groups: (1) single/separated/widowed or (2) married/lives with partner. The use of medication that could affect cortisol secretion was assessed by counting the number of different medications participants reported taking. Subsequently, a variable was computed indicating whether or not participants took medications that could influence HPA axis activity (e.g., anti-depressants, beta-blockers, or anti-inflammatory drugs).

2.4. Data analyses

Preliminary analyses were conducted to describe the sample (by calculating means), explore associations between the main constructs (by calculating correlations), and examine mean level differences over time (by calculating ANOVAs). The hypotheses were subsequently tested using standardized predictor variables in hierarchical linear regression models that controlled for relevant sociodemographic and health-related covariates. The effects of self-esteem change, depressive symptoms, and perceived stress on changes in diurnal cortisol volume were tested by conducting two separate regression analyses, using change scores of AUC_G: (1) from T1 to T2, and (2) from T2 to T3 as dependent variables. In the first step of the analyses, the main effects of self-esteem change (T1 to T2), levels of depressive symptoms and perceived stress (T1 and T2), and the covariates (partnership status, SES, mortality index, and cortisol-related medication) were tested for significance. The second step of the analyses examined separately whether the interaction terms of self-esteem change with levels of (1) T1 depressive symptoms, (2) T2 depressive symptoms, (3) T1 perceived stress and (4) T2 perceived stress would predict additional variance in the dependent variables. Because our interaction analyses involved testing multiple effects of four different indicators of psychological distress, we applied a Bonferroni correction to the significance levels of the interactions ($p < .0125$). Significant interaction effects were followed up with simple slope analyses, examining the associations between self-esteem change and the outcome variables one standard deviation above and below the sample mean of depressive symptoms and perceived stress.

3. Results

3.1. Preliminary analyses

The sample characteristics are presented in Table 1. At baseline, participants were on average 71 years old, approximately half of the sample was married or living with a partner, and half of the sample were women. The participants had on average, a collegial or trade education, and $34,000—$51,000 yearly incomes, indicating that the sample was of moderate SES. The majority of the sample used medication that could influence HPA axis activity. Between 3% and 18% of participants reported that they either had diabetes, cancer, respiratory disease, or a heart condition. Furthermore, approximately 40% of the participants had a body mass index (BMI) of less than 25. A minority of the sample was smoking and between 2% and 18% of the sample had different functional limitations. Taken together, the mortality index rate for the sample had an average rating of 6.10, which compared to Lee and colleagues' (2006) validation sample, would correspond to a 9% mortality risk over four years. The sociodemographic and health characteristics of the sample were within the normative range of known distributions among older adults residing at home (National Advisory Council on Aging [NACA], 2006).

The zero-order correlations between the main study variables are presented in Table 2. The significant associations showed positive correlations across waves for cortisol volume, self-esteem, depressive symptoms, and perceived stress, indicating some stability in these variables over time. Moreover, T1—T2 increases in cortisol were associated with higher T2 and T3 levels of cortisol volume, and T2—T3 increases in cortisol were associated with higher T3 levels of cortisol volume and lower T2 levels and T1—T2 reductions of self-esteem. In addition, T1—T2 increases in self-esteem were associated with lower T1 and T3 levels of cortisol as well as higher T2 levels of self-esteem and lower T2 levels of depressive symptoms and perceived stress. Finally, T1 and T2 levels of depressive symptoms and perceived stress were positively associated with each other, as well as with lower levels of self-esteem at T1 and T2.

ANOVAs showed that cortisol volume significantly increased from T1 to T3, $F(1, 146) = 9.13$, $p = .003$ (see Table 1). Mean levels of depressive symptoms also increased from T1 to T2, $F(1, 146) = 5.20$, $p = .024$, while levels of self-esteem and perceived stress did not significantly change in the entire sample from T1 to T2, $Fs < 1.04$, $ps > .31$.

3.2. Main analyses

The results of the first regression analysis are reported in Table 3, predicting concurrent changes in diurnal cortisol volume (T1 to T2). In the first step of the analysis, the main effects of self-esteem change (T1 to T2), levels of depressive symptoms and perceived stress (T1 and T2), or any of the incorporated covariates were not significantly associated with changes in AUC_G from T1 to T2, $Fs < 1.03$, $ps > .31$. In addition, the second step of the analysis showed that the four interaction terms between self-esteem change with depressive symptoms and perceived stress (at T1 and T2) did not predict significant changes in AUC_G from T1 to T2, $Fs < 1.46$, $ps > .23$.

The results of the second analysis, predicting subsequent changes in diurnal cortisol volume from T2 to T3, are also

Table 2 Zero-order correlations between main study variables ($N = 147$).

	1	2	3	4	5	6	7	8	9	10	11
1. Diurnal cortisol volume AUC_G (T1)											
2. Diurnal cortisol volume AUC_G (T2)	.37**										
3. Diurnal cortisol volume AUC_G (T3)	.30**	.43**									
4. Δ Diurnal cortisol volume AUC_G (T1 to T2)	.00	.93**	.34**								
5. Δ Diurnal cortisol volume AUC_G (T2 to T3)	.15	.00	.90**	−.06							
6. Self-esteem (T1)	−.01	.08	.02	.09	−.01						
7. Self-esteem (T2)	−.13	.00	−.15	.06	−.17*	.66**					
8. Δ Self-esteem (T1 to T2)	−.16*	−.06	−.22**	.00	−.21**	.00	.75**				
9. Depressive symptoms (T1)	−.07	−.09	−.02	−.07	−.02	−.57**	−.46**	−.11			
10. Depressive symptoms (T2)	−.01	.00	.02	.00	.03	−.35**	−.46**	−.31**	.56**		
11. Perceived stress (T1)	−.03	−.03	−.07	−.02	−.06	−.49**	−.39**	−.08	.71**	.54**	
12. Perceived stress (T2)	.06	.07	−.02	.05	−.05	−.38**	−.45**	−.26**	.51**	.69**	.63**

* $p < .05$.
** $p < .01$.

Table 3 Hierarchical regression analyses predicting changes in diurnal cortisol from T1 to T2, and from T2 to T3, by changes in self-esteem from T1 to T2 and T1 and T2 levels, baseline levels of perceived stress and depressive symptoms ($N = 147$).

Predictors	Δ Diurnal cortisol volume AUC_G (T1 to T2)		Δ Diurnal cortisol volume AUC_G (T2 to T3)	
	R^2	β	R^2	β
Main effects				
Married/living with partner (T1)	.00	.06	.00	.06
Socioeconomic status (T1)	.01	.09	.00	.06
Cortisol related medication (T1)	.00	−.03	.01	−.11
Mortality index (T1)	.00	−.01	.02	.17
Depressive symptoms (CES-D) (T1)	.00	−.07	.01	.13
Depressive symptoms (CES-D) (T2)	.00	.00	.00	.03
Perceived stress (PS) (T1)	.00	−.04	.00	−.07
Perceived stress (PS) (T2)	.01	.13	.01	−.14
Δ Self-esteem (T1 to T2)	.00	.00	.05**	−.25**
Interactions				
Δ Self-esteem × CES-D (T1)	.00	−.02	.04*	−.22*
Δ Self-esteem × CES-D (T2)	.01	.09	.06**	−.28**
Δ Self-esteem × PS (T1)	.01	.11	.07**	−.28**
Δ Self-esteem × PS (T2)	.01	.09	.07**	−.29**

Notes: R^2 values represent the unique proportion of variance explained in each step of the analyses. β represents standardized regression coefficients in each step of analyses. *Df*s for main effects = 1, 137; *df*s for interactions = 1, 136.
* $p < .05$.
** $p < .01$.

reported in Table 3. The first step of the analysis showed that the covariates and the main effects of depressive symptoms and perceived stress were not significantly associated with change in AUC_G from T2 to T3, Fs < 3.75, ps $> .05$. However, change in self-esteem from T1 to T2 significantly predicted change in AUC_G from T2 to T3, $F = 8.09$, $p = .005$. The negative sign of the regression coefficient demonstrates that to the extent participants experienced a steeper decline in their self-esteem over the first two years of study, they exhibited larger increases in diurnal cortisol volume over the subsequent two years (see Table 3).

The second step of the analysis showed significant interaction effects in predicting change in AUC_G from T2 to T3 between self-esteem change (T1 to T2) with (1) T1 levels of depressive symptoms, $F = 6.68$, $p = .011$, (2) T2 levels of depressive symptoms, $F = 10.01$, $p = .002$, (3) T1 levels of perceived stress, $F = 11.32$, $p = .001$, and (4) T2 levels of perceived stress, $F = 10.83$, $p = .001$.[3]

To investigate the significant interaction effects, we calculated the simple slopes for the associations between declines in self-esteem from T1 to T2 and subsequent increases in AUC_G (T2 to T3), separately for participants who scored one standard deviation above and below the sample means of depressive symptomatology or perceived stress at T1 or T2. The obtained results are documented in Table 4 and showed that self-esteem declines over the first two years of study were significantly associated with subsequent increases in AUC_G among participants who reported high T1 or T2 levels of depressive symptoms, or high T1 or T2 levels of perceived stress. By contrast, declines in self-esteem were statistically unrelated to subsequent increases in AUC_G among participants who reported low T1 or T2 levels of depressive symptoms, or low T1 or T2 levels of perceived stress.

Because of the similarity of the observed interaction effects, we repeated the second regression analysis, using a psychological distress composite of averaged depressive symptoms and perceived stress across the first two waves as a predictor variable (instead of the four separate measures of distress). We conducted this supplemental analysis to estimate the most reliable association between self-esteem change and subsequent cortisol increase among participants who reported high, average, or low levels of psychological distress. In the first step of this analysis, only high levels of the mortality index, $F(1, 140) = 4.25$, $R^2 = .03$, $\beta = .18$, $p = .041$, and declines in self-esteem from T1 to T2, $F(1, 140) = 7.92$, $R^2 = .05$, $\beta = -.24$, $p = .006$, were significantly associated with subsequent increases in AUC_G. Moreover, similar to the previous analysis, the second step of the analysis showed that self-esteem change significantly interacted with the psychological distress composite to predict change in AUC_G from T2 to T3, $F(1, 139) = 15.37$, $R^2 = .09$, $\beta = -.34$, $p < .001$. Fig. 1 illustrates the obtained associations between self-esteem change (T1 to T2) and subsequent increase in AUC_G for participants with low (-1 *SD*), average

[3] We obtained the same pattern of significant findings if we did not use change scores in our analyses, but instead operationalized change by using levels of predictor and outcome variables and controlling the analyses for previous levels of these constructs. This pattern also remained stable if we included T3 measures of self-esteem, depressive symptom, and perceived stress (and T1 levels of cortisol for predicting cortisol change from T2 to T3) as additional covariates into the analyses. Finally, follow-up analyses showed that the main effects of baseline self-esteem, and interactions including baseline self-esteem with depressive symptoms or perceived stress, did not predict changes in cortisol volume from T1 to T2 or T2 to T3.

Table 4 Associations between self-esteem change (T1 to T2) and subsequent changes in diurnal cortisol volume AUC_G (T2 to T3) for participants with high (+1 *SD*) and low (−1 *SD*) levels of depressive symptoms and perceived stress at T1 and T2 (*N* = 147).

	Δ Diurnal cortisol volume AUC_G (T2 to T3)							
	Depressive symptoms				Perceived stress			
	T1		T2		T1		T2	
	High	Low	High	Low	High	Low	High	Low
Δ Self-esteem (T1 to T2)	$-.49^{**}$	.03	$-.34^{**}$	.10	$-.51^{**}$	.11	$-.35^{**}$	.11

** $p < .01$.

(*M*), and high (+1 *SD*) levels of the psychological distress composite. Simple slope analyses demonstrated that the association between self-esteem declines and subsequently enhanced cortisol volume significantly increased to the extent that participants experienced higher levels of the psychological distress composite (+1 *SD*: $\beta = -.41$, $p < .001$; *M*: $\beta = -.10$, $p = .25$; −1 *SD*: $\beta = .21$, $p = .14$).

4. Discussion

The results from this study suggest that changes in self-esteem are associated with older adults' diurnal cortisol secretion. Although our study showed a net stability of self-esteem levels over the first two years of study, there was considerable variability in self-esteem over time and individual differences in self-esteem change were a significant predictor of alterations in participants' cortisol output. Specifically, older adults who experienced a decline in self-esteem over the first two years of study exhibited steeper increases in diurnal cortisol volume over the subsequent two years, as compared to participants who reported increases in self-esteem. Moreover, this association was enhanced among older adults who perceived high levels of depressive symptoms or perceived stress at baseline or two-year follow-up, but absent among their counterparts with comparably lower levels of perceived stress or depressive symptoms. This pattern of results was significant after controlling for potential confounds, such as SES, partnership status, mortality risk factors, or cortisol-related medication.

These findings suggest that increases in self-esteem can protect older adults from exhibiting distress-related increases in diurnal cortisol secretion. By contrast, older adults who experience a decline in their self-esteem may be more likely to exhibit elevated cortisol output in such circumstances. We think that such a process may occur because self-esteem can facilitate adaptive coping with stress (Baumeister et al., 2003). In the context of age-related stressors, an increase in self-esteem could likely result in more positive appraisals of challenging life circumstances and through this process buffer stressful experiences and subsequent increases in cortisol secretion. Participants who encounter a decline in their self-esteem, however, may be more likely to appraise challenges as threats (Orth et al., 2009) and thus, exhibit increases in diurnal cortisol secretion.

Note that our results showed that changes in self-esteem were associated only with subsequent, but not concurrent, changes in diurnal cortisol secretion. Although we were surprised by the absence of a concurrent association, one potential explanation for this finding may relate to the substantial time gaps between study assessments (i.e., two years). Given that cortisol change may have occurred at any time during the two-year interval, it is possible that

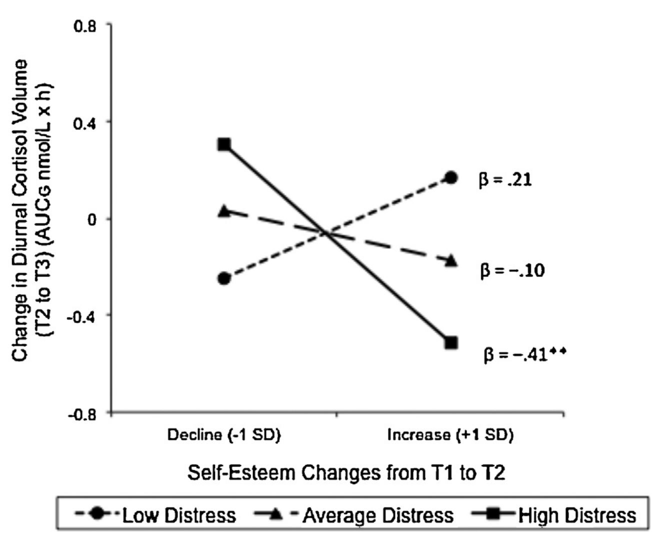

Figure 1 Associations between self-esteem changes (T1 to T2) and subsequent changes in diurnal cortisol volume AUC_G (T2 to T3), separately for participants who experienced low (−1 *SD*), average (*M*), and high (+1 *SD*) levels of psychological distress (averaged T1 and T2 scores of depressive symptoms and perceived stress). Standardized coefficients (β) are indicated for each group. $^{**}p < .001$.

increases in cortisol have preceded changes in self-esteem, were driven by factors other than self-esteem, and therefore not concurrently associated with self-esteem changes. However, the prediction of subsequent cortisol changes in our second analysis ensured that declines in self-esteem occurred before the observed increases in cortisol, demonstrating a directional association between self-esteem change and cortisol volume.

Our supplemental analyses further showed that baseline levels of self-esteem did not significantly contribute to increases in cortisol secretion (see Footnote 3). Consistent with other work, this result may imply that deviations from individuals' levels of self-esteem are more impactful in predicting stress-related biological consequences than levels of self-esteem alone (Ross et al., 2013). Although more research is needed to substantiate this conclusion, such patterns may occur if cortisol secretion habituates over time to individuals' typical perceptions about themselves or their lives (Jobin et al., 2013; Wüst et al., 2005; Miller et al., 2007). In such cases, deviations from accustomed levels of self-esteem could exert a more reliable effect on individuals' biological stress responses. Further, such a process may be observable particularly in older adulthood, when variability in self-esteem tends to increase (Trzesniewski et al., 2003).

The results from the present study have important implications for theory and research on stress-related disturbances of cortisol secretion. First, they extend previous research examining the protective functions of levels of self-esteem in the stress-related cortisol link (Pruessner et al., 1999). To this end, our results suggest that an increase of self-esteem over time can also be an adaptive and independent contributor to older adults' HPA axis functioning. Second, they shed light on some of the inconsistencies in the extant literature on the associations between distressing experiences and cortisol secretion. Similar to our findings, main effects of psychological distress on cortisol disturbances have not been reported consistently across studies (Kudielka et al., 2009). However, certain characteristics that enable individuals to cope with distressing experiences may obstruct such an association. Thus, a link between psychological distress and cortisol output may be observed particularly among individuals who have difficulty adjusting to critical life circumstances (Wrosch et al., 2007). Our findings are consistent with this conclusion by suggesting that to the extent participants experienced a greater decline in self-esteem, psychological distress became increasingly associated with subsequently enhanced levels of cortisol secretion (see Fig. 1).

However, we note that the flip side of the latter effect suggests that distress became increasingly associated with fewer increases in cortisol among participants who had experienced an increase in self-esteem (see Fig. 1). One potential explanation of this effect is that self-esteem increases could, under some circumstances, also enhance cortisol output. Such an association may occur if self-esteem activates maladaptive behaviors tendencies, a possibility that has been indicated in previous research (e.g., Narcissism, Neff, 2011). Alternatively, effects of distress on declines in cortisol output among participants who increased in self-esteem could be partially related to the possibility that these participants were exhausted because they had experienced a period of high distress and low self-esteem at baseline (cf. Tops et al., 2008).

Finally, the study's findings contribute to the emerging literature on self-esteem change in older adulthood (Robins et al., 2002; Collins and Smyer, 2005; Shaw et al., 2010; Orth et al., 2010). While our study cannot provide a firm answer to the question of whether or not self-esteem declines in old age, it points to the conclusion that there is considerable variability in older adults' self-esteem over time. Moreover, it demonstrates that such variability in personality functioning represents meaningful psychological changes that relate to trajectories of a hormone that has wide-ranging regulatory influences in the body (Weiner, 1992; Lupien et al., 2009).

4.1. Limitations and future research

There are limitations to the present study. First, our analyses were focused on predicting AUC_G of cortisol because it represents a reliable indicator of overall cortisol volume across the day. However, other research has studied the slope of cortisol from awakening to bedtime (Sephton et al., 2000) or the cortisol awakening response (CAR; Vrshek-Schallhorn et al., 2013). Supplemental analyses of our data showed that increased self-esteem was also associated with subsequently (but not concurrently) more normative (i.e., declining) changes in cortisol slope, $F(1, 137) = 6.45$, $\beta = -.23$, $p = .010$. However, there were no main effects of self-esteem change on CAR, and depressive symptoms or perceived stress did not moderate the associations between self-esteem change and cortisol slope or CAR, $Fs < 2.23$, $ps > .14$. While this pattern lends some further support to our conclusion that change in self-esteem is an important personality process in old age, it also suggests that cortisol slope and CAR may be less sensitive to differences in self-esteem and distress than AUC_G of cortisol.[4]

Second, although we used a mortality index as a parsimonious covariate, this measure did not address the associations with the single variables of the index. Supplemental correlation analyses, linking the separate variables of the mortality index with T1—T2 and T2—T3 changes in cortisol, showed that none of the single variables were significantly associated with cortisol change, all $|r|s < .17$, all $ps > 05$, except for sex. In particular, men exhibited larger cortisol increases than women from T2 to T3, $r = -.17$, $p = .038$. This result is consistent with some previous studies (Kirschbaum et al., 1992), and future research may identify the variables that could underlie sex-specific trajectories of cortisol secretion among older men and women.

Third, while the reported results suggest that changes in self-esteem preceded changes in cortisol output, our study is

[4] Not applying a Bonferroni correction, the supplemental analyses would have shown a significant interaction effect (i.e., T1—T2 self-esteem change × T2 perceived stress) in predicting change in cortisol slope from T1 to T2, $F(1, 136) = 4.84$, $R^2 = .03$, $p = .029$. Although this interaction was not found for the three other indicators of distress, and thus may be attributable to chance, we note that its pattern indicated a concurrent association between self-esteem increase and increasingly flatter cortisol slopes among participants with high, $\beta = .19$, $p = .048$, but not low, $\beta = -.13$, $p = .37$, T2 levels of perceived stress.

based on a naturalistic design and therefore cannot draw causal inferences regarding the observed associations. In addition, our data stem from a relatively small longitudinal project, which limits the generalizability of the study's conclusions. Thus, future research should replicate the reported findings in larger and representative studies. Such studies should also examine changes in other personality constructs (e.g., coping tendencies, optimism, or broader traits) and biological processes (e.g., inflammatory cytokines) that could influence a number of age-related diseases. Given that cortisol secretion could influence immune function and physical health (Björntorp and Rosmond, 1999; Sapolsky et al., 2000; Lupien et al., 2009; Rueggeberg et al., 2012), research along these lines may reveal how adaptive changes in personality functioning can protect quality of life in older adulthood.

5. Conclusion

The results from this study identify declines in self-esteem as a mechanism that may contribute to elevated cortisol volume among older adults who experience psychological distress. Increases in self-esteem, by contrast, are likely to ameliorate older adults' cortisol regulation in stressful circumstances. These findings may be used in interventions that target self-esteem to improve older adults' quality of life.

Conflict of interest

None of the authors have a conflict of interest to declare.

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