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Physical Health Problems, Depressive Mood, and Cortisol Secretion in Old Age: Buffer Effects of Health Engagement Control Strategies

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Objective: This study examined the protective role played by control behaviors aimed at overcoming physical health problems (health engagement control strategies; HECS) in the associations between older adults' physical health problems, depressive mood, and diurnal cortisol secretion. It was expected that adaptive levels of HECS would buffer the adverse effects of physical health problems on depressive mood and diurnal cortisol secretion. ***Design and Measures:*** Physical health problems and HECS were measured in a cross-sectional sample of 215 community-dwelling older adults. In addition, participants' depressive mood and patterns of diurnal cortisol secretion were assessed across 3 days. ***Results:*** The findings demonstrate that physical health problems predicted high levels of depressive mood and diurnal cortisol secretion, but only among older adults who reported low levels of HECS (and not among older adults who reported high levels of HECS). Moreover, depressive mood completely mediated the buffering effect of HECS on the association between physical health problems and cortisol secretion. ***Conclusion:*** The results suggest that adaptive levels of HECS represent a psychological mechanism that can protect older adults from experiencing the adverse emotional and biological consequences of physical health problems.

Keywords: control, depression, cortisol, health, aging

The experience of physical health problems can compromise older adults' emotional well-being. However, research also suggests that older adults who engage in active behaviors to overcome their physical problems do not experience enhanced levels of emotional distress (Wrosch, Schulz, & Heckhausen, 2002). These behaviors have been defined as health engagement control strategies and are characteristic of a person who invests time and energy, seeks external help, and increases the motivation for addressing a physical problem. To further explore the adaptive value of active control behaviors, we examined in this article whether health engagement control strategies (HECS) would also protect older adults from exhibiting patterns of biological dysregulation associated with physical health problems and emotional distress. More specifically, we hypothesized that the emotional benefits resulting from HECS would predict adaptive levels of diurnal cortisol secretion. Those older adults who are engaged in actively addressing their physical health problems should be more likely to experience reduced levels of depressive mood and consequently also exhibit lower levels of diurnal cortisol secretion, as compared with their same-age peers who are less engaged in overcoming their physical problems.

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Consequences and Management of Physical Health Problems in the Elderly

Despite the increase in human life expectancy (Oeppen & Vaupel, 2002), the likelihood of confronting physical health problems increases with age and places older adults at risk for experiencing depressive symptomatology. In fact, the association between physical declines and depressive symptoms is one of the most robust findings in the aging literature (for reviews, see Dew, 1998; Lenze et al., 2001). For example, elderly individuals with specific medical conditions (e.g., arthritis, cardiovascular disease, or stroke; Creed & Ash, 1992; Spencer, Tompkins, & Schulz, 1997; Timberlake et al., 1997) have been shown to experience elevated levels of depressive mood. More important, physical and emotional problems are interdependent and can reciprocally influence each other. Although poor health may increase depressive mood (Murrell, Meeks, & Walker, 1991), depression may also contribute to health declines in the elderly (Schulz, Martire, Beach, & Scheier, 2000). As a consequence, it is important to identify the mechanisms that link physical health threats and associated depressive mood with subsequent declines in older adults' physical health.

One of the pathways through which physical threats and depressive mood may compromise a person's prospective health is the dysregulation of diurnal cortisol secretion (Brown, Varghese, & McEwen, 2004; McEwen, 2003; Otte et al., 2004). In most individuals, cortisol secretion peaks during the early morning hours and declines steadily over the course of the day (Stone et al., 2001). A substantial body of research has shown that exposure to stressors and the experience of depressive symptoms can be associated with increased levels of cortisol secretion (Kirschbaum & Hellhammer, 1989; Sachar et al. 1973; Weiner, 1992).[1] Furthermore, dysregulated cortisol secretion has been linked to physical health problems, neurological impairments, and mortality (Heim, Ehlert, & Hellhammer, 2000; Lupien et al., 1998; Sephton, Sapolsky, Kraemer, & Spiegel, 2000). Finally, it has been demonstrated that negative mood can play a mediating role in the relationship between stressful events and cortisol secretion (van Eck, Berkhof, Nicolson, & Sulon, 1996). Thus, it is reasonable to assume that the occurrence of physical threats and the associated depressive mood have the potential to increase levels of diurnal cortisol secretion. Such an association should be particularly likely to emerge among older adults because effects of stressors on cortisol secretion tend to increase with advancing age (Otte et al., 2005).

The discussed link between physical health threats and emotional and biological problems further implies that it is important to identify psychological mechanisms that can prevent older adults from entering into a downward spiral, characterized by physical problems, depressive mood, biological dysregulation, and subsequent health declines. In this regard, we have suggested that control behaviors aimed at overcoming health threats (i.e., HECS) play an adaptive role in preventing emotional distress among older adults who confront physical health problems. These control behaviors are characteristic of a person who invests time and energy (*selective primary control*), seeks other people's help and advice (*compensatory primary control*), and increases the motivation (*selective secondary control*) to actively overcome physical health problems (for a more detailed discussion of control behaviors, see Heckhausen & Schulz, 1995; Schulz & Heckhausen, 1996). In fact, our previous work has demonstrated that these three types of control strategies are highly correlated among older adults (and converged to one single factor), buffered the effect of physical symptoms on depressive mood, and reduced levels of depression over time (Wrosch, Schulz, & Heckhausen, 2002, 2004).

Given the beneficial emotional effects of HECS and the discussed link between stressors, emotional well-being, and diurnal cortisol secretion, we hypothesized that the emotional gains resulting from active engagements in overcoming physical problems are predictive of adaptive levels of diurnal cortisol secretion. Those older adults who actively engage in overcoming their physical health problems may not only experience lower levels of depressive mood but also, consequently, exhibit lower levels of diurnal cortisol secretion, as compared with their same-age peers who do not actively address their physical problems.

To address additional factors that may influence a person's depressive mood or cortisol secretion, we controlled our analyses for sociodemographic characteristics (age, gender, and socioeconomic status [SES]). In addition, we controlled the analyses for individual differences in functional limitations. In this regard, it is important to note that some of the consequences of physical illness in the elderly, such as functional declines, are relatively intractable and may not be possible to overcome. Thus, our theoretical model would not predict HECS to relieve the emotional and biological problems of physical illness that are associated with functional limitations (Wrosch et al., 2004).

Method

Participants

The present study is based on the Montreal Aging and Health Study, examining a heterogeneous sample of 215 older adults from the Montreal, Quebec, Canada area. To be eligible for the study, participants had to be older than 60 years. No further inclusion criteria were used, as we were interested in examining a normative sample of older adults. Four additional participants were initially enrolled in the study and were excluded because they did not complete the procedures. The 215 participants were between 63 and 94 years old ($M = 72.41$, $SD = 5.91$). Forty-eight percent of the sample was male ($n = 104$), and 32% attained an undergraduate university degree or a higher education ($n = 66$).

We recruited the participants via newspaper advertisements. After contacting the laboratory, participants were invited for an initial appointment. Participants who were unable to visit the lab were assessed in their homes. During the initial appointment, they were instructed to complete a questionnaire, to collect saliva samples over the course of three non-consecutive typical days, and to respond to a short questionnaire at the end of each of the 3 days. After finishing the study, all materials were collected, and participants received $50 for participating in the study.

Materials

The main study materials consisted of measures of participants' levels of diurnal cortisol secretion, depressive mood, HECS, physical problems, functional limitations, and sociodemographic characteristics (age, gender, and SES). Zero-order correlations between these constructs are reported in Table 1.

Diurnal cortisol rhythms were assessed across 3 non-consecutive typical days. We asked the participants to collect saliva samples as they engaged in their normal daily activities. On each of the 3 days, the participants

[1] We note that stressors and depressive symptoms sometimes produce a flattened cortisol rhythm, related to either reduced levels of early morning cortisol secretion or increased levels of cortisol secretion in the afternoon and evening hours (e.g., Burke et al., 2005; Miller et al., in press; Miller et al., 2002). Although not much is known about the reasons for different types of cortisol dysregulation, we address these alternative possibilities in our analyses by not only examining the area under the curve of diurnal cortisol secretion but also exploring associations with cortisol slope and cortisol secretion across different times of day.

Table 1
Zero-Order Correlations Between Main Constructs Used in the Present Study

Construct	1	2	3	4	5	6	7	8
1. Diurnal cortisol secretion (AUC)[a]	—							
2. Depressive mood	.14*	—						
3. Health engagement control strategies	−.05	−.19**	—					
4. Physical health problems	.11	.17*	−.01	—				
5. Functional limitations	.03	.28**	−.17**	.16*	—			
6. Age	.07	.09	.04	.09	.11	—		
7. Gender[b]	−.16*	.06	−.15*	−.07	.17*	−.02	—	
8. Socioeconomic status	.07	−.18**	.05	−.09	−.12	−.06	.15*	—

[a] Area-under-the-curve (AUC) measure of cortisol secretion. [b] Higher values represent women as compared with men.
* $p < .05$. ** $p < .01$.

collected five saliva samples (by using salivettes) at specific times of the day: awakening, 30 min after awakening, 2 p.m., 4 p.m., and before bedtime. Participants were asked not to eat or brush their teeth immediately prior to saliva collection to prevent contamination with food or blood. They were provided with a timer that they had to set at 30 min at the time they collected their first saliva sample after awakening. To ensure compliance concerning the collection of the afternoon and evening samples, participants were called at 2 p.m. and 4 p.m. They were further instructed to collect the last sample of the day by themselves at the time they went to bed. The actual time of day was recorded by the participants for all of the collected saliva samples.

The saliva samples were stored in participants' home refrigerators until they were returned to the lab 2–3 days after collection was completed (for stability of cortisol concentrations in these conditions, see Clements & Parker, 1998). After the saliva containers were returned to the lab, they were spun in a centrifuge for 5 min until a clear, low-viscosity supernatant emerged, and they were subsequently frozen at −70°C until the completion of the study. Cortisol assays were performed at the University of Trier, Trier, Germany, in duplicate, using a time-resolved fluorescence immunoassay with a cortisol-biotin conjugate as a tracer (Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999). The intra-assay coefficient of variation was less than 5%.

To obtain measures of participants' levels of cortisol secretion over the day, we calculated the area under the curve (AUC) of cortisol secretion for each day separately, using the trapezoidal method (based on hours after awakening). Given that some saliva samples may have been contaminated with blood or food, we excluded all samples that deviated more than three standard deviations from the mean cortisol secretion for the time of day. Of the 3,223 samples, 96% were identified as valid samples, 3% did not include saliva, and 1% was associated with cortisol levels beyond three standard deviations above the mean of cortisol secretion. In addition, we calculated AUC only if the participants provided at least four out of five samples for a specific day. This procedure ensured that all scores were based on at least one valid morning sample (when cortisol secretion is usually increased) and two valid day or evening samples (when cortisol secretion is usually reduced). Six participants did not meet these criteria and were excluded from the analyses. In cases in which a single saliva sample was missing, we replaced the missing value with the sample mean before calculating AUC. Single-day measures of AUC were significantly correlated (rs = .51–.66, ps < .01), and we averaged the single-day measures to obtain a stable indicator of cortisol secretion (M = 121.12, SD = 55.16).

To explore patterns of cortisol secretion across day, we also calculated the slope of cortisol secretion by estimating a linear regression model for each participant for each of the 3 days separately, where his or her log transformed cortisol values were regressed on hours since waking. Single-day measures of cortisol slope were significantly correlated (rs = .29–.35, ps < .01), and we averaged the single-day measures to obtain a reliable index of cortisol slope (M = −.04, SD = .02).

Depressive mood was also assessed across the 3 typical days. At the end of each day, participants were asked to respond to a brief questionnaire that included two items assessing depressive mood (sad and unhappy). The items were measured with 5-point Likert-type scales, ranging from 0 (*very slightly or not at all*) to 4 (*extremely*), and participants reported the extent to which they experienced the two emotions during the day. To obtain a more reliable measure of depressive mood, we computed a sum score of the six items across the 3 days (M = 1.25, SD = 2.32). Single-day measures of depressive mood were significantly correlated (rs = .36–.48, ps < .01).

HECS were measured in the baseline questionnaire by administering a previously developed instrument (Wrosch et al., 2002). The instrument included nine items designed to measure three types of control strategies aimed at actively overcoming health problems (selective primary control [3 items]: e.g., "If I have a health problem that gets worse, I put in even more effort to get better"; compensatory primary control [3 items]: e.g., "If I develop a new health problem, I immediately get help from a health professional [e.g., doctor, nurse]"; and selective secondary control [3 items]: e.g., "When I decide to do something about a health problem, I am confident that I will achieve it"). Participants were asked to indicate how true each statement was for them on a 5-point Likert-type scale, ranging from 0 (*almost never true*) to 4 (*almost always true*). Considering that previous research has shown that these nine items form a single factor among older adults (Wrosch et al., 2002), we computed a mean score of the nine items (M = 3.11, SD = 0.70, α = .88).

Physical problems were measured in the baseline questionnaire by asking the participants to report whether they were affected by 17 different health problems. The health problems included, for example, the presence of coronary heart disease or heart attack, cancer, high blood pressure, stroke, osteoarthritis or rheumatoid arthritis, chronic lung disease, diabetes, serious liver problems, problems with blood circulation, or neurological problems. A count variable was computed to obtain an indicator of participants' levels of physical health problems (M = 2.46, SD = 1.66). Of the respondents, 10% reported no physical health problems, whereas 22% mentioned one problem, 44% reported two or three problems, and 24% mentioned having four or more physical health problems.

Functional limitations were assessed in the baseline questionnaire by asking whether participants had difficulty performing each of six activities of daily living (ADLs; eating, dressing, bathing, using the toilet, getting in or out of a bed or chair, walking around the home) and six instrumental activities of daily living (IADLs; heavy housework, light housework, shopping, preparing meals, managing money, using the phone). A simple count of the number of the respondent's ADL/IADL difficulties were tabulated for use in the present analyses. Seventy-five percent of the respondents reported no limitations, whereas 15% mentioned one limitation, 5% reported two limitations, and 5% mentioned having three or more limitations (M = 0.46, SD = 1.08).

Sociodemographic characteristics were assessed in the baseline questionnaire and included participants' age, gender, and SES. SES was measured with three variables: highest education level completed (0 = no education, 1 = high school, 2 = college, 3 = bachelor's degree, 4 = master's degree or doctorate; M = 2.03, SD = 1.04), yearly family income (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, 5 = more than $85,000; M = 1.49, SD = 1.29), and perceived SES (Adler, Epel, Castellazzo, & Ickovics, 2000; M = 6.16, SD = 1.76). To obtain a global measure of SES, we averaged the standardized scores of the three single SES variables (M = −.01, SD = .81, α = .72).

Results

To test whether HECS would buffer the adverse effects of physical health problems on older adults' levels of cortisol secretion, we conducted a multiple regression analysis, predicting the AUC of cortisol secretion as the dependent variable. In a first step, levels of physical problems and HECS were included in the regression analysis in addition to sociodemographic characteristics (age, gender, and SES) and levels of functional limitations. In a second step, we tested the interaction effect between physical problems and HECS for significance. Predictor variables were centered prior to conducting the analysis.

The results of the analysis are reported in Table 2. Of the sociodemographic characteristics, only gender was significantly associated with levels of diurnal cortisol secretion, $F(1, 202) = 5.17$, $p < .05$. Women had lower levels of cortisol secretion than men. The main effects of age, SES, functional limitations, physical problems, and HECS were not significantly associated with levels of diurnal cortisol secretion. The second step of the analysis demonstrated a significant interaction effect between levels of physical problems and HECS on predicting participants' diurnal cortisol secretion, $F(1, 201) = 4.99$, $p < .05$.

To illustrate the significant interaction effect, we plotted in Figure 1 the association between physical problems and cortisol

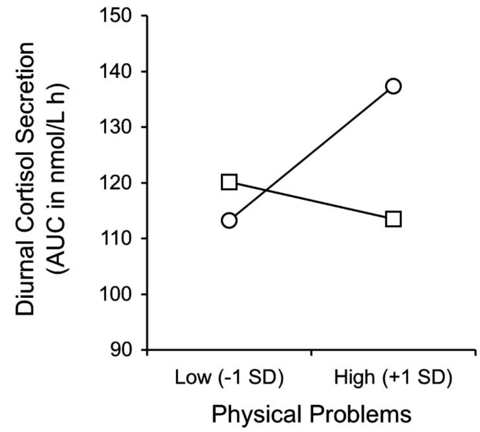

Figure 1. Interaction effect between physical health problems and health engagement control strategies (HECS) on participants' levels of diurnal cortisol secretion (area under the curve [AUC]). Open circles indicate low HECS (−1 *SD*); open squares indicate high HECS (+1 *SD*).

secretion separately for participants who scored low (−1 *SD*) and high (+1 *SD*) on the HECS scale (using techniques recommended by Aiken & West, 1991). In support of our hypotheses, the shape of the interaction effect suggested that elevated levels of cortisol secretion were found only among older adults who experienced high levels of physical problems and were not engaged in overcoming their health problems (low HECS). By contrast, participants who experienced high levels of physical problems exhibited lower levels of cortisol secretion if they reported high levels of HECS. These lower levels of cortisol secretion were comparable to participants who generally experienced reduced levels of physical problems. Analyses of the simple slopes supported this interpretation of the data. Physical problems were significantly associated with elevated levels of cortisol secretion among participants who reported low levels of HECS ($\beta = .22$, $p < .05$) but not among participants who reported high levels of HECS ($\beta = -.06$, $p > .10$). In addition, high levels of HECS were significantly associated with reduced levels of cortisol secretion among participants who reported high levels of physical problems ($\beta = -.21$, $p < .05$) but not among participants who reported low levels of physical problems ($\beta = .06$, $p > .10$).

To explore whether the obtained buffer effect of HECS was associated with cortisol secretion at a particular time of day, we plotted in Figure 2 the associations between cortisol secretion across day and groups of participants with different levels of physical problems (3 groups: 0–1 problems, 2–3 problems, and > 3 problems), separately for older adults who reported low levels of HECS (top panel, below median) and high levels of HECS (bottom panel, above median).[2] In addition, Figure 2 shows the partial correlations (controlling for sociodemographic characteristics and functional limitations) between levels of physical problems and cortisol secretion, separately for participants who scored high versus low on the HECS scale (Wrosch et al., 2002).

Table 2
Multiple Regression Analysis Predicting Levels of Diurnal Cortisol Secretion (AUC) by Participants' Sociodemographic Characteristics, Functional Limitations, Physical Problems, and Health Engagement Control Strategies (HECS)

	Diurnal cortisol secretion (AUC)[a]	
Predictor	R^2	β
Main effect	.05	
Age	.00	.06
Gender[b]	.02*	−.16*
Socioeconomic status	.00	.06
Functional limitations	.00	.03
Physical problems	.01	.09
HECS	.01	−.08
Interaction		
Physical Problems × HECS	.02*	−.15*

[a] Area-under-the-curve (AUC) measure of cortisol secretion. [b] Higher values represent women as compared with men.
* $p < .05$.

[2] The group variable distinguishing participants who reported high versus low levels of HECS also demonstrated a significant interaction effect with levels of physical health problems on participants' cortisol secretion, $F(1, 201) = 9.50$, $R^2 = .04$, $p < .01$.

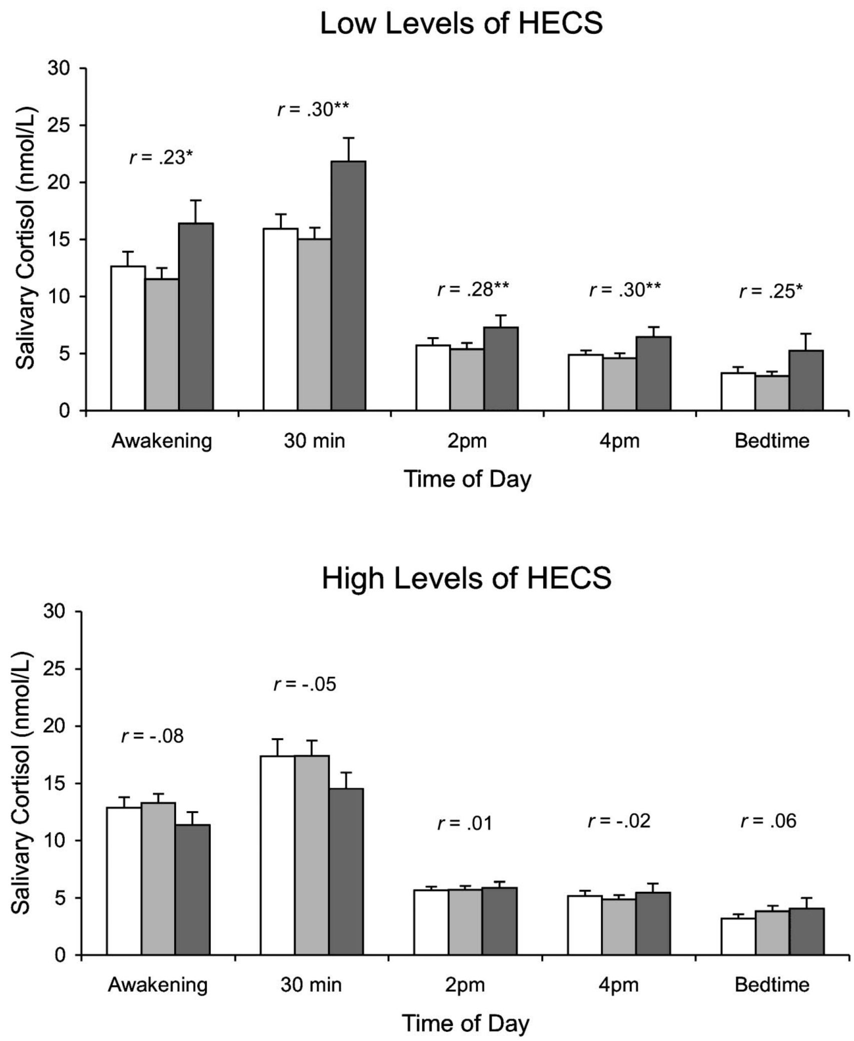

Figure 2. Associations between physical health problems and diurnal cortisol secretion across day for participants who scored low (top panel) and high (bottom panel) on health engagement control strategies (HECS; correlations represent associations with levels of physical health problems, controlled for sociodemographic characteristics and functional limitations). Open bars indicate 0–1 physical problems; gray bars indicate 2–3 physical problems; solid bars indicate > 3 physical problems. * $p < .05$. ** $p < .01$.

The obtained pattern of findings shows typical diurnal cortisol rhythms for all groups of participants, peaking 30 min after awakening, and subsequently declining steadily over the course of the day (see Figure 2). In addition, the reported correlations demonstrate that physical problems predicted elevated levels of cortisol secretion at all measurements across day for participants who reported low levels of HECS. By contrast, no significant associations between levels of physical problems and cortisol secretion were obtained among participants who reported high levels of HECS. The difference between these correlations is evidenced by significant interaction effects between physical problems and HECS group in predicting cortisol secretion for the first four measurements across day, all Fs(1, 201) > 6.09, all $R^2 > .02$, all ps < .05, and an interaction effect for bedtime that approached significance, $F(1, 201) = 3.06$, $R^2 = .01$, $p = .08$.[3] Moreover, additionally conducted regression analyses, predicting the slope of cortisol secretion across day, showed neither significant main effects of HECS or physical problems, Fs(1, 202) < .02, all $R^2 = .00$, ps > .70, nor a significant interaction effect between HECS and physical problems, $F(1, 201) = 1.09$, $R^2 = .00$, $p = .30$, further demonstrating that physical health problems were associ-

[3] It should be noted that a person's cortisol secretion could also be influenced by the use of medication (e.g., antidepressants, β-blockers, or anti-inflammatory drugs). To address this possibility, we controlled the reported analyses for the presence and number of drugs that may influence cortisol. All reported interaction effects as well as the association between physical problems and cortisol secretion among people with low levels of HECS remained significant after these variables were taken into account.

ated with increased levels of cortisol secretion across the entire day (among participants who reported low levels of HECS).[4]

To examine whether adaptive levels of HECS would also buffer the association between physical health problems and depressive mood, we conducted a regression analysis, predicting levels of depressive mood as the dependent variable by the same predictor variables as reported in the previous regression analysis.[5] The results of the analysis are reported in Table 3. Of the sociodemographic variables, only SES significantly predicted levels of depressive mood, $F(1, 202) = 4.30$, $p < .05$. Participants with a higher SES reported lower levels of depressive mood than participants with a lower SES. The main effects of age, gender, and physical problems did not significantly predict levels of depressive mood. However, the main effects of HECS, $F(1, 202) = 5.20$, $p < .05$, and functional limitations, $F(1, 202) = 9.71$, $p < .01$, were significantly associated with levels of depressive mood. Participants who reported high levels of HECS and participants who reported low levels of functional limitations experienced lower levels of depressive mood than participants who reported low levels of HECS and high levels of functional limitations. More important, the second step of the analysis confirmed a significant interaction effect between physical problems and HECS for predicting levels of depressive mood, $F(1, 201) = 4.37$, $p < .05$.

The shape of the interaction effect (see Figure 3) suggested that elevated levels of depressive mood were obtained only among participants who experienced high levels of physical problems and were not engaged in actively overcoming their health problems. By contrast, lower levels of depressive mood were found among participants who reported high levels of physical problems and high levels of HECS. These lower levels of depressive mood were comparable to participants who generally experienced low levels of physical problems. The analyses of the simple slopes supported this interpretation by demonstrating that physical problems were significantly associated with higher levels of depressive mood among participants who reported low levels of HECS ($\beta = .23$, $p < .01$) but not among participants with high levels of HECS ($\beta = -.02$, $p > .10$). In addition, HECS predicted low levels of depressive mood among participants who experienced high levels of physical problems ($\beta = -.27$, $p < .01$) but not among participants who reported low levels of physical problems ($\beta = -.03$, $p > .10$).[6]

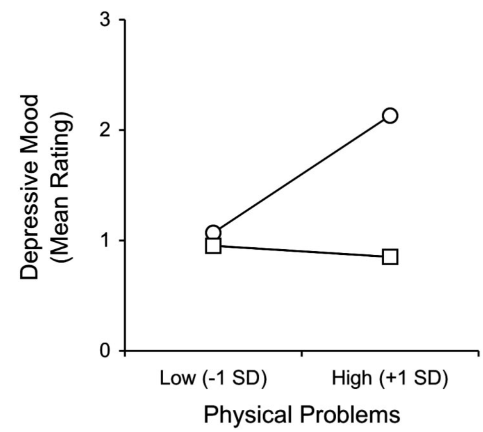

Figure 3. Interaction effect between physical health problems and health engagement control strategies (HECS) on participants' levels of depressive mood. Open circles indicate low HECS (-1 *SD*); open squares indicate high HECS ($+1$ *SD*).

Finally, we examined whether individual differences in depressive mood would statistically explain the buffering effect of HECS on the association between physical problems and cortisol secretion by repeating the originally reported analyses for predicting participants' levels of diurnal cortisol secretion and additionally controlling for depressive mood (and the two-way interactions between depressive mood and physical problems and between depressive mood and HECS; see Yzerbyt, Muller, & Judd, 2003). In this analysis, the previously significant interaction effect between physical problems and HECS on participants' level of diurnal cortisol secretion was rendered nonsignificant when the variance associated with depressive mood was taken into account, $F(1, 198) = 0.57$, $R^2 = .00$ $p = .45$. Individual differences in depressive mood thus completely mediated the buffering effect of HECS on the association between physical health problems and diurnal cortisol secretion.

Table 3
Multiple Regression Analysis Predicting Levels of Depressive Mood by Participants' Sociodemographic Characteristics, Functional Limitations, Physical Problems, and Health Engagement Control Strategies (HECS)

	Depressive mood	
Predictor	R^2	β
Main effect	$.14^{**}$	
Age	.00	.05
Gender[a]	.00	−.01
Socioeconomic status	$.02^{*}$	$-.14^{*}$
Functional limitations	$.04^{**}$	$.21^{**}$
Physical problems	.01	.11
HECS	$.02^{*}$	$-.15^{*}$
Interaction		
Physical Problems × HECS	$.02^{*}$	$-.14^{*}$

[a] Higher values represent women as compared with men.
$^{*} p < .05$. $^{**} p < .01$.

Discussion

In the present study, we examined the protective role played by HECS in the management of physical health problems in old age.

[4] The analysis also revealed significant effects of gender, $F(1, 202) = 10.22$, $\beta = -.22$, $R^2 = .04$, $p < .01$, and age, $F(1, 202) = 12.53$, $\beta = .24$, $R^2 = .05$, $p < .01$, on cortisol slope. Women and younger participants exhibited a steeper slope of cortisol secretion than men and older participants.

[5] Four participants did not report data for depressive mood. To ensure comparability of results across analyses, we replaced the missing data with the sample mean. The results of the analysis did not change if participants with missing data were excluded.

[6] We note that the interaction effect between physical illness and HECS on predicting depressive mood approached significance, $F(1, 201) = 3.40$, $R^2 = .015$, $p = .07$, if the analyses did not control for functional limitations, indicating that the beneficial emotional effect of HECS for managing physical illness is somewhat enhanced when associations between functional limitations and depressive mood are taken into account.

We hypothesized that the emotional consequences of physical problems can adversely affect older adults' diurnal cortisol secretion and that adaptive levels of HECS would buffer the negative consequences of physical problems on depressive mood and diurnal cortisol secretion.

The results from our analyses strongly support the hypotheses. Physical problems were associated with high levels of depressive mood and diurnal cortisol secretion, but only among older adults who were not engaged in actively overcoming their physical problems. By contrast, older adults who reported high levels of HECS were protected from the adverse effects of physical problems on depressive mood and diurnal cortisol secretion. Moreover, the analyses showed that the buffering effect of HECS on the association between physical health problems and diurnal cortisol secretion was completely mediated by individual differences in depressive mood. This pattern of results was statistically independent of factors that could influence cortisol secretion, such as sociodemographic characteristics or medication use.

The reported findings are consistent with previous research, documenting that emotional benefits can result from high levels of HECS among older adults who confront physical health challenges (Wrosch et al., 2002). In addition, the results extend the existing literature by suggesting that adaptive control behaviors can not only ameliorate the emotional consequences of physical problems, but the emotional benefits stemming from active control behaviors may further influence adaptive levels of diurnal cortisol secretion. This conclusion is consistent with laboratory research, demonstrating a strong effect of psychological challenge on cortisol secretion if a person is not able to control the challenge (Dickerson & Kemeny, 2004).

Taken together, active engagements in overcoming physical health problems may represent a psychological mechanism that can prevent older adults from entering into a downward spiral, characterized by physical problems, depressive mood, and biological dysregulation. In addition, given the detrimental effects of depressive symptoms and cortisol dysregulation on a person's physical health (e.g., Schulz et al., 2000; Sephton et al., 2000), adaptive levels of HECS may further contribute to maintaining older adults' physical health over time.

We also found that the buffering effect of HECS on the association between physical problems and depressive mood was stronger when we controlled for levels of functional limitation (which are difficult to overcome in old age). This finding indicates that HECS are particularly adaptive behaviors if individual differences in levels of depressive mood (that were associated with functional limitations) are not considered in the analysis. It further implies that the adaptive value of HECS is reduced among older adults who experience health symptoms that are difficult to remediate (such as functional disabilities) and increased among people who do not confront these types of challenges. Thus, active engagements in overcoming health problems are not a general-purpose mechanism. Instead, HECS are most effective when people have favorable opportunities for attaining their health-related goals.

Moreover, it is noteworthy that we found significant effects of participants' gender on volume and slope of cortisol secretion. As compared with men, women secreted lower levels and a steeper slope of diurnal cortisol secretion. This finding is consistent with previous research documenting that women exhibited lower levels of cortisol secretion than men in response to a laboratory stressor (Kirschbaum, Wüst, & Hellhammer, 1992; Kudielka et al., 1998). Women also showed lower cortisol levels than men in a study examining 24-hr urine cortisol levels (Prinz, Bailey, & Woods, 2000). Although our study statistically controlled for gender differences in cortisol secretion, the obtained main effect of gender on cortisol secretion may raise the question of whether gender differences in our predictor variables were associated with participants' cortisol secretion. To further explore this possibility, we conducted additional analyses (not previously reported), testing gender differences in the associations between cortisol secretion with sociodemographic variables, health stressors, or HECS for significance. None of these variables significantly interacted with gender in predicting participants' cortisol secretion.

Finally, we note that our analyses demonstrated that physical health problems predicted elevated levels of cortisol secretion across the entire day among participants who did not adaptively cope with their health problems. This finding implies that the occurrence of physical health stressors was not associated with a flattened cortisol response among this group of older adults. The fact that the literature reports mixed findings concerning the effects of stressors and depressive mood on increased versus flattened cortisol secretion (e.g., Burke, Davis, Otte, & Mohr, 2005; Miller, Cohen, & Ritchey, 2002) suggests that more research is needed to obtain generalizable conclusions concerning cortisol dysregulation. Some of the inconsistencies in the literature may be explained if research continues to take into account relevant moderators of the association between stressors and cortisol secretion (for a discussion of influencing factors, see Miller, Chen, & Zhou, in press). In addition, an important shortcoming of the existing literature is that many studies draw conclusions on the basis of small samples (for sample sizes of studies examining age effects of stressors on cortisol secretion, see Otte et al., 2005). The present study addressed this limitation by examining key variables in more than 200 older adults, and thus provides strong evidence for the protective role played by adaptive control behaviors in the management of older adults' physical problems and the maintenance of their psychological and biological health.

Limitations and Future Research

Although the findings supported our hypotheses, some limitations of the reported study should be addressed in future work. For example, we cannot draw conclusions about the direction of effects from the present data. Although our data showed depressive mood to mediate the effect of physical health problems on cortisol secretion, it may also be possible that cortisol has influenced participants' mood. In addition, considering the immunomodulatory effects of glucocorticoids (Sapolsky, Romero, & Munck, 2000), it is possible that cortisol dysregulation affected older adults' physical health problems. Whereas the latter effect would only be plausible if the observed cortisol dysregulation represented a stable personal characteristic, we note that our theoretical model would predict that biological dysregulation can influence older adults' prospective health (see Wrosch, Dunne, Scheier, & Schulz, 2006). Given that subsequent assessments of the present sample will be conducted over the coming years, we will be able to address these issues in our future work.

Furthermore, there may be underlying dispositions that affected older adults' reports of physical problems, depressive mood, and HECS as well as their levels of cortisol secretion. A trait that could produce such effects is neuroticism, given its effects on self-reports of physical health, depression, and cortisol secretion (e.g., Portella, Harmer, Flint, Cowen, & Goodwin, 2005; Watson & Pennebaker, 1989). Although not reported above, our study included a measure of neuroticism (Costa & McCrae, 1992). Although neuroticism was significantly associated with elevated levels of depressive mood ($r = .32$, $p < .01$), it did not predict participants' physical health problems or cortisol secretion, nor did it explain the observed buffering effects of HECS.

We note that our theoretical model can be used to help people deal with challenges that often arise during the aging process. This line of research may inform intervention programs aimed at identifying problems that can be overcome and teaching older adults to act on them. Given these considerations, we feel that future research should address the discussed limitations by conducting large-scale longitudinal studies and clinical intervention studies that engage older adults in adaptive control behaviors. The results of such studies may further illuminate the psychological mechanisms that help older adults to manage the occurrence of physical stressors and prevent negative effects on their psychological, biological, and physical health.

References

Adler, N. E., Epel, E., Castellazzo, G., & Ickovics, J. (2000). Relationship of subjective and objective social status with psychological and physiological functioning: Preliminary data in healthy White women. *Health Psychology, 19,* 586–592.

Aiken, L. S., & West, S. G. (1991). *Multiple regression: Testing and interpreting interactions*. Newbury Park, CA: Sage.

Brown, E. S., Varghese, F. P., & McEwen, B. S. (2004). Association of depression with medical illness: Does cortisol play a role? *Biological Psychiatry, 55,* 1–9.

Burke, H. M., Davis, M. C., Otte, C., & Mohr, D. C. (2005). Depression and cortisol responses to psychological stress: A meta-analysis. *Psychoneuroendocrinology, 30,* 846–856.

Clements, A. D., & Parker, C. R. (1998). The relationship between salivary cortisol concentrations in frozen versus mailed samples. *Psychoneuroendocrinology, 23,* 613–616.

Costa, P. T., & McCrae, R. R. (1992). *The NEO-PI-R (Personality Inventory Revised) manual*. Odessa, FL: Psychological Assessment Resources.

Creed, F., & Ash, G. (1992). Depression in rheumatoid arthritis: Aetiology and treatment. *International Review of Psychiatry, 4,* 23–33.

Dew, M. A. (1998). Psychiatric disorder in the context of physical illness. In B. Dohrenwend et al. (Ed.), *Adversity, stress, and psychopathology* (pp. 177–218). New York: Oxford University Press.

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin, 130,* 355–391.

Heckhausen, J., & Schulz, R. (1995). A life-span theory of control. *Psychological Review, 102,* 284–304.

Heim, C., Ehlert, U., & Hellhammer, D. (2000). The potential role of hypocortisolism in the pathophysiology of stress-related bodily disorders. *Psychoneuroendocrinology, 25,* 1–35.

Kirschbaum, C., & Hellhammer, D. (1989). Salivary cortisol in psychobiological research: An overview. *Neuropsychobiology, 22,* 150–169.

Kirschbaum, C., Kudielka, B. M., Gaab, J., Schommer, N. C., & Hellhammer, D. H. (1999). Impact of gender, menstrual cycle phase, and oral contraceptives on the activity of the hypothalamic-pituitary-adrenal axis. *Psychosomatic Medicine, 61,* 154–162.

Kirschbaum, C., Wüst, S., & Hellhammer, D. H. (1992). Consistent sex differences in cortisol responses to psychological stress. *Psychosomatic Medicine, 54,* 648–657.

Kudielka, B. M., Hellhammer, J., Hellhammer, D. H., Wolf, O. T., Pirke, K. M., Varadi, E., et al. (1998). Sex differences in endocrine and psychological responses to psychosocial stress in healthy elderly subjects and the impact of a 2-week dehydropiandrosterone treatment. *Journal of Clinical Endocrinology and Metabolism, 83,* 1756–1761.

Lenze, E. J., Rogers, J. C., Martire, L. M., Mulsant, B. H., Rollman, B. L., Dew, M. A., et al. (2001). The association of late-life depression and anxiety with physical disability: A review of the literature and prospectus for future research. *American Journal of Geriatric Psychiatry, 9,* 113–135.

Lupien, S. J., de Leon, M., De Santi, S., Convit, A., Tarshish, C., Nair, N. P. V., et al. (1998). Cortisol levels during human aging predict hippocampal atrophy and memory deficits. *Nature Neuroscience, 1,* 69–73.

McEwen, B. S. (2003). Mood disorders and allostatic load. *Biological Psychiatry, 54,* 200–207.

Miller, G. E., Chen, E., & Zhou, E. (in press). What goes up must come down: Chronic stress and the hypothalamic-pituitary-adrenocortical axis in humans. *Psychological Bulletin.*

Miller, G. E., Cohen, S., & Ritchey, A. K. (2002). Chronic psychological stress and the regulation of pro-inflammatory cytokines: A glucocorticoid resistance model. *Health Psychology, 21,* 531–541.

Murrell, S. A., Meeks, S., & Walker, J. (1991). Protective functions of health and self-esteem against depression in older adults facing illness or bereavement. *Psychology and Aging, 6,* 352–360.

Oeppen, J., & Vaupel, J. W. (2002, May 10). Broken limits to life expectancy. *Science, 296,* 1029–1031.

Otte, C., Hart, S., Neylan, T. C., Marmar, C. R., Yaffe, K., & Mohr, D. C. (2005). A meta-analysis of cortisol response to challenge in human aging: Importance of gender. *Psychoneuroendocrinology, 30,* 80–91.

Otte, C., Marmar, C. R., Pipkin, S. S., Moos, R., Browner, W., & Whooley, M. (2004). Depression and 24-hour urinary cortisol in medical outpatients with coronary heart disease: The heart and soul study. *Biological Psychiatry, 56,* 241–247.

Portella, M. J., Harmer, C. J., Flint, J., Cowen, P., & Goodwin, G. M. (2005). Enhanced early morning salivary cortisol in neuroticism. *American Journal of Psychiatry, 162,* 807–809.

Prinz, P. N., Bailey, S. L., & Woods, D. L. (2000). Sleep impairments in healthy seniors: Roles of stress cortisol, and interleukin-1 beta. *Chronobiology International, 17,* 391–404.

Sachar, E. J., Hellman, L., Roffwarg, H. P., Halpern, F. S., Fukushima, D. K., & Gallagher, T. F. (1973). Disrupted 24-hour patterns of cortisol secretion in psychotic depression. *Archives of General Psychiatry, 28,* 19–24.

Sapolsky, R. M., Romero, L. M., & Munck, A. U. (2000). How do glucocorticoids influence stress responses? Integrating permissive, suppressive, stimulatory, and preparative actions. *Endocrine Reviews, 21,* 55–89.

Schulz, R., & Heckhausen, J. (1996). A life span model of successful aging. *American Psychologist, 51,* 702–714.

Schulz, R., Martire, L. M., Beach, S. R., & Scheier, M. F. (2000). Depression and mortality in the elderly. *Current Directions in Psychological Science, 9,* 204–208.

Sephton, S. E., Sapolsky, R. M., Kraemer, H. C., & Spiegel, D. (2000). Diurnal cortisol rhythm as a predictor of breast cancer survival. *Journal of the National Cancer Institute, 92,* 994–1000.

Spencer, K. A., Tompkins, C. A., & Schulz, R. (1997). Assessment of depression in patients with brain pathology: The case of stroke. *Psychological Bulletin, 122,* 132–152.

Stone, A. A., Schwartz, J., Smyth, J., Kirschbaum, C., Cohen, S., Hellhammer, D., & Grossman, S. (2001). Individual differences in the diurnal cycle of salivary free cortisol: A replication of flattened cycles for some individuals. *Psychoneuroendocrinology, 26,* 295–306.

Timberlake, N., Klinger, L., Smith, P., Venn, G., Treasure, T., Harrison, M., & Newman, S. P. (1997). Incidence and patterns of depression following coronary artery bypass graft surgery. *Journal of Psychosomatic Research, 43,* 197–207.

van Eck, M., Berkhof, H., Nicolson, N., & Sulon, J. (1996). The effects of perceived stress, traits, mood states, and stressful daily events on salivary cortisol. *Psychosomatic Medicine, 58,* 447–458.

Watson, D., & Pennebaker, J. W. (1989). Health complaints, stress, and distress: Exploring the central role of negative affectivity. *Psychological Review, 96,* 234–254.

Weiner, H. (1992). *Perturbing the organism: The biology of stressful experience*. Chicago: University of Chicago Press.

Wrosch, C., Dunne, E., Scheier, M. F., & Schulz, R. (2006). Self-regulation of common age-related challenges: Benefits for older adults' psychological and physical health. *Journal of Behavioral Medicine, 29,* 299–306.

Wrosch, C., Schulz, R., & Heckhausen, J. (2002). Health stresses and depressive symptomatology in the elderly: The importance of health engagement control strategies. *Health Psychology, 21,* 340–348.

Wrosch, C., Schulz, R., & Heckhausen, J. (2004). Health stresses and depressive symptomatology in the elderly: A control-process approach. *Current Directions in Psychological Science, 13,* 17–20.

Yzerbyt, V. Y., Muller, D., & Judd, C. M. (2003). Adjusting researchers' approach to adjustment: On the use of covariates when testing interactions. *Journal of Experimental and Social Psychology, 40,* 424–431.