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The moderating role of meaning in life in the relationship between perceived stress and diurnal cortisol

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Running title: Meaning in life, perceived stress and diurnal HPA axis activity

Abstract

Previous studies have suggested that meaning in life may buffer the negative effects of stress. This study is the first to investigate the moderating role of meaning in life in the relationship between the perception of stress and diurnal cortisol in two independent samples of healthy adults. In Study 1 (*n*= 172, men= 82, women= 90, age range= 21-55 years, mean age= 37.58 years), the results of moderated regression analyses revealed that there was a significant positive relationship between overall perceived stress in the past month and both diurnal cortisol levels (Area under the curve with respect to the ground; AUCg) and the diurnal cortisol slope (DCS) only in individuals with low levels of meaning in life conceptualized as the degree to which one engages in activities that are personally valued and important. In Study 2 (*n*= 259, men= 125, women= 134, age range= 18-54 years, mean age= 29.06 years), we found a non-significant interaction term between meaning in life conceptualized as having goals and a sense of excitement regarding one's future and perception of stress in a model of both adjusted AUCg and DCS. The results were independent of age, sex, Body Mass Index, education, and race. The results shed light on the importance and the complexity of the construct of meaning in life and offer a possible explanation for why some people who face stressors may be more vulnerable than others to developing stress-related health problems.

Keywords: Perceived stress; meaning in life; diurnal cortisol slope; diurnal cortisol levels; HPA axis

Introduction

A disruption of the diurnal activity of the Hypothalamic-Pituitary-Adrenal (HPA) axis has been associated to stress-related health problems (Kudielka, Gierens, Hellhammer, Wüst, & Schlotz, 2012). Surprisingly, despite the link between the HPA axis and stress-related health problems, research investigating the relationship between perceived overall stress (e.g., the perception of stress during the previous month) and diurnal HPA activity in healthy populations has shown mixed results. The area-under-the-curve with respect to the ground (AUCg; reflecting the overall diurnal cortisol secretion) and the diurnal cortisol slope (DCS; reflecting the decrease in cortisol secretion from morning to evening) are two indexes of diurnal HPA axis activity. High AUCg and a flatter DCS (markers of HPA axis dysregulation) have been related to the perception of overall stress in some studies (e.g., Lovell, Moss, & Wetherell, 2011; Luecken et al., 1997; Sjörs, Ljung, & Jonsdottir, 2014), but not in others (e.g., Carlson, Campbell, Garland, & Grossman, 2007; Edwards, Hucklebridge, Clow, & Evans, 2003; Sjörs, Ljung, & Jonsdottir, 2014), suggesting that, although repeated exposure to stressors may disrupt the HPA axis, this effect would not occur in all individuals (Garrido, 2011).

Different theoretical considerations and empirical studies indicate that people with higher levels of meaning in life (ML) are less susceptible to strain than people whose lives are meaningless (for reviews: Czekierda et al., 2017; Glazer et al., 2014), and it was suggested that ML plays a protective role against the negative effects of stress (Cohen, Bavishi, & Rozanski, 2016). ML is a complex phenomenon that refers to *value*-related aspects (i.e., the perception of one's current activities as valuable and important) (Scheier et al., 2006) and *directedness*-related aspects (i.e., having goals and a sense of excitement about one's future) (Glazer et al., 2014; Ryff, 1989). These two aspects of ML can be measured using different methods (Park & George, 2013). The Life Engagement Test (Scheier et al., 2006) is considered a measure of the degree to which one considers that he/she engages in activities that are personally valued and important (i.e., value-related aspects of ML). The Purpose subscale of the Personal Well-Being

Scales is considered a measure of ML in terms of having goals and a sense of excitement about one's future (Ryff, 1989) (i.e., directedness-related aspects of ML). To date, research on the relationship between ML and diurnal cortisol secretion has considered only the *directedness*-related aspect, with mixed results (Lindfors &Lundberg, 2002; Ryff et al., 2004; Zilioli et al., 2015). Most importantly, no research has explicitly studied whether ML moderates the relationship between stress and diurnal cortisol secretion.

In two independent samples, we investigated whether the value-related aspects of ML (Study 1) and the directedness-related aspects of ML (Study 2) moderate the relationship between diurnal cortisol secretion (indexed as AUCg and DCS) and perceived stress in the previous month in healthy adults. We propose that, in people with low levels of ML, but not those with high ML, perceived stress will be significantly and positively related to higher AUCg and flatter DCS.

Method

Participants

The data included in Study 1 and Study 2 were collected by the Laboratory for the Study of Stress, Immunity, and Disease at Carnegie Mellon University under the directorship of Sheldon Cohen, PhD, and they were accessed via the Common Cold Project website (www.commoncoldproject.com; grant number NCCIH AT006694).

Study 1.

Participants in Study 1 were recruited as part of the Pittsburgh Mind-Body Center Study, a prospective viral challenge study conducted from 2000-2004 in 193 healthy volunteers aged 21-55 years (mean age= 37.3 years; *SD*= 8.8 years). The final sample included in Study 1 was composed of 172 individuals (see *Data management and statistical analyses* section for a description of the exclusion of participants from the analyses). Table 1 shows the characteristics of the Study 1 sample.

Study 2.

Participants in Study 2 were recruited as part of the Pittsburgh Cold Study 2, a prospective viral challenge study conducted from 1997-2001 with healthy volunteers aged 18-54 years (mean age= 28.9 years; *SD*= 10.4 years). The final sample included in Study 2 was composed of 259 individuals (see *Data management and statistical analyses* section for a description of the exclusion of participants from the analyses). The characteristics of the Study 2 sample are shown in Table 1.

The non-inclusion criteria for participating in the entire research protocol of the two studies were: regular medication regimen (including, but not limited to, use of antidepressants, sleeping pills, or tranquilizers), previous nasal/otologic surgery, psychiatric hospitalization within the past five years, history of chronic illness or psychiatric disorder treated within one year of study enrollment, human immunodeficiency seropositivity, an abnormal clinical profile (discovered via urinalysis, complete blood count, or analysis of blood chemistry), current pregnancy or lactation (or plans to become pregnant within three months of study enrollment), participation in another study involving psychological questionnaires and/or research products within the past 30 days or plans to participate in such research while enrolled in the current study, cold or flu-like illness within 30 days prior to quarantine (i.e., the last part of the protocol), previous hospitalization as a consequence of a flu-like illness, use of steroids or immunosuppressants within three months of the trial, and allergies to eggs or egg products.

Procedure

Both studies were approved by both Carnegie Mellon University and the University of Pittsburgh Internal Review Boards, and participants provided written informed consent prior to taking part in the research. The protocols for both studies are described in detail on the website of the project (www.commoncoldproject.com). As indicated by the researchers of the

Common Cold Project, each project was designed to test a series of specific hypotheses, and so differences in the projects' protocols may exist. However, in spite of the differences between projects, the studies from the Common Cold Project offer valuable information to test important hypotheses about factors that may affect diurnal cortisol secretion. In the current study, we focus on data from two of these projects to investigate the moderating role of ML in the relationship between stress and diurnal cortisol levels. Additionally, we focus on the AUCg and the DCS because of their relevance in the development of stress-related disorders (Kudielka et al., 2012).

The protocols lasted between 12 and 14 weeks for Study 1 and between 11 and 12 weeks for Study 2. We focus on the measures of diurnal cortisol levels, perceived stress in the previous month, and ML, which were collected during the baseline period before the participants were exposed to a common cold virus. As part of the protocol during the baseline period, participants filled out the psychological instruments to measure their levels of ML and their perception of psychological stress in the previous month (half of the items to measure ML in Study 2 were administered after the participants were exposed to the virus). To assess diurnal cortisol levels, participants were asked to provide several salivary samples on three different days: (i) Two non-consecutive days in participants' natural environment from 2 to 4 weeks before the day the participants filled out the questionnaire to measure perceived stress and (ii) the same day the participants filled out the questionnaire to measure stress, and under the supervision of the staff. Importantly, the cortisol levels were not affected by the virus because they were measured before the participants were exposed to it.

Measures

Perceived Stress.

In both studies, the degree to which people perceived their lives as stressful in the previous month was measured using the 10-item Perceived Stress Scale (Cohen & Janicki-

Deverts, 2012; Cohen et al., 1983). The respondents were asked to indicate on a 5-point frequency scale (ranging from 0: never to 4: very often) how often they found their lives to be unpredictable, uncontrollable, and overloaded in the past month. Sample items were: “In the last month, how often have you been upset because of something that happened unexpectedly?” and “In the last month, how often have you felt nervous and “stressed”?” Internal consistency of the scale in both studies was Cronbach’s α = .88.

Meaning in life.

Study 1. In Study 1, the value-related ML, which was understood as the extent to which individuals perceive their life activities to be valuable and important, was measured using a 6-item Life Engagement Test (LET) (Scheier et al., 2006). The respondents were asked to use a 5-point Likert scale (from 1: strongly disagree, to 5: strongly agree) to rate how much they agreed with self-descriptive statements about the meaningfulness of their lives. The sample item was “To me, the things I do are all worthwhile.” The internal consistency of the scale in the current study was Cronbach’s α = .74.

Study 2. In Study 2, the directedness-related ML, which was understood as having goals and a sense of excitement about one’s future, was measured using the 9-item Purpose subscale of the Personal Well-Being Scales (Ryff, 1989). The respondents were asked to use a 6-point Likert scale (from 1: strongly disagree, to 6: strongly agree) to indicate the extent of their agreement or disagreement with self-descriptive statements reflecting the directedness of their lives. The sample item was “I live life one day at a time and don’t really think about the future” (reversed). The internal consistency of the scale in the current study was Cronbach’s α = .84.

Cortisol levels.

Salivary samples for cortisol analyses were collected using Salivettes (Sarstedt, Rommelsdorft, Germany). Before salivary collection, participants were instructed not to eat or brush their teeth for one hour before the scheduled saliva collection time, and to abstain from smoking for 30 minutes before collection time. Participants received the salivettes, along with detailed written instructions and either a handheld computer (Study 1) or a pre-programmed wristwatch (Study 2) to alert participants at each collection time. The signaling device provided an alphanumeric code for each collection, and participants were instructed to write the code as well as the exact time and date of collection on each tube right after it was sealed. *Study 1.* Salivary samples were collected seven times daily on two non-consecutive days in participants' natural environment (1, 2, 4, 6, 8, 12 and 14 hr after awakening) and eight times on a different day under the supervision of the staff (immediately after awakening, one hour after awakening, and at 10.00am, 11.55am, 01.00pm, 03.00pm, 05.00pm, and 10.00pm). Cortisol levels were determined using a competitive enzyme-linked immunosorbent assay (ELISA; Salimetrics, State College, PA) procedure with an average deviation between individual pairs of replicates of 4%.

Study 2. Salivary samples were collected 11 times daily on two non-consecutive days in participants' natural environment (Immediately after awakening, 30min after awakening, and then 1, 2, 4, 6, 8, 10, 12, 14 and 16hr after awakening) and 12 times on a different day under the supervision of the staff (immediately after awakening at 5.45am, at 6.15am, 6.45am, 8.00am, 9.00am, 10.00am, 11.00am, 12.00am, 1.00pm, 2.00pm, 3.00pm, 4.00pm). Cortisol levels were determined using time-resolved fluorescence immunoassay with a cortisol-biotin conjugate as a tracer. Intra- and inter-assay variability were less than 12%.

Importantly, Dressendörfer et al. (1992) showed a high correlation (r=.95) between the methods used to measure cortisol levels in Study 1 (ELISA) and Study 2 (fluorescence immunoassay).

Data Management and Statistical Analyses

Cortisol levels were log transformed because they did not follow a normal distribution. To control for differences in cortisol levels due to differences in the awakening time, all cortisol samples were adjusted according to time of awakening. Two indexes were calculated using the salivary samples from the three days in each study and the real salivary sample collection times provided by the participants: (i) The AUCg was computed as an index of overall cortisol secretion (see Pruessner et al., 2003 for the formula), and (ii) the DCS was computed by regressing cortisol values at each sample collection time for each participant. For DCS, a larger value is interpreted as a flatter slope, reflecting a lower cortisol decline during the day, whereas a smaller value is interpreted as a steeper slope, reflecting a more rapid diurnal decline. In Study 1, participants did not collect salivary samples immediately and 30min after awakening on the two non-consecutive days in the participants' natural environment. Thus, to control for the increase in cortisol levels due to the cortisol awakening response, and in order to compare the results across studies, the AUCg and DCS were calculated excluding the salivary samples collected immediately and 30min after awakening. Cortisol indexes were calculated only for participants with no missing cortisol sample data, and only participants with at least two days of cortisol sampling were included in the study. (Study 1: *n*=172; Study 2: *n*=259). Body Mass Index was missing from 1 participant in Study 1. ML data were missing from 2 participants in Study 2.

Correlation analyses were used to investigate the relationships among the cortisol indexes, ML, perceived stress, and the covariates included in the study. Moderated regression analyses and bootstrapped bias-corrected 95% confidence intervals of the interaction effect were computed using the PROCESS macro in SPSS (Model 1) with 5000 bootstrapped samples. Confidence intervals that do not contain zero indicate a significant interaction effect. As independent variable, dependent variable, and moderator, we included perceived stress, cortisol indexes (AUCg and DCL), and ML, respectively. The analyses were first performed without covariates. Then, we repeated the analyses, including the following covariates: age, sex (men=0, women=1), body mass index, education (years), and race (dichotomized as white or non-white due to the small number of non-black racial groups represented) in the model. These control variables have been used in previous studies using data from the Pittsburgh

Mind-Body Center Study, given their possible effects on diurnal cortisol levels (Chin, Murphy, Janicki-Deverts, & Cohen, 2017; Janicki-Deverts, Cohen, Turner, & Doyle, 2016). Tolerance and VIF values indicate that there are no collinearity issues for the variables included in the model. To control for deviations from the saliva sampling protocol, previous studies using data from the Common Cold Project have excluded from the analyses salivary samples that were not collected within 45min of the scheduled collection time (e.g., Chin et al., 2017; Janicki-Deverts et al., 2016). If we use the same procedure in the current study, the same statistical conclusions are observed.

Outliers were defined as values ±3 SD and winsorized by replacing their values with values equal to the mean ±3 SD. In Study 1, 3 outliers were detected for AUCg, 3 for DCS, and 2 for ML. In Study 2, 1 outlier was detected for AUCg, 2 for DCS, 1 for perception of stress, and 3 for ML. Statistical analyses were carried out using SPSS v.24.

Results

Results of Study 1

Correlations among the variables used in Study 1 are shown in Table 2. Results show that cortisol indexes were not significantly related to perception of stress or value-related ML (all *p*s>.05). Higher value-related ML was related to a lower perception of stress (*p*<.001). Higher AUCg was related to higher DCS (*p*<.001).

The results of the unadjusted moderation analysis show a significant interaction term between value-related ML and perception of stress in a cortisol DCS model (*Est*. = -.189; *IC* 95% [-.345, -.033]). The results show that there is a significant positive relationship between perception of stress and cortisol DCS in people with low levels of value-related ML (*Est*. = .275, *IC* 95% [.021, .529]). This relationship is no longer significant in people with medium and high levels of value-related ML (*IC* 95% [-.083, .258] and [-.303, .104], respectively). After controlling for age, sex, body mass index, education, and race, the results of the moderation analysis show a significant interaction term between value-related ML and perception of stress in a cortisol DCS model (*Est*. = -.197; *IC* 95% [-.354, -.039]). As observed for the analyses without covariates, there is a significant positive relationship between perception of stress and cortisol DCS in people with low levels of value-related ML (*Est*. = .297, *IC* 95% [.041, .553]). This relationship is no longer significant in people with medium and high levels of value-related ML (*IC* 95% [-.070, .272] and [-.301, .111], respectively) (see Table 3).

Furthermore, the results of the unadjusted moderation analysis show a significant interaction term between value-related ML and perception of stress in a model of adjusted AUCg (*Est*. = -.227; *IC* 95% [-.380, -.073]). The results show a significant positive relationship between perception of stress and AUCg in people with low levels of value-related ML (*Est*. = .369, *IC* 95% [.118, .620]). This relationship is no longer significant in people with medium and high levels of value-related ML (*IC* 95% [-.025, .311] and [-.283, .118], respectively). After controlling for covariates, the results of the moderation analysis show a significant interaction term between value-related ML and perception of stress in a model of adjusted AUCg (*Est*. = -.237; *IC* 95% [-.390, -.084]). As observed for the analyses without covariates, the results show a significant positive relationship between perception of stress and AUCg in people with low levels of value-related ML (*Est*. = .393, *IC* 95% [.145, .642]). This relationship is no longer significant in people with medium and high levels of value-related ML (*IC* 95% [-.009, .324] and [-.278, .122], respectively) (see Table 3).

Results of Study 2

Correlations among the variables used in Study 2 are shown in Table 2. Results show that cortisol indexes were not significantly related to perception of stress or directedness-related ML (all *p*s>.05). Higher meaning in life was related to lower perception of stress ($p<.001$). Higher AUCg was related to higher DCS ($p<.001$).

The results of the unadjusted moderation analysis show non-significant interaction terms between directedness-related ML and perception of stress in a cortisol DCS model (*IC*

95% [-.070, .201]), and between directedness-related ML and perception of stress in a model of adjusted AUCg (*IC* 95% [-.009, .198]). After controlling for age, sex, body mass index, education, and race, the same results are observed. Directedness-related ML does not moderate the relationship between perception of stress and AUCg or the relationship between perception of stress and DCS (see Table 4).

Discussion

The aim of the present study was to investigate the moderating role of ML (*value*- and *directedness*-related) in the relationship between the perception of stress and diurnal cortisol secretion in healthy adults. In agreement with our hypothesis, in Study 1, the results show that value-related ML moderates the relationship between perception of stress and both overall diurnal cortisol secretion (i.e., AUCg) and the decline in cortisol levels from the morning to the evening (i.e., DCS). Specifically, the results show that higher overall perceived stress in the past month was related to higher diurnal cortisol secretion and less decline in cortisol levels in people with low levels of value-related ML, but not in those with medium or high value-related ML. However, in Study 2, directedness-related ML did not moderate the relationship between perception of stress and cortisol indexes.

At first glance, the results from Study 1 and Study 2 might be considered contradictory. However, we can interpret these results in light of the differences in the conceptualization and operationalization of ML in each study. In Study 1, the value-related aspect of ML was measured using the Life Engagement Test (Scheier et al., 2006), which evaluates the degree to which one currently experiences and engages in activities that are personally valued and important. In Study 2, the directedness-related aspect of ML was measure using the Purpose in Life scale (Ryff, 1989), which evaluates ML in terms of having goals and a sense of excitement about one's future. Exploring the differences between the two scales used to measure the two different aspects of ML, Scheier and colleagues (2006) suggested that, in contrast to the Life

Engagement Test, which measures value-related meaning, the Purpose in Life scale, which measures directedness-related meaning (which we can interpret as finding value in the future), would not reflect the *current experience* of ML because it is less time-sensitive. In this regard, directedness-related ML has been related to allostatic load ten years later, but not to allostatic load at the moment of ML assessment (Zilioli et al., 2015). Taken together, it is possible that, as observed in Study 1, overall stress perception in the previous month does not disrupt the HPA axis activity if the activities performed by the individuals are personally valued and important in the present. However, having goals and a sense of directedness and excitement about one's future could be important in protecting individuals from the negative effects of stress in the long run, after several years, but it would not play a protective role in the present, as observed in Study 2, and supported by Zilioli et al. (2015). Thus, our results shed light on the temporal dimension of eudaimonia, which, until now, had not been sufficiently explored (Sonnentag, 2015). Moreover, our findings highlight the importance of using more than one method to measure ML in order to capture the complexity of this construct, as suggested by Park and George (2013).

The results of the Study 1 support previous research suggesting that having greater levels of ML can buffer stressors' deleterious effects on strain (Glazer et al., 2014). Along this line, in a recent meta-analysis, Cohen and colleagues (2016) suggested that ML's positive effect on health can be due to its buffering effects on the pathophysiological response to psychosocial stressors. Importantly, previous studies have shown that stress and exposure to high cortisol levels are related to the development of health problems such as cardiovascular, endocrine, and psychological disorders (Hammen, 2005; Kelly & Ismail, 2015; Miller, Chen, & Zhou, 2007; Staufenbiel, Penninx, Spijker, Elzinga, & van Rossum, 2013; Steptoe & Kivimäki, 2013). Thus, our results suggest that the value-related aspect of ML might play a protective role in reducing the negative consequences of stress on health. Nonetheless, it is important to note that we did not investigate whether the differences in the relationship between stress and diurnal cortisol levels in people with high and low ML are related to differences in the development of stress-related disorders. Thus, further studies are clearly needed to link the results from this study to studies showing the protective role of ML and the effect of high diurnal cortisol secretion on the development of health problems.

The results from Study 1 support different theoretical considerations by pointing to a possible mechanism (i.e., the role of the HPA axis) to explain the protective role of ML. For instance, our results coincide with Antonovsky's (1987) theory of *sense of coherence*, which suggests that ML is an important aspect of coping with stress (Danvers, O'Neil, & Shiota, 2016), because it enhances individuals' ability to make cognitive sense of the situation, perceive experiences as challenges, and make emotional and motivational sense of demands (Strümpfer, 1995), which helps to maintain health in spite of stress and, therefore, mitigate strain (Strümpfer, 2003). Moreover, the results are in consonance with conservation of resources theory (Hobfoll, 2001), which proposes that having ML can be an important protective psychological resource against stress. Thus, our results provide empirical evidence for these theories by showing that the protective role of ML might be exerted through its moderating role in the relationship between stress perception and cortisol.

Additionally, although it was not the main focus of our study, we have to point out that we did not find significant correlations between perception of stress and cortisol levels (DCS, AUCg), or between ML and cortisol levels (DCS, AUCg). First, the former result agrees with several studies showing no relationship between overall stress (e.g., the perception of stress during the previous month) and diurnal cortisol secretion in healthy population (Carlson et al., 2007; Edwards et al., 2003; Vedhara et al., 2003). As Garrido (2011) and Ouanes and colleagues (2017) suggest, it is possible that, although repeated exposure to stressors may produce a disruption of the HPA axis, the negative effect of stress does not occur in all individuals. Second, the lack of a correlation between ML and cortisol levels supports the findings of Ryff and colleagues (2004), who showed non-significant associations between directedness-related ML and diurnal cortisol secretion and diurnal cortisol slopes in a sample of 135 women aged 65-75. Furthermore, these findings coincide with Zilioli and colleagues (2015), who showed a non-significant cross-sectional relationship between directedness-related ML and cortisol levels assessed using an overnight urinary sample in 983 participants aged 25-74. Our results expand these findings by showing that value-related ML does not directly explain the inter-individual differences in diurnal cortisol secretion in young adults.

It is important to highlight that the AUCg and the DCS are not the only components of diurnal cortisol secretion. The cortisol awakening response is considered an independent component of the HPA axis (Edwards et al., 2001) that has also been related to stress-related health problems, such as cardiovascular disorders, depression, and posttraumatic stress disorders (e.g., Fries, Dettenborn, & Kirschbaum, 2009; Pulopulos, Hidalgo, Puig-Perez, & Salvador, 2017; Wessa, Rohleder, Kirschbaum, & Flor, 2006). In the current study, however, the cortisol awakening response could not be investigated for methodological reasons (i.e., Study 1 measured the cortisol awakening response on only one day, and both studies used only two salivary samples to measure the cortisol awakening response) that affect the investigation of the cortisol awakening response (see Stalder et al., 2016). Thus, further studies are needed to investigate whether ML may also moderate the relationship between the cortisol awakening response and stress.

Some limitations warrant a cautious interpretation of the results of this study. First, two methods were used to measure two different aspects of ML in two separate samples, and the number and timing of the salivary sample collection were not the same in both studies. These methodological differences should be considered when interpreting the results. Thus, although both studies used the same questionnaire to measure perceived stress in healthy young adults, and both studies included a relatively large number of salivary samples to capture the dynamic pattern of the cortisol levels, a direct comparison of the two studies should be made with caution. Therefore, although our results shed light on the role of ML in the relationship between stress and diurnal cortisol, there is a need for future research to investigate whether different conceptualizations of ML can moderate the relationship between diurnal cortisol and perceived stress in the same sample. Second, the participants in the present studies were carefully screened for good health and then, the generalizability of the findings must be considered. Finally, the associations reported in this study are correlational; therefore, causal inferences cannot be drawn.

To conclude, evidence from an increasing number of studies points to the importance of ML in mitigating stressors' deleterious effects. To our knowledge, the present study is the first to show the buffering role of ML in the relationship between perceived stress and diurnal cortisol secretion. Thus, this study helps to explain why some people develop strains, but others do not, when confronting stressful situations. The importance of ML and its protective role against the deleterious effects of stress clearly warrant future study.

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Contributors

MMP and MWK performed the data analyses and wrote the manuscript.

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Conflict of interest

The authors state that there are no conflicts of interest associated with the research.

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Lay summary

The results of this study indicate that people who perceive their life activities to be valuable and important will show a healthier secretion of cortisol (the stress hormone) in stressful periods. In this way, this study helps to explain why some people might develop health problems, whereas others do not, when confronting stressful periods.

Table 1. Sample characteristics and descriptive statistics in two studies

	Mean/Count (SD/%)			
	Study 1		Study 2	
Age	37.58	(*SD*=8.72)	29.06	(*SD*=10.48)
Sex				
Male	82	(47.7%)	125	(48.3%)
Female	90	(52.3%)	134	(51.7%)
Educational attainment in years	13.81	(*SD*=2.16)	13.43	(*SD*= 1.78)
Race/Ethnicity				
White/Caucasian	99	(57.6%)	171	(66.0%)
Black/African American	62	(36.0%)	81	(31.3%)
Native American, Eskimo, Aleut	1	(0.6%)	3	(1.2%)
Asian or Pacific Islander	1	(0.6%)	2	(0.8%)
Hispanic	1	(0.6%)	2	(0.8%)
Other (e.g., mixed race)	8	(4.7%)	-	
Body mass index (kg/m^2)	28.89	(*SD*=7.07)	26.78	(*SD*= 6.10)
Perceived stress (PSS)	14.15	(*SD*=6.41)	15.05	(*SD*= 6.81)
Purpose in life	25.08	(*SD*=3.64)	41.83	(*SD*= 7.42)
Diurnal Cortisol Slope	.001	(SD= .122)	.002	(*SD*= .090)
Diurnal Cortisol Levels	431.03	(*SD*= 211.41)	740.47	(*SD*= 155.90)

Note. *N* = 172 (Study 1) except for BMI (*N*=171) and *N* = 259 (Study 2) except for ML (*N*=257).

Table 2. Correlations

	age	sex	BMI	Education	Race / Ethnicity	Perceived Stress	Meaning in Life[a]	Cortisol DCS	Cortisol AUCg
age		-.06	.32**	.12*	-.05	-.01	-.12	-.03	-.07
sex	.08		.04	.01	.09	.09	.16**	-.14*	-.06
BMI	.04	.13		.02	-.13*	-.02	.00	-.02	-.07
Educational	.12	.17*	-.01		.11	-.06	.08	.01	.02
Race/Ethnicity	-.01	.03	-.15	.32**		-.05	-.04	.07	.12
Perceived Stress	-.12	-.03	.02	-.01	-.03		-.46**	.04	.05
Meaning in Life[a]	.10	.13	-.08	.05	-.06	-.46**		-.09	-.06
Cortisol DCS	.04	-.151*	-.03	-.12	-.05	.05	-.03		.91**
Cortisol AUCg	.04	-.21**	-.08	-.14	-.05	.11	-.09	.85**	

Note. *N* = 172 (Study 1) except for BMI (*N*=171) and *N* = 259 (Study 2) except for ML (*N*=257); *df* in Study 1 = 170, except for correlations with BMI in which case *df*=169; df in Study 2 = 257, except for correlations with ML in which case *df*=255. The correlations for the Study 1 are shown below the diagonal. The correlations for the Study 2 are shown above the diagonal. *p <.05 level (2-tailed), ** p < .01 (2-tailed). [a] In the Study 1, value-related meaning in life was measured using the Life Engagement Test (Scheier et al., 2006), whereas in the Study 2 directedness-related meaning in life was measured using the Purpose subscale of the Personal Well-Being Scales (Ryff, 1989).

Table 3. Conditional effect of perception stress on dependent variables at different values of purpose in life, Study 1.

Dependent variable: Cortisol DCS						
ΔR^2 interaction=.033		*F*=5.727, *df*(1,2)=1, 168		*p*=.018	*LLCI*=-.345	*ULCI*=-.033
Purpose in life	Effect	*SE*	*t*	*p*	*LLCI*	*ULCI*
-.993	.275	.129	2.139	.034	.021	.529
0.00	.088	.086	1.017	.311	-.083	.258
.993	-.100	.103	-0.968	.334	-.303	.104
Dependent variable: Cortisol AUCg						
ΔR^2 interaction=.048		*F*=8.506, *df*(1,2)=1, 168		*p*=.004	*LLCI*=-.381	*ULCI*=-.073
Purpose in life	Effect	*SE*	*t*	*p*	*LLCI*	*ULCI*
-.993	.369	.127	2.904	.004	.118	.620
0.00	.143	.085	1.682	.094	-.025	.311
.993	-.082	.102	-0.809	.420	-.283	.118

Note. *N* = 171; Values for quantitative moderators are the mean and plus/minus one SD from mean.

Table 4. Conditional effect of perception stress on dependent variables in Study 2 at different values of purpose in life, controlling for age, sex, body mass index, education, and race.

Dependent variable: Cortisol DCS						
ΔR^2 interaction=.005		*F*=0.927, *df*(1,2)=1, 248		*p*=.337	*LLCI*=-.070	*ULCI*=.204
Purpose in life	Effect	*SE*	*t*	*p*	*LLCI*	*ULCI*
-.999	-.040	.098	-0.409	.683	-.233	.153
.000	.027	.071	0.381	.704	-.112	.166
.999	.094	.101	0.935	.351	-.104	.292
Dependent variable: Cortisol AUCg						
ΔR^2 interaction=.012		*F*=3.306, *df*(1,2)=1, 248		*p*=.070	*LLCI*=-.008	*ULCI*=.209
Purpose in life	Effect	*SE*	*t*	*p*	*LLCI*	*ULCI*
-.999	-.061	.077	-0.786	.433	-.213	.092
.000	.040	.068	0.585	.559	-.094	.173
.999	.140	.096	1.454	.147	-.050	.329

Note. *N* = 257; Values for quantitative moderators are the mean and plus/minus one SD from mean.