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Do Chronic Stressors lead to Physiological Dysregulation? Testing the theory of Allostatic Load

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ABSTRACT

Objectives. We explore three questions: 1) Do chronic stressors predict physiological dyregulation? 2) Is that relationship moderated by characteristics of the individual and social environment? and 3) Do perceived levels of stress mediate the relationship between stressors and dysregulation?

Methods. Data come from a nationally representative, longitudinal study of older Taiwanese (n=916). Regression models are used to examine the relationship between the number of life challenges (i.e., stressors) during 1996-2000 and physiological dysregulation (in 2000) based on 16 biomarkers that reflect neuroendocrine function, immune system, cardiovascular function, and metabolic pathways. We include interaction terms to test whether psychosocial vulnerability moderates the impact of stressors. Additional models evaluate the mediating effects of perceived stress.

Results. We find a significant association between the number of stressors and physiological dysregulation only for those with high vulnerability. Even among this group, the magnitude of the effect is small. The level of perceived stress partly mediates the relationship between chronic stressors and physiological dysregulation.

Conclusions. Our results provide some support for the theory of allostatic load, although the relationship between life challenges and physiological dysregulation is weak. The evidence also supports the stress-buffering hypothesis: the combination of low social position, weak social networks, and poor coping ability is associated with increases in the physiological consequences of life challenges.

Keywords: Chronic stressors, physiological dysregulation, allostatic load, perceived stress, stressful experiences, Taiwan

Abbreviations: BMI = Body mass index; DHEAS = Dehydroepiandrosterone sulfate; HDL = high-density lipoprotein; HPA = Hypothalamic-pituitary-adrenal; IGF-1 = Insulin-like growth factor 1; IL-6 = Interleukin-6; SD = Standard deviation; SEBAS = Social Environment and Biomarkers of Aging Study; SEI = Socioeconomic index; SNS = Sympathetic nervous system; UCL = Union Clinical Laboratories

INTRODUCTION

The idea that the chronic stressors of contemporary life can have adverse health consequences is receiving increasing attention in both popular and scientific media. The numerous theories that propose possible mechanisms to explain this link all share the (sometimes implicit) assumption that there are physiological pathways through which stressors affect health; Most also agree that potentially stressful life events ("stressors") do not affect everyone in the same way.

Our theoretical model (see Figure 1) is based on previously developed paradigms (1, 2) that posit that the physiological response to a stressor depends on a person's perception or interpretation of the situation. These perceptions, in turn, are shaped by the social environment (e.g., social position, social networks and support) and individual characteristics (e.g., personality, coping skills). Over time, repeated or prolonged physiological response to life challenges may have a cumulative effect on health. While there is a large literature focusing on the link between stressors and health outcomes, there has been less attention to establishing the link between chronic stressors and the intermediate physiological dysregulation (3).

In this paper, we use longitudinal data from a nationally representative sample of older Taiwanese to explore three questions. First, does the number of stressors (summed across survey waves) predict physiological dysregulation? Second, if so, do the social environment and personal characteristics moderate the effects of these life challenges on physiological dysregulation? And finally, do perceived levels of stress mediate the physiological effects of chronic stressors, the social environment, and individual characteristics?

What is Allostatic Load and How is it Measured?

Allostatic load refers to the cumulative cost ("wear and tear") of repeated neuroendocrine response resulting from chronic environmental challenges (4). According to this framework, chronic stressors, over time, can cause dysregulation of multiple interrelated physiological systems, which if prolonged, may ultimately lead to deteriorations in health (4, 5). Such dysregulation is characterized by elevated (or reduced) operating levels of biological parameters that reflect functioning of the sympathetic nervous system (SNS), hypothalamic-pituitary-adrenal (HPA) axis, immune system, cardiovascular and metabolic processes.

Measures of allostatic load have been shown to predict diverse health outcomes, including cognitive and physical functioning, cardiovascular disease, and mortality (6-10). An initial operationalization of allostatic load was a simple count of the number of biomarkers (out of 10) for which individuals fell into the highest risk quartile (8). More recent formulations incorporate additional biomarkers believed to be associated with the stress response (e.g., inflammatory parameters) and define risk in both tails of the distribution where appropriate (10).

The Link between Stressful Life Events and Physiology

Many studies have investigated the relationship between stressors and physical or mental health (11-14), but the literature addressing the physiological mechanisms that mediate the link between stressful life events and health outcomes is more sparse. Most studies of physiological parameters focus on the acute stress response to experimental challenges rather than the long-term effects of chronic stressors.

Very few studies have demonstrated an association between stressful life events and a measure of multi-system physiological dysregulation (15-18). Rather, most have focused on individual biological measures believed to be part of the stress response. For example, several studies have found stressful experience to be associated with both higher ((19-21) and lower levels of cortisol (22). While some research has demonstrated that life challenges are associated with higher levels of urinary epinephrine or norepinephrine (21, 23), others find no such relationship (20, 24). Other evidence suggests that life challenges may contribute to higher levels of IL-6 (25, 26), DHEAS (27), blood pressure (28-30), cholesterol (31-33), triglycerides (30), and glycosylated hemoglobin (34-36).

Social Environment and Individual Characteristics as Moderators

Social status may affect both exposure to stressors and access to resources that enable one to effectively cope with those stressors (2, 37). Education is a particularly important determinant of social status and upward mobility in Taiwan (38). Elderly Taiwanese adults with no education report higher levels of stress than their educated counterparts (39). Studies in Taiwan find an association between education and physiological dysregulation for women, but not men (40, 41).

Strong social networks may reduce the negative effects of life events and strains and moderate the physiological response to challenge (42). Considerable research has documented the impact of social connections on health outcomes (43), but only with the recent inclusion of biological markers in social surveys have we been able to explore how the social environment is linked to the physiological factors that influence well-being and mortality. Analyses based on data from Taiwan (18, 41) confirm earlier

findings from US data related to the importance of inadequate social support for physiological dysregulation, although the association appears to be weaker than that found in Western societies (44, 45).

Individual characteristics such as personality and coping skills may also influence perceptions of stressful experience and the physiological impact of stressors (46). For example, an optimistic personality is associated with lower levels of subsequent perceived stress (47, 48) and better adjustment to stressful events (49, 50). Other studies suggest that a sense of personal mastery may moderate the health consequences of stressors (51, 52), although some research suggests that compared with persons with an external locus of control, those with a strong sense of personal mastery may be more vulnerable to stressors over which they have no control (53).

METHODS

Data

The data for this study are based on a follow-up of the Survey of Health and Living Status of the Near-Elderly and Elderly in Taiwan. The longitudinal survey began in 1989 with a national sample of 4049 persons aged 60 and older (response rate, 92%), and was expanded in 1996 to include 2462 near-elderly persons aged 50 to 66 in 1996 (response rate, 81%). Both cohorts were interviewed in 1999 (response rate, 90% of survivors).

Among those interviewed in 1999, a random sub-sample was selected for the 2000 Social Environment and Biomarkers of Aging Study (SEBAS), with oversampling of persons 71 years and older (in 2000) and residents of urban areas. SEBAS consisted of an in-home interview and a hospital examination: 1497 persons aged 54 and older

provided interviews in SEBAS (92% of survivors) and 1023 participated in the physical examination (68% of those interviewed). Of the 474 who did not undergo the exam, 111 were not asked to participate based on specified exclusion criteria (i.e., living in an institution, being seriously ill, on kidney dialysis, using a catheter or diaper). Disproportionately high non-participation rates were found among the healthiest respondents as well as the least healthy, with persons who received the medical exam reporting the same average health status (measured on a five-point scale) as those who did not. Results presented elsewhere (54) suggest that, in the presence of controls for age, estimates from the medical exam portion of SEBAS are unlikely to be seriously biased.

SEBAS respondents who participated in the medical exams collected a 12-hour overnight urine sample (7pm to 7am) in order to obtain integrated values of cortisol and catecholamines, fasted overnight and visited a nearby hospital the following morning. Compliance with the urine collection protocol was extremely high. Medical personnel drew a blood sample and took blood pressure and anthropometric measurements during the hospital visit. Written informed consent was obtained for participation in the interview and physical examination.

Measures

Physiological Dysregulation

Blood and urine specimens were analyzed at Union Clinical Laboratories (UCL) in Taipei. In addition to the routine standardization and calibration tests performed by the laboratory, during the early stages of fieldwork nine individuals (outside the target sample) contributed triplicate sets of specimens. The results indicate intra-lab reliability

of 0.86 or higher for duplicates sent to UCL and inter-lab correlations of 0.65 or higher between results from UCL and Quest Diagnostics (in the US).

The physiological dysregulation score is based on 16 biomarkers that reflect neuroendocrine, immune system, and cardiovascular function, and metabolic pathways. BMI was calculated as weight divided by height squared (kg/m^2) and the waist/hip ratio was based on waist circumference measured at its narrowest point and hip circumference measured at the maximal buttocks. Diastolic and systolic blood pressure were calculated as the average of two seated readings based on a mercury sphygmomanometer. Epinephrine, norepinephrine, dopamine, and cortisol were obtained from the overnight urine specimen, which provides integrated values of these neurotransmitters and hormones for a period when most participants were at home and resting; these markers are reported as micrograms per gram creatinine to adjust for body size. The remaining markers were obtained from the fasting blood specimen: dehydroepiandrosterone sulfate (DHEAS), IL-6, IGF-1, triglycerides, total serum cholesterol, the ratio of total serum cholesterol to high-density lipoprotein (HDL) cholesterol, glycosylated hemoglobin, and fasting glucose. The assays used to measure the biomarkers from the blood and urine samples are described elsewhere (3).

The physiological dysregulation score counts the number of biomarkers for which the individual's value is below the 10^{th} percentile (or below assay sensitivity in the case of epinephrine and Il-6) or above the 90^{th} percentile. For comparability with previous research in which DHEAS and the ratio of total to HDL cholesterol have been treated as one-tailed, we dichotomize the values for DHEAS (<10%) and the ratio of total to HDL cholesterol (>90%) to identify elevated risk with only one end of the distribution.

Number of stressors

Survey waves in 1996, 1999, and 2000 include extensive information regarding potential stressors and aspects of the individual and social environment that may moderate the effects of stressors. We present results based on one strategy for consolidating these data and provide information about our exploration of alternative measures in the discussion section.

Our measure of chronic stress is derived from a count of the number of stressors at each wave (1996, 1999, & 2000). Stressors comprise experiences that we expect most people would find stressful: marital disruption, moving, death of a child, spouse's ill health, financial difficulty, decline in financial position, serious consequences of the 2000 earthquake, and crime/fraud victimization (data vary across waves; see Appendix Table 1 for details). If data are missing for only one stressor in a given wave, we sum across valid responses and rescale accordingly. Subsequently, we aggregate the number of stressors across all three waves (potential range: 0-18).

Psychosocial Vulnerability

As described in more detail below, we define three domains that reflect psychosocial vulnerability to stressful experience: position in social hierarchies, social networks, and internal resources. We incorporate measures of these domains into our models in two ways. First, we allow for direct associations between physiological dysregulation and each of these three domains. Second, we construct a composite measure of psychosocial vulnerability defined as: low (at least two domains high and moderate or high on the third), moderate, and high (at least two domains low and moderate or low for the third). An interaction term between this measure and number of stressors is

included to test whether vulnerability amplifies the association between stressors and dysregulation. We use the composite indicator rather than separate measures for each domain in the interaction term both because we have limited statistical power and because we believe that strength in one domain may compensate for inadequacy in another. Descriptive statistics for the summary measures pertaining to each domain as well as overall vulnerability are given in Table 1. Appendix Table 1 presents descriptive statistics for the components upon which these summary measures are based.

Position in Social Hierarchies. Social position is categorized as low, medium or high based on the respondent's years of education and a socioeconomic index (SEI) for the major lifetime occupation of the respondent (if male) or (most recent) spouse (if female). The SEI, developed by Tsai and Chiu (55), ranges from 55.1 for farm laborers to 76.1 for doctors (including Chinese-style and dentists) and is missing for the two female respondents who never married.

Low social position comprises those who are illiterate or have no formal education. High social position includes: a) those with seven or more years of education, and b) those with six years of education and SEI ranging from 66.4 (soldiers, army officer, and police) to 76.1 (doctors including Chinese-style and dentists). The middle group comprises the remainder (including 8 individuals for whom SEI is missing).

Social Networks. The extent of the respondent's social networks is based on 1996 and 1999 indicators of social ties, participation in social activities, and availability of emotional support. The variable denoting social ties counts the number of relatives, friends, and neighbors with whom the respondent reports having regular contact. Because the definition of "regular" contact (monthly vs. weekly) was not always

consistent across waves, we define high social ties as being at or above the 25th percentile of social ties at a given survey (28+ in 1996; 22+ in 1999).

We also count the number of social activities in which the respondent reports participating; these include: 1) playing games (e.g., chess, cards, or mahjong); 2) socializing with friends/neighbors/relatives; 3) joining organized group activities; 4) doing volunteer work; and participating in 5) religious groups, 6) business associations, 7) political groups, 8) clan associations, 9) elderly organizations, 10) neighborhood associations, and 11) social service organizations. The score is calculated if at least nine items have valid responses (and rescaled if not all items are valid). We define high social activity as participation in two or more activities.

Emotional support is based on asking how willing others are to listen to the respondent, take care of the respondent when s/he is ill, make her/him feel loved and cared for, and how satisfied the respondent is with the overall level of emotional support received; these four items were coded on a 0 to 4 scale. An index for each wave was created by summing the items and dividing by the number of valid items (if at least three items are valid); range is 0 to 4, and alpha reliability is 0.84 in 1996 and 0.87 in 1999. An index score of 4 is coded as high emotional support.

We count how many of the three indicators are classified as high in each wave. Social networks are classified as strong (respondent scores $\geq$2 in one wave and $\geq$1 in the other wave), moderate, or weak (0 in one wave and $\leq$1 in the other).

Internal Resources. Our indicator of personality and coping ability is based on questions relating to locus of control, engagement, optimism, and attitudes toward growing old. The locus of control index is based on the 7-item Pearlin scale (56)

included in the 2000 interview. Each item is scored on a 4-point ordinal scale; two items are reverse-coded so that higher values indicate greater personal mastery for all items. The index is computed by summing across items (if at least four items are valid) and dividing by the number of valid items; the resulting score ranges from 0 to 3 and the alpha reliability is 0.64. If the score is greater than 1.5, the respondent is coded as expressing personal mastery.

Engagement is based on two questions asked in 1996 and 1999: "Do you find what you do interesting?" and "Do you feel that most of what you do is monotonous and of no interest?" We code the respondent as engaged if s/he responds "yes" to the first and "no" to the second question in both waves.

Optimism is also based on a question asked in 1996 and 1999: "Do you expect that in the future happy things will occur?" The respondent is classified as optimistic if s/he responds "yes" in both waves.

In 1996, respondents were asked to rate (on a 4-point scale) the importance of seven advantages of growing old (e.g., can live a more relaxed leisurely life, can spend more time with spouse and/or children). If an item is not applicable (e.g., respondent does not have a spouse), it is coded to 0. The items are summed (if at least 5 items are valid) and divided by the number of valid items resulting in an index ranging from 0 to 3 where higher values indicate a more positive view of growing old; the alpha reliability is 0.75. If the score is greater than 1.5, we code the respondent as having a positive attitude toward growing old.

A summary score is calculated by summing the four dichotomous indicators (if at least three are valid): high personal mastery, engagement, optimism, and positive attitude

toward aging. We then categorize internal resources as low (<2), moderate (2), or high (3-4).

Perceived Stress

An index of perceived stress is based on the respondent's report (in 2000) of whether each of eight situations "makes you feel stressed or anxious." Three of these situations refer to the respondent's life (own financial situation, job, and getting along with family members), and an additional four items pertain to his or her family (the family's or children's health, financial situation, job, and marital situation). Each item is coded on a three-point scale: no (0), some (1), a lot of stress (2). If the respondent reported an item to be "not applicable," it is assigned a value of 0. The index is calculated by summing across all items if there are at least six valid items: if one is missing, the score is based on all valid items (and rescaled). The potential range for this index is 0 to 14, and the alpha reliability is 0.78.

Control Variables

Demographic controls include age (in years), sex, and urban residence. Age is measured as of the 2000 interview based on the respondent's reported date of birth.

Analytical Strategy

The analysis sample consists of 916 SEBAS participants, excluding 10 participants missing data on at least one of the biomarkers, 53 for whom a proxy completed one of the interviews, and 45 who were missing one of the covariates. Descriptive statistics shown in Table 1 are weighted to compensate for the over-sampling by age and urban residence.

For regression models, we use a robust estimator of variance and adjust for clustering by primary sampling units to produce corrected standard errors (57). Using a linear model, we first regress the physiological dysregulation score on the number of stressors and control variables. In the second model, we add the main effects for social position, social networks, and individual characteristics as well as interaction terms between overall vulnerability and number of stressors. The third model adds the index of perceived stress.

Finally, we estimate two linear models using the perceived stress index as the dependent variable. These models include the same covariates described above for Models 1 and 2, respectively.

RESULTS

In this sample, the mean physiological dysregulation score was 3.5 and number of stressors across 1996-2000 waves averaged 2.8 (Table 1). One-fifth of the sample fell into the high vulnerability group, while 24% of the sample was classified as low vulnerability. On average, this sample scored 1.8 on the perceived stress index in 2000.

Results from the models predicting physiological dysregulation are presented in Table 2. Model 1 confirms a significant association between number of stressors and physiological dysregulation, although the magnitude is small: a one standard deviation (SD) increase in stressors (2.1 additional stressors) is associated with a 0.17 point increase in the dysregulation score (less than one-tenth of a SD).

In model 2, we find no evidence that the three domains related to psychosocial vulnerability are directly associated with physiological dysregulation: joint tests of the

main effects for each domain and a joint test for all domains are not significant. As noted previously, the interaction term is based on a measure of vulnerability that incorporates all three domains; to ease interpretation, we combine the interaction terms with the main effect of the variable denoting the number of stressors so that the coefficients represent the effect of stressors at each level of vulnerability. The relationship between the number of stressors and dysregulation is significant only for those with high vulnerability (b=0.14, $p<0.05$), but even here the effect is small.

In model 3, we find the expected direct relationship between perceived stress and physiological dysregulation. Although significant, the magnitude of this relationship is not large: a one SD increase in the perceived stress index (2.5) is associated with one-tenth of a SD increase in the dysregulation score. If perceived stress mediates the effects of stressors on dysregulation, then we would also expect the coefficient associated with number of stressors to be substantially diminished by the addition of perceived stress to the model. We find that the coefficient among those with high vulnerability is attenuated (from 0.14 to 0.09) and becomes marginally significant.

In Table 3, we present results from regression models that examine the perceived stress index as a function of the number of stressors. The estimates for model 1 confirm the expected positive relationship between the number of stressors and perceived stress. In model 2, we test whether this association is moderated by the degree of vulnerability. Again, the results support the stress-buffering hypothesis: stressors have a larger association with perceived stress level at higher levels of vulnerability. For example, among the most vulnerable, a person with four stressors would be expected to score 1.2 points higher on the perceived stress index (nearly half

a SD) than someone with only two stressors. In contrast, among those with low vulnerability, two additional stressors translate into a 0.7 point increase in the perceived stress score.

DISCUSSION

Because the key variables in our models could have been defined in many ways, we carried out an extensive set of exploratory analyses to assess the robustness of our results. First, we tested several ways of modeling stressors (e.g., grouping stressors by domain, time period, or duration). Second, we explored alternative definitions for high and low vulnerability and included separate interaction terms for distinct domains of vulnerability. Third, we tested for a non-linear relationship between stressors and physiological dysregulation. Finally, we performed analyses that incorporated additional waves (1989-2000) of the survey based on persons older than 70. Our results changed little across these alternative specifications.

The findings suggest that the combination of low social position, weak social networks, and limited internal resources can render individuals more vulnerable to the adverse consequences of life challenges, although the magnitude of the association is small. While these results indicate a stress-buffering mechanism, we find no evidence that these components of vulnerability are directly associated with physiological dysregulation. This distinction between direct and moderating effects is important for researchers developing theoretical models describing the linkages among the social environment, life challenges, and biological response.

We propose several explanations for the weak relationship between stressors and physiological dysregulation. First, it is impossible to retrospectively construct an

accurate, detailed picture of lifetime exposure to stressors in a large-scale survey of an older population. A second factor is sample attrition: because of the strong association between physiological dysregulation and survival (6), individuals with the greatest lifetime exposure to stressors and the highest vulnerability are more likely than others to have died before the most recent interview and, thus, to have been excluded from the sample. Additional analyses (not shown) confirm that this process leads us to underestimate the magnitude of the association between the number of stressors and physiological dysregulation. Third, our measure of physiological dysregulation has several limitations: 1) it excludes biological markers that are likely to be important components of the stress response, some of which are impossible to measure in this type of fieldwork, 2) the designations for high and low values on many of the markers are largely arbitrary, because little is known about appropriate clinical cutoffs, 3) SEBAS collected these biomarkers at a single time, and 4) a dysregulation score that combines a large number of biomarkers may obscure important relationships with individual measures. Finally, we recognize that our identification of a weak relationship between life challenges and physiological dysregulation in Taiwan may not be generalizable to non-Western contexts or to other populations, in part because of cultural differences in the nature of stressful experiences and coping mechanisms.

Our results further suggest that the association between stressors and physiological dysregulation we do observe in Taiwan is not fully mediated by perceived stress, perhaps because our index of perceived stress (measured in 2000) does not adequately reflect the effect of life challenges in earlier years. Moreover, respondents may be unwilling to report negative emotions to interviewers. An alternative explanation is that

life events may have physiological consequences even if individuals do not perceive them as stressful.

The relationship between life challenges and physiological response proposed by the theory of allostatic load cannot be tested in a laboratory. Despite the difficulty of collecting the requisite biological and experiential information, such an analysis requires observational data for a population-based sample. SEBAS provides a rare opportunity to evaluate the hypothesized link between chronic stressors and allostatic load. A second wave of SEBAS, which is currently in the field, will provide additional biological measures associated with the stress response as well as reports of traumatic experiences, major life events, and daily hassles that will enable us to investigate these relationships further.

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Table 1 – Descriptive Statistics for Outcome and Covariates, Weighted Estimates

Variable	Mean (SD) or Percent
Physiological dysregulation in 2000 (0-10)	3.5 (1.9)
Number of stressors, 1996-2000 (0-11)	2.8 (2.1)
Position in social hierarchies	
% Low	31.9
% Moderate	38.3
% High	29.8
Social networks	
% Weak	38.4
% Moderate	30.3
% Strong	31.2
Internal Resources	
% Weak	24.9
% Moderate	30.8
% Strong	44.2
Psychosocial vulnerability	
% Low	24.2
% Moderate	55.8
% High	20.0
Perceived stress index, 2000 (0-13)	1.8 (2.5)
% Female	42.6
Age in 2000 (54-91)	66.1 (7.9)

Variable	Mean (SD) or Percent
% Urban residence	43.8
Number of respondents	916

The observed range is shown in parentheses.

Table 2 – Coefficients (and Standard Errors) from Regression Models Predicting Physiological Dysregulation

	(1)	(2)	(3)
Female	0.577**	0.499**	0.498**
	(0.157)	(0.148)	(0.148)
Age	0.015*	0.012	0.016+
	(0.007)	(0.008)	(0.008)
Urban residence	0.022	0.060	0.064
	(0.126)	(0.117)	(0.114)
Number of stressors	0.083**	--	--
	(0.023)		
Position in social hierarchies			
(Low)	--	--	--
Moderate	--	-0.122	-0.131
		(0.184)	(0.175)
High	--	-0.073	-0.070
		(0.200)	(0.195)
Social networks			
(Weak)	--	--	--
Moderate	--	-0.074	-0.062
		(0.160)	(0.162)
Strong	--	0.242	0.243

		(0.170)	(0.165)
Internal resources			
(Low)	--	--	--
Moderate	--	-0.048	-0.048
		(0.162)	(0.159)
High	--	-0.124	-0.114
		(0.184)	(0.182)
Low vulnerability X number of stressors	--	0.046	0.020
		(0.045)	(0.050)
Medium vulnerability X number of stressors	--	0.046	0.015
		(0.028)	(0.032)
High vulnerability X number of stressors	--	0.136*	0.092+
		(0.052)	(0.053)
Perceived stress index	--	--	0.075*
			(0.028)
Constant	1.970**	2.281**	1.966**
	(0.477)	(0.700)	(0.733)
R^2	0.04	0.05	0.06

+ significant at 10%; * significant at 5%; ** significant at 1%

Table 3 – Coefficients (and Standard Errors) from Regression Models Predicting Perceived Stress

	(1)	(2)
Female	0.163	0.021
	(0.170)	(0.206)
Age	-0.050**	-0.054**
	(0.007)	(0.007)
Urban residence	-0.121	-0.064
	(0.277)	(0.244)
Number of stressors	0.494***	--
	(0.057)	
Position in social hierarchies		
(Low)	--	--
Moderate	--	0.123
		(0.222)
High	--	-0.036
		(0.283)
Social networks		
(Weak)	--	--
Moderate	--	-0.165
		(0.179)
Strong	--	-0.014
		(0.230)

Internal resources		
(Low)	--	--
Moderate	--	0.009
		(0.180)
High	--	-0.128
		(0.225)
Low vulnerability X number of stressors	--	0.340*
		(0.140)
Medium vulnerability X number of stressors	--	0.416**
		(0.063)
High vulnerability X number of stressors	--	0.582**†
		(0.085)
Constant	3.713**	4.214**
	(0.495)	(0.612)
R^2	0.21	0.23

+ significant at 10%; * significant at 5%; ** significant at 1%

† Coefficient differs significantly (p<0.05) from that for "Medium vulnerability X stressors"; it does not significantly differ from "Low vulnerability X stressors."

Appendix Table 1 – Descriptive Statistics for Component Measures, Weighted Analyses

Variable	Mean (SD) or Percent			
	1996	1999	2000	Overall
Stressors				
% with marital disruption[a]	21.2	3.1	2.2	--
% who have moved to a new residence[b]	8.3	8.2	2.7	--
% whose child died[a]	12.8	0.2	--	--
% with spouse in not so good or poor health	19.5	14.5	18.0	--
% with difficulty meeting living expenses	21.2	28.2	26.8	--
% financially worse off than three years ago	25.2	31.5	--	--
% affected by earthquake[c]	--	--	23.4	--
% respondent/spouse/children victimized by crime/fraud in the past year	--	--	11.3	--
Mean number of stressors (0-5)	1.1 (1.0)	0.9 (1.0)	0.8 (0.9)	--
Position in social hierarchies				
Education (0-17)	5.2 (4.6)			

Variable	Mean (SD) or Percent			
	1996	1999	2000	Overall
Socioeconomic Index (55.1-76.1)	61.6 (4.7)			
Social networks				
Number of social ties (0-120)	24.4 (14.0)	19.4 (13.1)	--	--
Number of social activities (0-8)	1.5 (1.3)	1.8 (1.4)	--	--
Index of emotional support (0-4)	3.0 (0.7)	3.2 (0.8)	--	--
Overall social support score (0-3)	0.9 (0.8)	1.1 (0.9)	--	--
Internal Resources				
Locus of control index (0.1-3)	--	--	1.6 (0.4)	--
% committed	69.0	66.1	--	50.6
% optimistic	84.3	78.4	--	66.2
Index of advantages of growing old (0-3)	1.6 (0.6)	--	--	--
Overall internal resources score (0-4)	--	--	--	2.3 (1.1)
Number of respondents	916	916	916	916

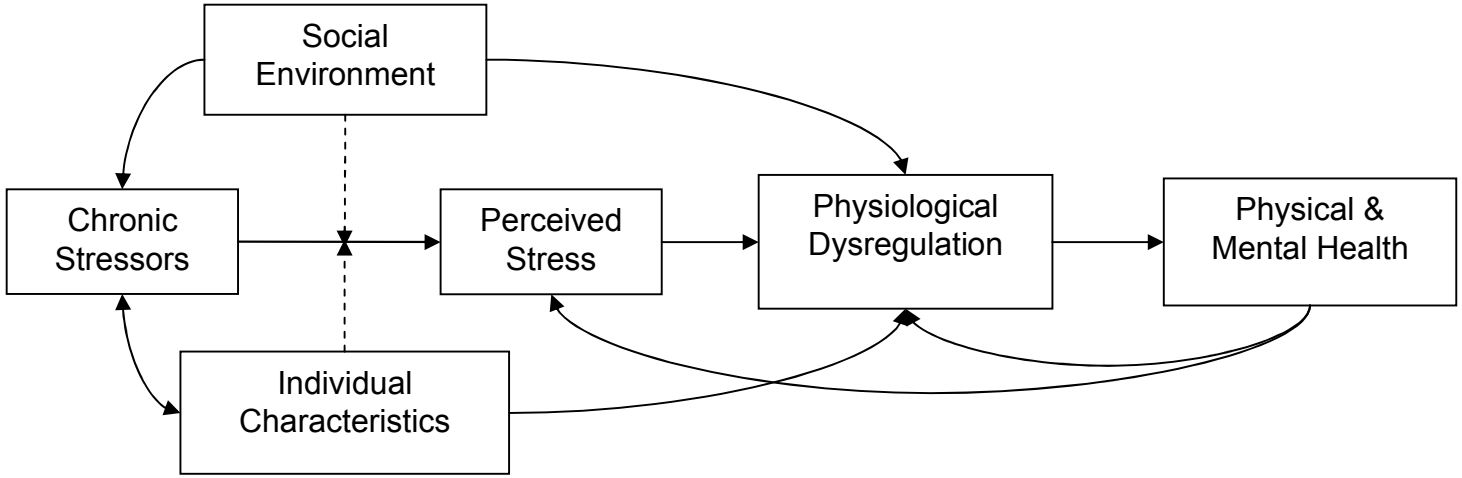
The observed range is shown in parentheses.

[a] Indicates the proportion who have *ever* experienced the event (by 1996) or who have experienced this event since the previous survey wave (as of 1999 & 2000).

[b] In the past three years (as of 1996) or since the previous survey (as of 1999 & 2000).

[c] Earthquake (in 2000) resulted in injury to the respondent, injury/death to family or close friend, temporary displacement, or damage to home or other property.

Figure 1. A Theoretical Model Linking Chronic Stressors and Health



Note: Dashed arrows indicate factors which moderate the relationship between stressors and perceived stress.