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ORIGINAL RESEARCH REPORT

Perceived stress and mortality in a Taiwanese older adult populationSarinnapha Vasunilashorn¹, Dana A. Gleit², Maxine Weinstein², and Noreen Goldman¹¹Office of Population Research, Princeton University, Princeton, New Jersey, USA and ²Center for Population and Health, Georgetown University, Washington, District of Columbia, USA**Abstract**

Perceived stress is associated with poor health outcomes including negative affect, increased susceptibility to the common cold and cardiovascular disease; the consequences of perceived stress for mortality, however, have received less attention. This study characterizes the relationship between perceived stress and 11-year mortality in a population of Taiwanese adults aged 53+ years. Using the Survey of Health and Living Status of the Near Elderly and Elderly of Taiwan, we calculated a composite measure of perceived stress based on six items pertaining to the health, financial situation, and occupation of the respondents and their families. Proportional hazard models were used to determine whether perceived stress predicted mortality. After adjusting for sociodemographic factors only, we found that a one standard deviation increase in perceived stress was associated with a 19% increase in all-cause mortality risk during the 11-year follow-up period (hazard ratio, HR = 1.19, 95% confidence interval, CI 1.13–1.26). The relationship was greatly attenuated when perceptions of stress regarding health were excluded, and was not significant after adjusting for medical conditions, mobility limitations and depressive symptoms. We conclude that the association between perceived stress and mortality is explained by an individual's current health; however, our data do not allow us to distinguish between two possible interpretations of this conclusion: (a) the relationship between perceived stress and mortality is spurious, or (b) poor health acts as the mediator.

Keywords

Aging, all-cause mortality, cancer mortality, cardiovascular mortality, perceived stress, reverse causality

History

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Introduction

The impact of an event is partly determined by an individual's interpretation of how stressful it may be (Lazarus, 1966, 1977). This perception plays an important role in the emotional and physiological responses that ensue (Goldman et al., 2005). Cohen et al. (1997) proposed a theoretical model that links the experience of stressors (e.g. environmental demands and life events) to physiological and behavioral responses. This model presents the stress process as a sequence of steps in which events lead to either a benign appraisal or to the perception of stress. In the former case, no stress response is elicited. In the latter case, perceived stress results in negative emotional responses, which in turn lead to a physiological or behavioral response. Hence, crucial points in this pathway are the individual's appraisal of the demands inflicted by the events or stressors and his/her adaptive capacities (e.g. the availability of coping resources). In this view, it is the cognitively mediated emotional response to the life event, not the event itself, which leads to the behavioral or physiological responses (Lazarus, 1977; Mason, 1971). The importance of this insight is underscored by variations

in the assessment of stressors, and these variations may be influenced by multiple factors, including personal experiences, personality, coping mechanisms and social support (Biondi & Picardi, 1999; Schwartz et al., 1996). Currently, the psychological processes solicited by a stressor are thought to bridge the concepts of stress exposures and stress responses (e.g. perceptions of stress) (Van Praag et al., 2004).

While most studies that have examined stress and disease (or mortality) use the occurrence of "objective" stressful events (e.g. death of a spouse) to assess these associations, the links between perceptions of stress and mortality have received much less attention. Our study aimed to address the question: is perceived stress predictive of mortality in a population of older Taiwanese adults? Among the few previous studies of perceived stress and mortality, the findings have been mixed. On the one hand, perceptions of high levels of stress were not predictive of all-cause mortality in a Scottish population (Macleod et al., 2001). On the other hand, high appraisal of stress was associated with a greater risk of all-cause mortality among South Koreans and Danes (Khang & Kim, 2005; Nielsen et al., 2008). We hypothesized that our study of older Taiwanese adults would reveal an association between perceived stress and mortality, such that higher perceptions of stress and chronic reports of perceived stress would predict greater mortality. We also hypothesized that the link between perceived stress and cardiovascular and cancer-related

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mortality would be especially pronounced given the association between perceived stress and these conditions (Dimsdale, 2008; Macleod et al., 2002; May, 2002).

Methods

Study population

We used data from the Survey of Health and Living Status of the Near Elderly and Elderly (or Taiwan Longitudinal Study of Aging [TLISA]), a nationally representative random sample of adults in Taiwan. The oldest cohort comprised 4049 respondents (ages 60+ years) who were first interviewed in 1989; in 1996, 2462 participants (ages 50–66 years) were added. Follow-up interviews were conducted with both cohorts in 1999 ($n=4440$; 90% of survivors), 2003 ($n=3777$; 92% of survivors) and 2007 ($n=4534$; 90% of survivors; Chang & Hermalin, 1998a,b; Hermalin et al., 1989). The participant's native language (Mandarin, Taiwanese or Hakka) was used for the interview with the study participants. Several bilingual individuals provided translations of the Chinese questionnaires into English.

In this study, we used interview data from 1999, 2003 and 2007 and survival status through 2010. Survival status (as of December 31, 2010) and date of death were obtained by linking the survey data to death certificate files maintained by the Taiwan Department of Health and to the household registration file from the Taiwanese Ministry of the Interior. Linkage of one database to another creates newly generalizable information about potential cause-and-effect relationships and provides additional, more specific, information about the study participants. The citizen ID was matched with the Department of Health death certificate file in a manner that maintained the confidentiality of individual participant information (Muse et al., 1995; Neutel et al., 1991). All protocols were approved by the Institutional Review Boards at Princeton University, Georgetown University, and the Bureau of Health Promotion, Department of Health, Taiwan.

This sample comprised 4440 survivors at the time of the 1999 survey, 1864 of whom died by December 31, 2010 (see Figure 1 for a flowchart). On average, decedents were observed for 5.6 years (range 0.2–12.6 years) before their death, whereas those who survived to 2010 were followed for 11.8 years (range 2.5–13.0 years). Participants who were lost to follow-up (LFU) during the observation period included people who were alive but not interviewed and those who had emigrated before December 31, 2010. Of the eligible sample for this study, 238 had no valid data in 1999, 2003 and 2007 and were therefore excluded from our analysis. There were 2471 individuals with complete data. The remaining 1731 respondents had valid information for at least one wave but were LFU for one or two waves; these individuals did not contribute data for periods during which they were LFU. For example, if a participant was interviewed in 1999, LFU in 2003, interviewed in 2007 and was alive at the end of 2010, that person would have contributed data for 1999–2003 and 2007–2010 (but not 2003–2007). Those with unknown vital status or who emigrated were treated as censored at the date of their last interview.

We compared the sociodemographic characteristics of respondents who were LFU for one or more waves with

individuals who had complete data ($n=2471$). Those with no valid data at any of the three waves ($n=238$) and those who were LFU for one or two waves ($n=1731$) were significantly ($p<0.001$ from t -tests) older at baseline and had fewer years of education than individuals with complete data.

To examine cause-specific mortality, we used cause of death (COD) categories that were based primarily on the International Classification of Disease (ICD)-9 codes. Among the 1864 individuals who died during our study period (1999–2010), we have COD information for 1844 individuals [20 (about 1%) were missing]. For the 317 individuals with ICD-9 codes missing, 297 individuals had values for ICD-10 codes, which were used to determine COD. The ICD-10 codes were grouped with the appropriate ICD-9 coding categories based on the ICD-10/ICD-9 Comparability Ratio Table from the National Center for Health Statistics (Wisconsin Department of Health Services, 2013). Although we did not have the power to investigate the relationship between perceived stress and most cause-specific deaths (e.g. <5% of deaths were from external causes, with only 14 suicides), we were able to investigate links between perceived stress and mortality from two groups of causes: cardiovascular- ($n=458$; ICD-9 codes 280–289, 390–459 and ICD-10 codes D50–D89.9, I00–99.9) and cancer-related deaths ($n=446$; ICD-9 codes 140–239 and ICD-10 codes COO–D48.9).

Measures

Perceived stress

Perceived stress was based on participant self-report (in 1999, 2003 and 2007) of whether each of six situations “makes you feel pressure or anxiety” [coded 0 = none, 1 = some, 2 = or a lot; (Goldman et al., 2005)]. These situations included: (1) the individual's own health; (2) own financial situation; (3) own job; (4) relationship with family members; (5) a family member's health, financial situation, job or marriage; and (6) any other situation. The perceived stress index was created by summing the six items. The index ranged from 0 to 12, with higher scores indicating greater perceived stress. Respondents who were missing values for more than two domains were excluded from the analyses (6.9% of the sample at each wave).¹ For individuals with missing values on one or two domains, the perceived stress index was calculated from the available domains.² The six items loaded highly on one factor (eigenvalues were 1.64 in 1999, 1.49 in 2003 and 1.45 in 2007). Cronbach's alpha for the three waves were 0.68 in 1999, 0.65 in 2003 and 0.64 in 2007. We also examined a perceived stress index measure that excluded the individual's own health (range 0–10). To aid in interpreting the magnitude of the coefficients, perceived stress was

¹(1) In 1999, 16 individuals were missing 1 domain, 1 individual was missing 3 domains and 307 were missing all 6 domains; (2) In 2003, 3 individuals were missing 1 domain, 1 individual was missing 3 domains and 280 individuals were missing all 6 domains; and (3) In 2007, 1 participant was missing 1 domain, 1 participant was missing 4 domains and 294 participants were missing all 6 domains.

²In calculating the full perceived stress index (range: 0–12) for individuals missing 1 or 2 domains, the following equation was used: [sum of scores (0, 1, or 2) for available perceived stress domains/(6 – #missing domains)*6].

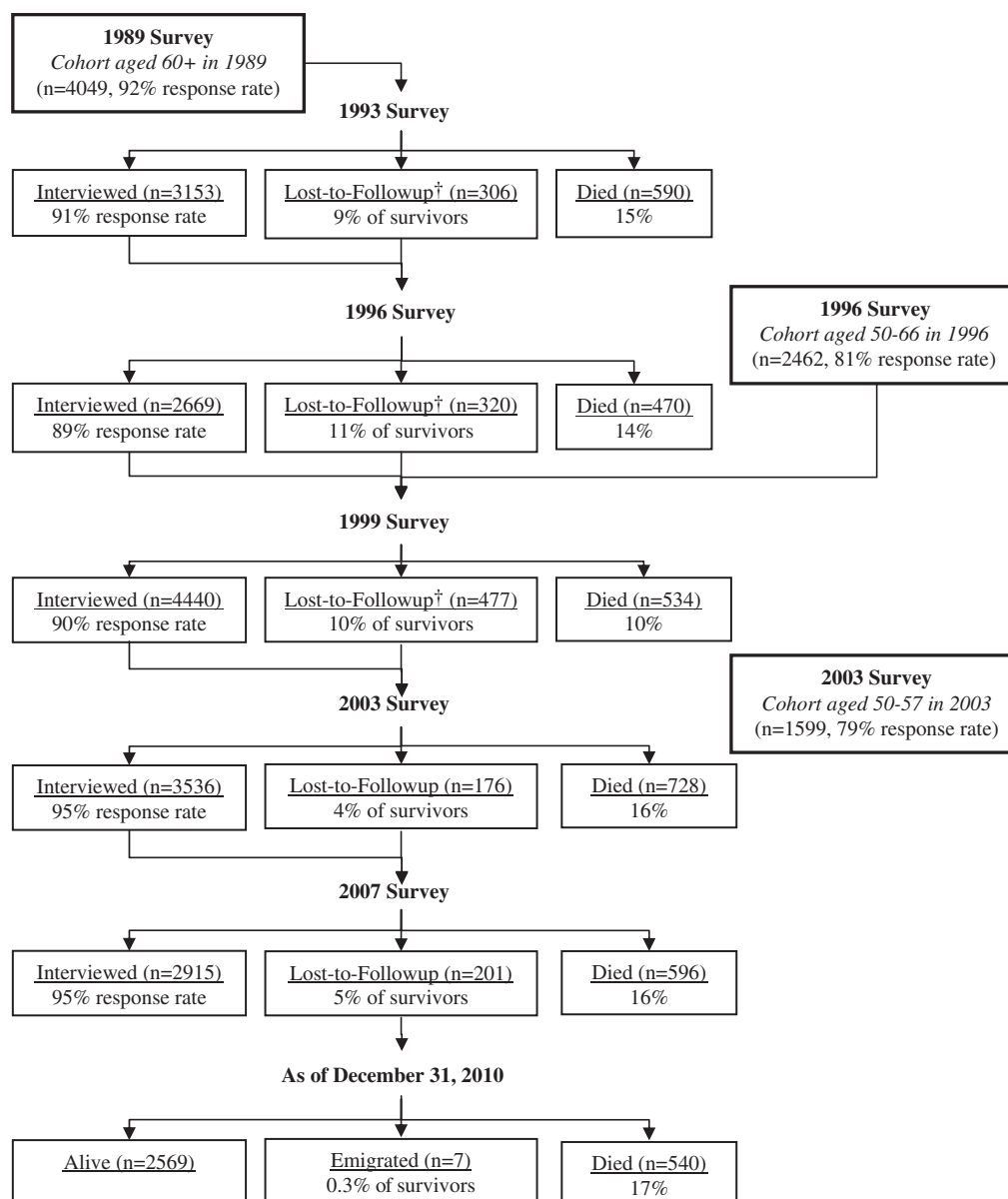


Figure 1. Taiwan Longitudinal Study of Aging (TLSA), 1989–2007. †At each survey wave, efforts were made to contact and interview all respondents from the original cohorts ($n = 4049$ in 1989; $n = 2462$ in 1996; $n = 1599$ in 2003), even if they were lost to follow-up (LFU) in a previous wave. Thus, a person may be LFU in one survey wave, but interviewed in subsequent waves. This flowchart displays the inclusion of a refresher cohort in 2003, but no individuals from this cohort were included in the current study. Our analytic sample includes only respondents who were interviewed in at least one of the following waves: 1999, 2003 and 2007.

standardized ($M = 0$, $SD = 1$) in the models. We consider 1999, 2003 and 2007 because the perceived stress questions were asked in the same manner for these study dates.

Control variables

We controlled for sociodemographic and health characteristics that have been related to both perceived stress and mortality. These variables included sex, educational attainment in years, age, marital status, chronic conditions, mobility limitations, depressive symptoms, emotional support, smoking status and alcohol consumption. Participants were classified as married if they reported having a spouse or currently having a live-in companion. We controlled for health because poor health may be either a cause or a consequence of perceived stress.

We included a summary count measure for seven medical conditions (hypertension, diabetes, heart disease, stroke,

kidney disease, liver disease, cancer), all of which are among the top 10 leading causes of death in Taiwan (Department of Health, 2011). Mobility limitations were defined as the number of mobility activities the participant reported any difficulty completing range 0–8 (Collins et al., 2008). These activities included squatting, standing for 15 min, grasping with fingers, reaching over one's head, walking 200–300 m, running 20–30 m, climbing 2–3 flights of stairs and lifting/carrying 11–12 kg (Nagi, 1969, 1976). The presence of medical conditions and reports of mobility limitations have been associated with mortality in older adult populations (Melzer et al., 2003; Weiner et al., 2004).

High levels of depressive symptoms have been reported as a risk factor for mortality in older adults (Schulz et al., 2000; Wulsin et al., 1999). Depressive symptoms were measured using a subset of 10 items from the 20-item Center for

Epidemiological Studies Depression Scale (CES-D; Radloff, 1977). Reliability has been reported for abbreviated versions of the CES-D in Western (Andresen et al., 1994; Kohout et al., 1993) and Chinese populations (Krause & Liang, 1992; Ofstedal et al., 1999), including populations in Hong Kong (Boey, 1999) and Taiwan (Chiao et al., 2009; Lee et al., 2009). Participants reported how often they experienced a number of different situations or feelings in the past week (0 = not at all, 1 = rarely or one day, 2 = sometimes or two to three days and 3 = often/chronically or four or more days). The questions asked about poor appetite, poor sleep, exhaustion, being in a bad mood, unfriendliness of others, loneliness, inability to get going, anguish, feeling joyful and feeling that life was going well. Positive items were reverse-scored and a summary measure was created (range 0–30), with higher scores reflecting more frequent depressive symptoms (Collins et al., 2009).

Given the protective effect of social support on mortality (Holt-Lunstad et al., 2010; Rosengren et al., 1993), we included emotional support in our models. Emotional support was represented by an index score created by summing responses to four items (range 4–20), with higher scores reflecting lower emotional support (Glei et al., 2012). In four questions, the participants were asked to what extent they felt that family, relatives or friends: were willing to listen when they needed to talk, made them feel loved and cared for, were satisfactorily providing them with emotional support and could be counted on to take care of them when ill (1 = a great deal, 2 = quite a bit, 3 = some, 4 = very little, 5 = not at all). We also included current smoking status and whether or not participants drank alcohol (0 = no, 1 = yes) because these behaviors have been associated with mortality (LaCroix et al., 1991; Shaper, 1990).

Data analysis

Hazard models were estimated to examine the relationship between perceived stress and age-specific mortality. In the analytic models shown here, perceived stress was treated as a time varying measure; in separate models described in the discussion section, a measure of chronic perceived stress was considered fixed. Controls included fixed variables (sex and educational attainment) and time varying covariates (marital status, self-rated health, chronic conditions, mobility limitations, depressive symptoms, emotional support, smoking status and alcohol consumption). For all time varying covariates, the values in a given wave (1999, 2003 and 2007) were used to predict mortality between that wave and the following wave.

We used a proportional hazards model to assess the association between perceived stress and age-specific mortality (1999–2010), using age as the primary clock. We did not find evidence for non-proportional hazards (i.e. the slope of mortality did not differ significantly by our covariates). The underlying hazard function was modeled with a Gompertz distribution, which was a good fit to our data and is often used to describe death rates at older ages (Horiuchi & Coale, 1982). Model I adjusted for sex, education, marital status and survey wave. In Model II, health indicators were added: number of medical conditions, mobility limitations

and depressive symptoms. To consider potential coping indicators, Model III adjusted for emotional support and behavioral factors (current smoking and alcohol consumption status) in addition to the covariates included in Model II. Given prior studies indicating that the relationship between perceived stress and mortality differed by sex (Iso et al., 2002), we also tested an interaction between sex and perceived stress. All analyses were conducted using STATA version 11 (StataCorp, 2007).

Results

Table 1 reports the sociodemographic characteristics and health status of the study population. There were slightly more men than women (50.7%), and the participants had an average of 5.0 years of total education. At baseline (1999), the average age was 68.6 years (range 50–95 years), 69% were married, the mean mobility limitation score was 2.2, 24% were current smokers, 24% were current alcohol consumers and the mean perceived stress score was 1.8. By the end of 2010, 16% of the sample population had died. To identify factors considered to contribute to perceived stress, we examined the perceived stress score by sex and marital status (not shown). We found that men reported lower perceived stress than women at each of the three waves and married individuals reported lower perceived stress than non-married individuals in the 1999 and 2003 waves only.

The hazard ratios (HR) relating fixed and time varying covariates, including perceived stress, to mortality during the 11-year follow-up period are shown in Table 2. The first model includes the fixed baseline variables and the time varying covariates, survey wave and marital status. Higher perceived stress was associated with greater mortality such that a one standard deviation increase in perceived stress was associated with a 19% increase in mortality risk (HR = 1.19;

Table 1. Sociodemographic characteristics and health status of the study population.

	1999 <i>n</i> = 4132	2003 <i>n</i> = 3255	2007 <i>n</i> = 2915
Fixed baseline characteristics			
Male (%)	50.7		
Education (years)	5.0 (4.5)		
Time varying covariates			
Age (years)	68.6 (9.2)	72.3 (8.6)	74.4 (8.2)
Married (%)	69.2	72.0	69.0
Medical conditions (0–7) ^a	0.9 (1.1)	0.9 (1.1)	1.1 (1.1)
Mobility limitations (0–8)	2.2 (2.5)	2.0 (2.4)	2.1 (2.5)
Depressive symptoms (0–30)	5.4 (6.1)	4.8 (5.6)	4.8 (5.7)
Emotional support (4–20)	7.3 (2.9)	7.6 (2.9)	7.4 (2.7)
Currently smoking (%)	24.1	19.1	15.4
Currently consuming alcohol (%)	24.2	23.7	23.9
Perceived stress			
Mean (SD):			
Full index (0–12) ^b	1.8 (2.1)	1.7 (2.0)	1.6 (1.9)
Index excluding own health (0–10)	1.3 (1.7)	1.2 (1.6)	1.1 (1.5)
Died by end 2010 (%)		16.0	

Means (SD) presented, unless stated otherwise.

^aMedical conditions included hypertension, diabetes, cardiovascular disease, stroke, cancer, liver disease, kidney disease.

^bPerceived stress – Full Index included reported stress on any of 6 perceived stress domains pertaining to the respondent's: own health; own financial situation; own job; family member's health, financial situation, job, marriage, etc.; relationship with family members; and any other domain.

Table 2. Hazard ratios from Gompertz models predicting age-specific mortality (between 1999 and the end of 2010) from perceived stress as a time varying measure.

Predictor	Model I		Model II		Model III	
	HR	95% CI	HR	95% CI	HR	95% CI
Fixed baseline characteristics						
Male	1.92*	1.68–2.21	2.49*	2.17–2.86	2.38*	2.04–2.76
Education	0.97*	0.96–0.98	0.98	0.97–1.00	0.98	0.97–1.00
Time varying covariates						
Control variables						
Survey wave	0.98*	0.96–0.99	0.97*	0.95–0.99	0.97*	0.95–0.99
Married	1.02	0.98–1.05	1.01	0.98–1.05	1.01	0.98–1.05
Medical conditions			1.13*	1.08–1.19	1.13*	1.08–1.19
Mobility limitations			1.22*	1.19–1.26	1.21*	1.18–1.25
Depressive symptoms			1.02*	1.01–1.04	1.02*	1.01–1.03
Emotional support					1.01	0.99–1.03
Currently smoking					1.28*	1.10–1.49
Currently consuming alcohol					0.77*	0.66–0.91
Perceived stress ^a	1.19*	1.13–1.26	0.94	0.87–1.01	0.94	0.87–1.01
Gamma for age (time clock)	0.09*	0.09–0.10	0.07*	0.06–0.08	0.07*	0.06–0.08

HR = Hazard ratio; CI = Confidence interval.

* $p < 0.05$.^aStandardized ($M = 0$, $SD = 1$).

95% confidence interval, CI, 1.13–1.26; Model I). In Model II, the presence of additional medical conditions, mobility limitations and depressive symptoms was associated with higher mortality, but perceived stress was no longer associated with mortality. These relationships did not change in the full model (Model III). Models that tested for a sex interaction with perceived stress showed no evidence that the effect of perceived stress differed significantly by sex (not shown). An alternate operationalization of the perceived stress index that excluded an individual's own health resulted in a 45% reduction in the size of the coefficient for perceived stress in Model I (HR = 1.10; 95% CI 1.04–1.17; results not shown). We also examined the causal effect of perceived stress on mortality after excluding deaths during the first five years of the study period; the fully adjusted model indicated no association between perceived stress and mortality (Supplementary Table 1).

When considering cardiovascular and cancer-related mortality, perceived stress was not significantly associated with cardiovascular or cancer mortality in the fully adjusted model (similar to Model III, Table 2: HR = 0.98, 95% CI 0.85–1.14 for cardiovascular mortality and HR = 0.94, 95% CI 0.82–1.07 for cancer-related mortality; Supplementary Tables 2 and 3, respectively).

Discussion

Our study found that perceived stress predicted all-cause mortality in an older adult population in Taiwan. This relationship was, however, greatly attenuated when perceptions of stress regarding health were excluded, and it was not significant after adjusting for medical conditions, mobility limitations and depressive symptoms. Prior studies of adult populations in South Korea (Khang & Kim, 2005) and Denmark (Nielsen et al., 2008) found that higher levels of perceived stress were associated with higher mortality, while a study in Scotland (Macleod et al., 2001) found no association. We extended this prior work by expanding the

scope of perceived stress and by controlling for indicators of health, social support and behavioral factors in our analysis. As in some prior studies, we found that after adjustment for sociodemographic factors alone, older adults with higher levels of perceived stress had a higher risk of dying within the follow-up period.

We suggest that there are two ways of explaining these findings. The results are consistent with a model in which health mediates the effects of perceived stress on mortality. In other words, higher perceived stress results in poorer health, which in turn, leads to a higher risk of dying. Thus, once current health is included in the model, perceived stress does not significantly affect mortality. Alternatively, one could argue that poor health affects both perceptions of stress and the risk of dying. If this were true, it would support the explanation that the relationship between perceived stress and mortality is spurious.

In support of the first explanation are findings from studies on the influence of stress (perceived stress and stress exposures) on cardiovascular, immune and endocrine function (Adler et al., 2001; Black, 2003; Cohen et al., 1991). Goldman et al. (2005) observed a positive association between perceived stress and indicators of physiological dysregulation, including elevated levels of cortisol and triglycerides and low levels of dehydroepiandrosterone sulfate (DHEAS), fasting glucose and inflammatory marker interleukin-6. Extreme levels of many of these biological measures have been associated with poor health outcomes (Alley et al., 2007; Barrett-Connor et al., 1986; Gleit et al., 2004; Reuben et al., 2002; Roth et al., 2002), including mortality.

The alternate explanation focuses on the reverse causal process: high levels of perceived stress may be a result of the presence, development or progression of health conditions. This explanation is supported by our finding that, in comparison with a measure that included stress related to the respondent's own health, the strength of the relationship between mortality and the measure of perceived stress that *excluded* the respondent's own health was greatly attenuated.

Our data do not allow us to distinguish between these two causal explanations. We speculate that the dominant effect is that of reverse causality: concerns about health greatly contributed to the effect of perceived stress on mortality, and of course, diminished health predicts mortality.

To further test the relationship between perceived stress and mortality, we investigated the association between chronic perceived stress and mortality. Studies have demonstrated that persistent stress is linked to numerous poor health outcomes, including: vulnerability to the intensity and extent of the inflammatory cascade and healing conditions; reactivation of latent viruses (e.g. Epstein Barr virus and herpes simplex); and vulnerability to infections, HIV, cancer and cardiovascular disease (Andersen et al., 1994; Baum, 1990; Capitanio et al., 1998; Cohen et al., 1991, 1997; Cohen & Williamson, 1991; Glaser et al., 1994; Kiecolt-Glaser & Glaser, 1999; Marucha et al., 1998; McKinnon et al., 1989; O'Leary, 1990). To test the association between chronic perceived stress and mortality, we created a dichotomous variable that identified individuals who reported moderate or high levels of stress at each of three waves (1999, 2003 and 2007) and used this variable, along with the sets of control variables shown in Table 2, to predict mortality in the period 2007–2010. Our results mirror those based on the time varying perceived stress index in Table 2: relative to individuals without chronic perceived stress, those with chronic perceived stress had an increased risk of mortality in Model I (HR 1.40, 95% CI 1.09–1.79); however, after adjusting for health conditions and behaviors (as in Models II and III), this relationship was no longer significant.

Our study has a number of strengths. This population-based survey of older Taiwanese adults included questions about perceived stress that were asked consistently at three times over an 8-year period. Multiple observations are important because variations in exposure to stress, which may underlie variations in perceived stress, have been associated with long-term alterations in the emotional, behavioral and physiological responses that influence susceptibility to poor health outcomes (Cohen et al., 1997; McEwen et al., 1998). Consideration of perceived stress as a time varying covariate also allows us to maximize the use of the data that are available. To our knowledge, only one other study (Macleod et al., 2001) has considered perceived stress at more than one time. Our six-item summary measure of perceived stress enabled us to consider an index of stress from multiple domains; previous studies examining the relationship between perceived stress and mortality have used a single question (Iso et al., 2002; Khang & Kim, 2005) or four questions (Macleod et al., 2001) to assess stress. Lastly, the inclusion of multiple controls (fixed and time-varying) that comprised sociodemographic variables, indicators of health, social support and behavioral factors permitted us to consider a wide range of potential confounders and to examine the impact of reverse causality on the estimates.

We also note limitations of our study. One limitation is our 11-year follow-up period. Other studies that have examined the relationship between perceived stress and mortality include over 20 years of follow-up (Macleod et al., 2001; Nielsen et al., 2008). Underreporting of perceived stress or variations (e.g. by sex or socioeconomic status) in thresholds

for reporting perceived stress may attenuate or potentially bias the observed relationship between perceived stress and mortality.

In conclusion, we find that the association between perceived stress and mortality is largely explained by an individual's current health. Whether the causal arrow underlying this association flows from perceived stress to health to mortality or from the effects of health on both perceived stress and mortality remains unresolved. There are two ways in which further studies could help determine whether there is a true effect of perceived stress (i.e. health as a mediator) or whether the association is spurious: by starting at younger ages (before the subjects have succumbed to various health problems) or by having frequent follow-ups (that allow one to precisely measure the timing of health problems relative to elevations in perceived stress). Such studies will require careful temporal ordering of events to establish the causal direction and will be critical to understanding the complex relationship between perceptions of stress and adverse health outcomes.

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Declaration of interest

The authors declare no conflict of interest.

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References

- Adler R, Felten DL, Cohen N. (2001). *Psychoneuroimmunology*. 3rd ed. San Diego: Academic Press.
- Alley DE, Crimmins E, Bandeen-Roche K, Guralnik J, Ferrucci L. (2007). Three year change in inflammatory markers in elderly people and mortality: the Invecchiare in Chianti Study. *J Am Geriatr Soc* 55: 1801–7.
- Andresen EM, Carter WB, Malmgren JA, Patrick DL. (1994). Screen for depression in well older adults: evaluation of a short form of the CES-D. *Am J Prev Med* 10:77–84.
- Barrett-Connor E, Khaw KT, Yen SS. (1986). A prospective study of dehydroepiandrosterone sulfate, mortality, and cardiovascular disease. *N Engl Med* 315:1519–24.
- Biondi M, Picardi A. (1999). Psychological stress and neuroendocrine function in humans; the last two decades of research. *Psychosom Psychosom* 68:114–50.
- Black PH. (2003). The inflammatory response is an integral part of the stress response: implications for atherosclerosis, insulin resistance, type II diabetes and metabolic syndrome X. *Brain Behav Immun* 17: 350–64.
- Boey KW. (1999). Cross-validation of a short form of the CES-D in Chinese elderly. *Geriatr Psychiatr* 14:608–17.

- Capitanio JP, Mendoza SP, Lerche NW, Mason WA. (1998). Social stress results in altered glucocorticoid regulation and shorter survival in simian acquired immune deficiency syndrome. *Proc Natl Acad Sci USA* 95:4714–19.
- Chang MC, Hermalin AI. (1998a). 1996 Survey of health and living status of the middle aged and elderly in Taiwan. (A) Survey of those over 50–66 years of age (No. 98–49). Ann Arbor: Population Studies Center, University of Michigan.
- Chang MC, Hermalin AI. (1998b). 1996 Survey of health and living status of the middle aged and elderly in Taiwan. (B) Survey of those over 67 years of age (No. 98–49). Ann Arbor: Population Studies Center, University of Michigan.
- Chiao C, Weng L-J, Botticello A. (2009). Do older adults become more depressed with age in Taiwan? The role of social position and birth cohort. *J Epidemiol Community Health* 63:625–32.
- Cohen S, Kessler RC, Gordon LU. (1997). Measuring stress: a guide for health and social scientists. New York: Oxford University Press.
- Cohen S, Tyrell DA, Smith AP. (1991). Psychological stress and susceptibility to the common cold. *N Engl J Med* 325:606–12.
- Cohen S, Williamson GM. (1991). Stress and infectious disease in humans. *Psychol Bulletin* 109:5–24.
- Collins AL, Gleit DA, Goldman N. (2009). The role of life satisfaction and depressive symptoms in all-cause mortality. *Psychol Aging* 24: 696–702.
- Collins AL, Goldman N, Rodríguez G. (2008). Is positive well-being protective of mobility limitations among older adults? *J Gerontol B Psychol Sci Soc Sci* 63:321–7.
- Department of Health, Executive Yuan R.O.C. (Taiwan). (2011). 2010 Statistics of Cause of Death, available at http://www.doh.gov.tw/EN2006/DM/DM2.aspx?now_fod_list_no=12228&class_no=390&level_no=2 (accessed 15 May 2012).
- Dimsdale JE. (2008). Psychological stress and cardiovascular disease. *J Am Coll Cardiol* 51:1237–46.
- Gleit DA, Goldman N, Ryff CD, Lin Y-H, Weinstein M. (2012). Social relationships and inflammatory markers: an analysis of Taiwan and the U.S. *Soc Sci Med* 74:1891–9.
- Gleit DA, Goldman N, Weinstein M, Liu IW. (2004). Dehydroepiandrosterone sulfate (DHEAS) and health: does the relationship differ by sex? *Exp Gerontol* 39:321–31.
- Goldman N, Gleit DA, Seplaki C, Liu I-W, Weinstein M. (2005). Perceived stress and physiological dysregulation in older adults. *Stress* 8:95–105.
- Hermalin AI, Liang J, Chang MC. (1989). 1989 Survey of health and living status of the elderly in Taiwan: questionnaire and survey design. Comparative study of the elderly in Asia (No. 89–1). Ann Arbor: Population Studies Center, University of Michigan.
- Holt-Lunstad J, Mith TB, Layton JB. (2010). Social relationships and mortality risk: a meta-analytic review. *PLoS Med* 7:e1000316.
- Iso H, Date C, Yamamoto A, Toyoshima H, Tanabe N, Kikuchi S, Kondo T, et al. (2002). Perceived mental stress and mortality from cardiovascular disease among Japanese men and women. The Japan Collaborative Cohort study for evaluation of cancer risk sponsored by Monbusho (JACC Study). *Circulation* 106:1229–36.
- Khang Y-H, Kim HR. (2005). Explaining socioeconomic inequality in mortality among South Koreans: an examination of multiple pathways in a nationally representative longitudinal study. *Int J Epidemiol* 34: 630–7.
- Kiecolt-Glaser JK, Glaser R. (1999). Chronic stress and mortality among older adults. *JAMA* 282:2259–60.
- Kohout FJ, Berkman LF, Evans DA, Cornoni-Huntley J. (1993). Two shorter forms of the CES-D (Center for Epidemiologic Studies Depression) depression symptoms index. *J Aging Health* 5:179–93.
- Krause N, Liang J. (1992). Cross-cultural variations in depressive symptoms in later life. *Int Psychogeriatr* 4:185–202.
- LaCroix AZ, Lang J, Scherr P, Wallace RB, Cornoni-Huntley J, Berkman L, Curb JD, et al. (1991). Smoking and mortality among older men and women in three countries. *N Engl J Med* 324:1619–25.
- Lazarus RS. (1966). Psychological stress and the coping process. New York: McGraw-Hill.
- Lazarus RS. (1977). Psychological stress and coping in adaptation and illness. In: Lipowski ZJ, Lipsitt DR, Whybrow PC, editors. Psychosomatic medicine: current trends. New York: Oxford University Press. p 14–26.
- Lee KL, Ou Y-L, Chen S-H, Weng L-J. (2009). The psychometric properties of a short form of the CES-D used in the Taiwan longitudinal study on aging. *J Formosa Ment Health* 22:383–410.
- Macleod J, Smith GD, Heslop P, Metcalfe C, Carroll D, Hart C. (2001). Are the effects of psychosocial exposures attributable to confounding? Evidence from a prospective observational study on psychological stress and mortality? *J Epidemiol Comm Health* 5:878–84.
- Macleod J, Smith GD, Heslop P, Metcalfe C, Carroll D, Hart C. (2002). Psychological stress and cardiovascular disease: empirical demonstration of bias in a prospective observational study of Scottish men. *BMJ* 324:1247–52.
- Mason JW. (1971). A re-evaluation of the concept of non-specificity in stress theory. *J Psychiatr Res* 8:323–33.
- May M. (2002). Does psychological distress predict the risk of ischemic stroke and transient ischemic attack? The Caerphilly Study. *Stroke* 33: 7–12.
- McEwen BS. (1998). Protective and damaging effects of stress mediators. *N Engl J Med* 338:171–9.
- Melzer D, Lan T-Y, Guralnik JM. (2003). The predictive validity for mortality of the index of mobility-related limitation – results from the EPESE study. *Age Ageing* 32:619–25.
- Muse AG, Mikl J, Smith PF. (1995). Evaluating the quality of anonymous record linkage using deterministic procedures with the New York State AIDS registry and a hospital discharge file. *Statistics Med* 14:499–509.
- Nagi SZ. (1969). Disability and rehabilitation: legal, clinical, and self concepts and measurement. Columbus: Ohio State University Press.
- Nagi SZ. (1976). An epidemiology of disability among adults in the United States. *Milbank Memorial Fund Quarterly* 54:439–68.
- Neutel CI, Johansen HL, Walop W. (1991). New data from old: epidemiology and record-linkage. *Progress Food Nutr Sci* 15:85–116.
- Nielsen NR, Kristensen TS, Schnohr P, Grønbaek M. (2008). Perceived stress and cause-specific mortality among men and women: results from a prospective cohort study. *Am J Epidemiol* 168:481–91.
- Ofstedal MB, Zimmer ZS, Lin HS. (1999). A comparison of correlates of cognitive functioning in older persons in Taiwan and the United States. *J Gerontol Psych Sci Soc Sci* 54:291–301.
- Radloff LS. (1977). The CES-D scale: a self-report depression scale for research in the general population. *Appl Psychol Measurement* 1: 385–401.
- Reuben DB, Cheh AI, Harris TB, Ferrucci L, Rowe JW, Tracy RP, Seeman TE. (2002). Peripheral blood markers of inflammation predict mortality and functional decline in high-functioning community-dwelling older persons. *J Am Geriatr Soc* 50:638–44.
- Rosengren A, Orth-Gomér K, Wedel H, Wilhelmsen L. (1993). Stressful life events, social support, and mortality in men born in 1933. *Br Med J* 307:1102–5.
- Roth GS, Lane MA, Ingram DK, Mattison JA, Elahi D, Tobin JD, Muller D, Metter EJ. (2002). Biomarkers of caloric restriction may predict longevity in humans. *Science* 297:811.
- Schwartz JE, Pickering TG, Landsbergis PA. (1996). Work-related stress and blood pressure: current theoretical models and considerations from a behavioral medicine perspective. *J Occup Health Psychol* 1: 287–310.
- Schulz R, Beach SR, Ives DG, Martire LM, Ariyo AA, Kop WJ. (2000). Association between depression and mortality in older adults. *Arch Intern Med* 160:1761–8.
- Shaper AG. (1990). Alcohol and mortality: a review of prospective studies. *Br J Addict* 85:837–47.
- StataCorp. (2007). Stata statistical software: release 11 [Computer software]. College Station, TX: StataCorp.
- Van Praag HM, De Kloet ER, Van Os J. (2004). Stress, the brain and depression. Cambridge: Cambridge University Press.
- Weiner DE, Tighiouart H, Amin MG, Stark PC, MacLeod B, Griffith JL, Salem DN, et al. (2004). Chronic kidney disease as a risk factor for cardiovascular disease and all-cause mortality: a pooled analysis of community-based studies. *J Am Soc Nephrol* 15:1307–15.
- Wisconsin Department of Health Services. Comparing causes of death between years: accounting for the change from ICD-9 to ICD-10. Last online revision September 5, 2012 http://www.dhs.wisconsin.gov/deaths/ICD10_ICD9.htm (accessed 15 January 2013).
- Wulsin LR, Vaillant GE, Wells VE. (1999). A systematic review of the mortality of depression. *Psychosomatic Med* 61:6–17.