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Social relationships and allostatic load in Taiwanese elderly and near elderly

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Abstract

Despite the increasing evidence linking aspects of the social environment to a range of health outcomes, important questions remain concerning the precise mechanisms or pathways through which social circumstances exert their influence. Biological pathways are one important area of current research interest. Using data from the Social Environment and Biomarkers of Aging Study (SEBAS) in Taiwan, we examined relationships between social environment characteristics and an index of cumulative biological dysregulation (''allostatic load,'' AL) in near elderly (NE) (aged 54–70) and elderly Taiwanese (aged 71+). Longitudinal data on levels of social integration and extent of social support were used to predict cumulative AL at the final survey year. Linear regression analyses revealed that among the NE, presence of a spouse between 1996 and 2000 was associated with lower AL in 2000 among men, but not women. Among the elderly, ties with close friends and/or neighbors were found to be significantly related to lower AL for both men and women. Perceived qualities of these social relationships did not show consistent associations with AL. This relatively modest set of significant relationships stands in contrast to somewhat stronger patterns of findings from studies in Western societies. Cross-cultural differences between Western societies and an East Asian society such as Taiwan raise the intriguing possibility that contextual, normative influences on social experience affect the patterns of association between features of these social worlds and the physiological substrates of health.

Keywords: Allostatic load; Social relationships; Social support; Taiwan

Introduction

The question of whether and how social relationships may influence health has been a topic of considerable research interest for some time. Recently, there has been growing interest in elucidating the actual pathways through which social relationships may affect morbidity and mortality. This article seeks to extend efforts to understand the biological pathways through which any health effects must ultimately be transmitted.

Although a growing body of research has begun to document links between characteristics of the social environment and biological substrates for health in both animal and human populations, this research has largely focused on specific, individual physiological parameters or systems (e.g., blood pressure, cortisol, lipids; Uchino, Cacioppo, & Kiecolt-Glaser, 1996; Seeman & McEwen, 1996). Such an approach, while useful in providing initial evidence linking social factors to physiology, does not address the likelihood that cognitive–emotional processing of social experience

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likely involves simultaneous impacts on multiple biological regulatory systems.

The concept of allostatic load (AL), first introduced by McEwen and Stellar (1993), proposes that a multi-systems view of physiological risk may be a more useful heuristic in thinking about the impact of life experiences (including social factors) on health and well-being. The concept of AL reflects the idea that there is cumulative physiological wear and tear exacted on the body's regulatory systems through our efforts to adapt to life's demands. Such wear and tear (or AL) is postulated to result from adaptive physiological responses that are chronically outside normal operating ranges. The rate and extent of accumulation of AL for an individual is hypothesized to result from both dynamic patterns of regulatory systems' responses to challenge as well as their more general levels of operation outside optimal ranges under non-challenge conditions. AL thus represents the cumulative physiological toll of such dysregulations across multiple systems over time, reflecting both a multi-system and life-span orientation.

Growing evidence provides support for the hypothesized role of AL as a pathway between life experiences (including experiences of social integration and support) and health outcomes. An initial operationalization of AL, based on information regarding the hypothalamic–pituitary–adrenal axis, sympathetic nervous system, cardiovascular system, and metabolic processes, was shown to be positively related to risks for a range of pathologies, including incident cardiovascular disease, declines in cognitive and physical functioning and mortality (Seeman, Singer, Horwitz, & McEwen, 1997; Seeman, Singer, Rowe, & McEwen, 2001). Differences in AL have also been shown to be related to aspects of social environments. Longitudinal data from the Wisconsin longitudinal study (WLS) have shown that childhood exposure to a caring parent and adult exposure to a supportive partner are associated with lower AL in late middle-age (Singer & Ryff, 1999). The MacArthur Study of Successful Aging has also documented a relationship between lower AL and greater social integration and emotional support from others, as well as associations between negative aspects of social experience (e.g., demands/criticism from others) and greater AL (Seeman, Singer, Ryff, & Levy-Storms, 2002).

Cross-cultural considerations

The Social Environment and Biomarkers of Aging Study (SEBAS)—a study of health outcomes in near elderly (NL) (54–70) and elderly (71+) Taiwanese—offers an opportunity to investigate links between social experience and biological risk. Available measures of both social and biological factors are similar (though not identical) to those used in previous studies in the US, allowing for comparisons of at least the general patterns of findings. Historically, Western and Asian cultures have been shown to differ in their cultural norms regarding social relationships, particularly in their views of the individual or "self" in relation to others. Influenced by Confucian emphasis on interrelatedness, Asian social norms emphasize collectivism/interdependence and give rise to views of the self that emphasize connections to others; by contrast, Western norms emphasize individualism/independence, encouraging views of the self as a more autonomous entity (for reviews, see Markus & Kitayama, 1991; Markus, Mullally, & Kitayama, 1997; Takahashi, Ohara, Antonucci, & Akiyama, 2002). One important result of these differential norms may be the degree to which individuals in Asian cultures, who are relatively socially isolated in terms of our traditional measures of social integration (e.g., reported "close" ties with others or membership in groups), nonetheless experience less increase in health risks as a result of a greater culturally induced sense of belonging or connection to the larger social world. One might, therefore, expect to find weaker associations between standard measures of social integration and health outcomes.

Another factor that could mitigate any negative impact of impoverished "personal" social worlds, at least for older adults in Taiwan, is that Chinese culture places significantly greater emphasis on respect for the elderly. Such a norm, involving deeply embedded patterns of deference towards older adults, could have important positive social consequences for older Taiwanese (Ingersoll-Dayton & Saengtienchai, 1997; Ho, 1982; Fricke, Chang, & Yang, 1994). Such deference, for example, if generalized throughout the culture (i.e., not linked to an individual's own close social relationships), might be expected to result in weaker associations between traditional measures of social integration or support and biological outcomes because even those reporting fewer specific ties and/or less specific support may benefit from a more general sense of social deference based on their age.

Finally, Taiwanese culture (like other Asian cultures) places considerable emphasis on social relationships involving family ties and obligations (Hermalin, Ofstedal, & Chang, 1996; Lee, Parish, & Willis, 1994; Mason, 1992). While this may result in higher levels of social integration among Taiwanese, social integration that reflects normative "social obligations", rather than voluntary ties, may not confer unadulterated health benefits, particularly if such ties increase the likelihood of exposure to negative social interactions (e.g., criticism or demands from others; unwanted or unpleasant obligations). Under such conditions, greater social integration might be less strongly positive in its effects on health. Consistent with this possibility, previous findings from the Survey of Health and Living Status among the elderly and near elderly (NE) in Taiwan (the larger population survey from which the SEBAS participants were sampled) suggest that lower levels of social integration and support are only modestly related to risks for poorer self-rated health and/or mortality (Beckett, Goldman, Weinstein, Lin & Chuang, 2002; Cornman, Goldman, Glei, Weinstein, & Chang, 2003; Weinstein, Goldman, Hedley, Yu-Hsuan, & Seeman, 2003; Zimmer, Liu, & Chuang, 1998)—findings that parallel similar evidence of weaker or less consistent associations of social integration with better health outcomes from other studies in Asian cultures (e.g., Sugisawa, Liang, & Liu, 1994; Liang et al., 1999).

We seek to extend these earlier findings by examining relationships between characteristics of the social environment and an integrated measure of physiological functioning in the Taiwanese SEBAS participants. These analyses provide a counterpoint to previous research on middle-aged and older US adults using comparable measures of the social environment and an identical measure of physiological functioning (Seeman et al., 2002). A particular strength of the SEBAS data is the availability of longitudinal data on social experiences over periods of 4 years for the NE cohort and 11 years for the elderly cohort. In contrast to previous research, which has largely focused on single point-in-time assessments of social relationships, the SEBAS data provide information about cumulative social experiences.

We tested the hypothesis that those reporting social environments characterized by greater social integration and more emotional support will show lower AL, while those reporting more frequent negative interactions with others (e.g., demands, criticism) will have higher ALs. Based on previous findings from Asian cultures, we hypothesized that the observed relationships would be weaker than those seen in US populations (Singer & Ryff, 1999; Seeman et al., 2002). Also, based on previous research indicating that marital status may be more consistently related to better health in younger vs. older adults (Seeman, Kaplan, Knudsen, Cohen, & Guralnik, 1987), we hypothesized that marital status would be related to lower AL in the near elderly but not the elderly cohort. Furthermore, based on theory and empirical evidence suggesting that men and women may be differentially responsive to social situations (see Seeman & McEwen, 1996; Taylor, 2002 for reviews), and, more specifically, that women may be more physiologically reactive to negative social interactions (Kiecolt-Glaser & Newton, 2001; Malarkey, Kiecolt-Glaser, Pearl, & Glaser, 1994), we hypothesized that negative interactions would be more strongly related to AL among women.

Methods

Analyses are based on data collected as part of the Survey of Health and Living Status of the NE and elderly in Taiwan. This longitudinal survey began in 1989 with a national sample of 4049 persons aged 60 and older; this sample was re-interviewed in 1993. In 1996, the original sample was again re-contacted and the study was also expanded to include a national sample of 2462 (NE) persons aged 50–66 in 1996 (Taiwan Provincial Institute of Family Planning, 1989). Both groups of respondents were re-interviewed in 1999. At each survey, participants were asked to provide information regarding their financial situation, household composition and exchanges, social contacts with others outside the household, and social support from others, as well as information on physical and mental health.

In 2000, a national sub-sample of respondents was selected randomly for the Social Environment and Biomarkers of Aging Study (SEBAS). On a scheduled day several weeks after an initial interview, participants collected a 12-h overnight urine sample, fasted overnight, and visited a nearby hospital the following morning for a physical examination. During the hospital visit, medical personnel drew a blood sample from the participant and took blood pressure and anthropometric measurements. Among the 1713 respondents selected for the SEBAS, a total of 1497 provided interviews (92% of survivors), and 1023 participated in the physical examination (68% of those interviewed). A comparison of the characteristics of nonparticipants and participants in the medical exam revealed that respondents over age 71 were less likely than NE persons to participate. There were no differences with respect to sex, various measures of socioeconomic status, or aspects of health status, suggesting that, in the presence of controls for age, estimates derived from clinical information are unlikely to be seriously biased (Goldman, Lin, Weinstein, & Lin, 2003).

For this analysis, we draw indicators of the social environment and covariates from the 1989, 1993, 1996 and 1999 survey waves (for the NE sample, data are available only for 1996 and 1999). The dependent variable, AL, comes from the physical exam and biomarker collection in 2000.

Characteristics of the social environment: Summary measures for aspects of the social environment generally reflect counts of the number of survey waves where subjects score high or low on specific characteristics. The decision to summarize by counting across survey waves was based on our interest in developing measures reflecting cumulative experience across time as well as the need to account for some variation in actual item/scale content across survey waves. Thus, rather than taking an average score across waves (which may mask differences in cumulative exposure), we identified categories that represent low or high levels of social integration (or other features of the social environment) at each wave and then counted the number of waves for which such levels of integration were reported.[1]

Marital status: Measured by two dummy variables representing respondents who reported being married at each survey (1989–1999 for the elderly; 1996–1999 for the NE) and those who were married at baseline (1989 for the elderly; 1996 for the NE) but were separated, divorced, or widowed between baseline and the 1999 survey. The reference group included all those who were not married at baseline.

Number of other social ties (*i.e., ties with immediate family, other relatives and friends/neighbors*): Ties with whom the respondent (R) either lived or had ''regular'' contact were also assessed. Because the definition of ''regular'' contact (monthly vs. weekly) was not always consistent across waves, measures of social ties (by type) were categorized at each wave into low (bottom 10% of distribution), middle, and high (top 10% of distribution) and the number of waves with ''low'' and ''high'' ties was counted (range 0–2 for NE and 0–4 for elderly).

Social activity (i.e., doing things with others): Measured as the number of waves where no social activities were reported.

Emotional support: Assessed based on items asking how willing others are to listen to you, take care of you when you are ill, make you feel loved and cared for, and general levels of satisfaction with this support. Though actual item formatting varied somewhat across survey years, the general content of the items was very similar as were the response categories. All items were recoded to a 0–4 scale, where 4 indicated high emotional support. An index was created for each survey year by summing individual items and dividing by the number of valid items (range from 0–4); each of the indices has good psychometric properties (data available on request).

Within each survey year, we recoded the index of emotional support into low (using a cutoff based on response categories that reflect ''somewhat unwilling'' to provide such support or less support), middle and high (cutoff based on categories ''very/extremely willing'') and counted the number of waves with ''low'' and ''high'' support. We also tested a dichotomous measure indicating that low support was reported during at least one survey wave in order to assess the possibility of a threshold effect.

Criticism from others: In 1999 and 1996, R was asked whether family, relatives, or friends are sometimes or very often critical of what R does. A similar question in 1993 asked whether people close to R complain about or find fault with things R does. For 1989, when Rs were asked separately about criticism from spouse, children and others, we calculated the average among valid responses to the 3 sub-questions. For each wave, a dichotomous variable was created reflecting any reported criticism (1) vs. ''never'' or ''not at all'' (0); we counted the number of waves in which R reported receiving any criticism. A dichotomous variable was also created, indicating criticism from others at least once across the survey waves, in order to test for a threshold effect.

For the elderly cohort, it was also possible to create a measure of ''*excessive demands from others*'' based on items asked in 1989 and 1993. For 1989, we calculated the average among valid responses to 3 items asking Rs how much (on a 5-point ordinal scale) they felt that their spouse/children/others make too many demands on them. The single 1993 item asked ''do you feel that people make too many demands on you?'' (3-point ordinal scale). For each year, measures were recoded to a 0/1 classification reflecting responses of ''not at all'' vs. any perception of excessive demands from others, and the number of waves (0–2) with too many demands were counted.

AL: Measured based on systolic and diastolic blood pressure (indices of cardiovascular activity); waist–hip ratio (an index of metabolism and adipose tissue deposition; Bjorntorp, 1987); serum HDL and total cholesterol (indices of risk for cardiovascular disease—higher total cholesterol and lower HDL cholesterol being associated with increased risk); blood plasma levels of glycosylated hemoglobin (Hb_{A1c}, an integrated measure of glucose metabolism over the previous 30–90 days; Koenig et al., 1976; Dunn et al., 1979), serum dehydroepiandrosterone sulfate (DHEA-S, a functional HPA axis antagonist; Svec & Lopez, 1989), urinary cortisol excretion (an integrated measure of 12-h HPA axis activity), and urinary norepinephrine and epinephrine excretion levels (integrated indices of 12-h SNS activity).

Systolic (SBP) and diastolic (DBP) blood pressure were calculated as the average of two seated blood pressure readings. Waist/hip ratio (WHR) was calculated based on waist circumference (measured at its narrowest point between the ribs and iliac crest) and hip circumference (measured at the maximal buttocks; Lohman, Roche, & Martorell, 1988). Fasting blood samples for assays of HDL cholesterol, total cholesterol, glycosylated hemoglobin and DHEA-S were obtained when subjects arrived at the health clinic for their physical examination. Sera and heparinized blood were sent to Union Clinical Laboratories (in Taipei) for measurements of HDL and total cholesterol, DHEA-S, and glycosylated hemoglobin (Hb_{A1c}). HDL was measured by dextran sulfate (Ciba Corning, MA), with an inter-assay coefficient of variation (CV) of 4.7 and

[1] Among the elderly, we created summary measures if they had valid data for at least 3 of 4 waves (for any one measure, fewer than 60 were missing data for one wave; their scores were rescaled by taking the average across the 3 waves and multiplying by 4). The NE were required to have valid data for both (1996 and 1999) waves.

sensitivity = 7 mg/dl. Total cholesterol was measured by enzymatic methods (Siedel, Hagele, Ziegenhorn, & Wahlefeld, 1983) with CV = 1.34 and sensitivity = 5 mg/dl. Hb_{A1c} was measured by high-pressure liquid chromatography (HPLC) with CV = 2.14 and sensitivity = 0.4%. DHEA-S was measured by RIA (Dudley et al., 1985) with CV = 12.9 and sensitivity = 1.1 μg/dl.

Subjects completed an overnight urine collection from 7 pm to 7 am on the morning of their visit to the health clinic. These samples provide integrated assessments of overnight excretion of cortisol as well as norepinephrine and epinephrine, reflecting differences in "basal" (i.e., non-stimulated) levels of HPA axis and SNS as subjects generally spent this time at home (and much of that time in bed). Urine samples were sent to UCL for assays of norepinephrine (NOR), epinephrine (EPI), and cortisol (CORT). Determinations were made by HPLC (Canalis, Reardon, & Caldarella, 1982; Krstulovic, 1983). Lower detection limits were 2, 2 and 4 μg/l, respectively, for NOR, EPI and CORT. Results for each of the three outcomes are reported as "micrograms (NOR, EPI, or CORT) per gram creatinine" in order to adjust for body size.

Following the algorithm initially developed by Seeman et al. (1997), each of the 10 biological parameters outlined above was classified into quartiles based on the distribution of scores in the entire sample. AL was measured by summing the number of parameters for which the subject fell into the "highest" risk quartile (i.e., top quartile for all parameters except HDL cholesterol and DHEA-S for which membership in the lowest quartile corresponds to highest risk). Table 1 presents the actual cut-points used for each component of AL. Use of the "top/bottom quartile" criterion reflects a data-driven partitioning of the sample in order to identify those with more extreme levels of system activity relative to the rest of the sample. Alternative algorithms for summarizing these data (e.g., alternative cut-points; averaging *z*-scores) have been examined and yield comparable findings with respect to health risks (Seeman et al., 1997).

Table 1
Operationalization of allostatic load

Biomarkers	Criterion for "high risk"
Systolic blood pressure	> 150 mmHg
Diastolic blood pressure	> 89 mmHg
HDL cholesterol	< 39 mg/dl
Ratio of total cholesterol to HDL cholesterol	> 5.1
Glycosylated hemoglobin (HbA_{1c})	> 5.7%
Waist–hip ratio	> 0.927
DHEA-S (dihydroepiandrosterone sulfate)	< 40.8 μg/dl
Urinary free cortisol	> 30.0 μg/g creatinine
Urinary norepinephrine	> 27.1 μg/g creatinine
Urinary epinephrine	> 3.65 μg/g creatinine

Covariates: Variables included in the multivariate models control for age, sex, socio-economic status and ethnicity. Age was measured as of the date of the health exam in 2000 based on date-of-birth. Socio-economic status (SES) was assessed in terms of education. We used respondent's own education for male respondents and husband's education for female respondents because we believe the latter better reflects the SES of the women in these cohorts, many of whom had very little formal education ("own education" was used for the 2 women who were never married). A longitudinal measure of financial hardship reflecting the number of waves where R reported that it was difficult to meet living expenses was also included as an additional index of SES. Ethnicity (coded as 2 indicator variables) reflects Fukien or Mainlander identity with Hakka as the reference group.[2] Longitudinal measures of health status and physical functioning were also included as covariates, including: (1) the number of waves with reported "poor" or "not so good" self-rated health and (2) the number of waves with any reported functional difficulties in climbing 2–3 flights of stairs, walking 200–300 m, lifting or carrying 11–12 kg, squatting, reaching over head/raising both arms above head, and grasping or turning objects with fingers. We also included a dichotomous indicator of whether R reported having a spouse "in poor health" at any wave.

Analyses: All analyses were conducted separately for the elderly and NE samples for two reasons. First, the longitudinal data differed across the two groups (4 waves for elderly vs. 2 waves for NE). Second, based on prior research suggesting possible age differences in relationships between social ties and health (e.g., Seeman et al., 1987), we sought to evaluate the hypothesis that there might be age differences in relationships between social factors and AL. Linear regression was used to test for hypothesized relationships between the social environment and AL and to test for hypothesized sex differences in these patterns of

[2] Fukienese are descendents of immigrants from the southern Fukien province of China; the Hakka arrived from the eastern Kwangtung province (Lamely, 1981). Mainlanders refers to the Nationalist military and civilian supporters (and their offspring) who migrated to Taiwan in 1949 after the fall of the Kuomintang. Mainlanders assumed high-ranking posts and continue to be over-represented in the national government, military, and high-level provincial positions associated with wealth, special privileges and political power (Gates, 1981; Tsai, 1992). Even among younger cohorts, Mainlanders have more education, higher status jobs, and larger incomes than the Hakka and Fukienese (Gates, 1981; Tsai, 1992). Differences between the other two ethnic groups are more modest, although the Hakka have been and continue to be better educated than the dominant Fukienese (Tsai, 1992).

association. The first set of models examined relationships with each aspect of the social environment individually, controlling only for age and sex. Social measures showing a main or interaction effect ($p<0.05$) with respect to AL for either age group were then included simultaneously in a multivariate model (for each age group) including socio-demographic and prior health status covariates, to assess the independent relationship of social factors with AL. Longitudinal (pre-existing) health status variables were also included in order to reduce the possibility that any observed relationship between social environment and AL was spurious (e.g., poor health results in less social interaction as well as higher AL). Results from models controlling only for demographic variables (data not shown) are similar to those reported with all covariates. Among the NE sample, 46 respondents (8%) with missing data on either AL ($n=5$) or other covariates ($n=41$) and one person of "other" ethnicity were excluded from the analysis. Among the elderly, 26 (5%) were excluded ($n=5$ missing outcome data; $n=21$ missing covariate data). Thus, the analysis sample consists of 531 NE (aged 54–70 by 2000) and 419 elderly (aged 71 and older) participants. Stata version 7.0 was used for all analyses (Stata Corp, 2001).

Results

Table 2 provides descriptive statistics for the NE and elderly cohorts. Statistical comparisons between the two cohorts were not possible for measures of the social environment because of differences in the number of waves of available data for the two groups. For comparable demographic characteristics and biological measures, p-values are provided indicating differences between the cohorts. As a result of the selective migration of males from Mainland China after the Communist victory in 1949, the elderly group had a higher percentage of men than the NE (64% vs. 54%). Consistent with the nearly 15 year average age difference between the two cohorts, the elderly exhibited higher average AL scores (2.7 vs. 2.4). Examination of the individual components of AL indicated that the elderly were more likely to have high SBP, WHR, total/HDL cholesterol, and urinary NOR and were more likely to have low DHEA-S. The elderly also tended to have higher urinary CORT and EPI and lower HDL cholesterol, though these latter differences were not significant.

Table 3 presents results from a series of linear regression models, testing each of the social indicators for a relationship with AL, adjusting only for age and sex. Social factors are numbered, indicating the different models that were run; groups of indicator/dummy variables, included in a given model, to code for comparisons across mutually exclusive groups, are designated with letters (e.g., the two marital status indicators denoted by 1a and 1b are both included in Model 1, Table 3). We also tested for possible sex-by-social indicator interactions. Results from main effects models are shown in the column labeled "main effects model". The column labeled "sex interactions" lists coefficient for interactions that were significant for the NE; no such interactions were found for elderly, so only "main effects" results are presented.

As shown in Table 3, several measures of the quantity of social support were found to be related to AL. Among the NE, there were three significant interactions with sex. For marital status, the coefficient comparing those who were married throughout the survey periods (relative to those not married at baseline) was negative for men but positive for women; although neither of these individual coefficients was statistically significant ($b=-0.42$, $p=0.13$ for men; $b=0.32$, $p=0.18$ for women), the sex difference was significant ($p<0.04$). A significant sex interaction was also seen for "number of follow-up waves with low reported ties with other relatives" ($p<0.02$): more frequent reporting of low ties among men was associated with higher allostatic load ($b=0.29$, $p=0.04$) whereas the effect was not significant among women ($b=-0.17$, $p=0.24$).

Perceived qualities of the social environment were also found to be related to allostatic load among the NE. For both men and women, those who reported being the recipient of criticism from family and/or friends at one or more waves had, as predicted, significantly higher AL scores ($b=0.29$, $p=0.03$). A significant sex interaction among the NE also indicated that for women, those reporting low emotional support at any wave had lower AL ($b=-0.63$; $p=0.06$)—a rather counterintuitive finding that is further explored below. No significant effect was seen among the men.

Among the elderly, marital status was unrelated to AL, but number of waves with high ties with non-relatives was significantly and negatively related to AL ($b=-0.29$; $p=0.005$). There were no significant interactions with sex among the elderly.

Multivariate linear regression models were run for the two age groups. Models presented in Table 4 include adjustments for all covariates (i.e., age, sex, ethnicity, education, financial hardship, health status and functional ability).[3] These results show that the protective effect of marriage among NE men remained marginally significant ($p=0.10$). Among the elderly, ties with non-relatives remained a significant predictor of lower AL (no differences by sex). Low emotional support also remained a significant predictor of lower AL among the NE women but not NE men. Additional analyses were

[3] Models including only age and sex were also run and revealed parallel results.

Table 2
Descriptive statistics for near elderly and elderly cohorts

	Near elderly ($N=531$)	Elderly ($N=419$)	p-value[#]
Demographic characteristics	M (S.D.)[a] or %	M (S.D.)[a] or %	
Age in 2000 (mean)	62.0 (4.8)	76.4 (4.1)	<0.001
Male (%)	54.4%	63.5%	0.005
Ethnicity			
Hakka (%)	15.1	10.0	0.02
Fukien (%)	77.2	60.6	<0.001
Mainlander (%)	7.7	29.4	<0.001
Male respondent or husband's education (mean years)	6.8 (4.5)	5.7 (4.9)	<0.001
Number of waves with difficulty meeting expenses[b] (mean)	0.50 (0.69)	0.74 (1.03)	—
Social indicators			
Marital status			
Married throughout survey period[b] (%)	79.7%	54.9%	—
Married at baseline, but divorced/separated/widowed subsequently[b] (%)	3.8	20.0	—
Social ties with immediate family			
Number of waves with low social ties[b] (mean)	0.26 (0.56)	0.46 (1.00)	—
Number of waves with high social ties[b] (mean)	0.22 (0.50)	0.47 (0.90)	—
Social ties with other relatives			
Number of waves with low social ties[b] (mean)	0.72 (0.70)	2.03 (1.27)	—
Number of waves with high social ties[b] (mean)	0.24 (0.48)	0.46 (0.76)	—
Social ties with non-relatives (close friends & neighbors)			
Number of waves with low social ties[b] (mean)	0.26 (0.49)	0.86 (1.01)	—
Number of waves with high social ties[b] (mean)	0.20 (0.43)	0.48 (0.77)	—
Number waves with no social activities[b] (mean)	0.39 (0.60)	0.81 (1.05)	—
Low emotional support in any wave[b] (%)	10.7%	27.0%	—
Family/friends are critical in any wave[b] (%)	52.5	71.6	—
Allostatic load summary score and components			
Summary allostatic load (mean score)	2.4 (1.6)	2.7 (1.6)	0.02
Systolic BP (% high[c])	19.8%	31.3%	<0.001
Diastolic BP (% high[c])	28.2	23.4	0.09
Waist–hip ratio (% high[c])	20.9	30.6	0.001
Total/HDL cholesterol (% high[c])	27.9	22.2	0.05
Glycosylated hemoglobin (HbA_{1c}) (% high[c])	27.3	25.5	0.54
Cortisol (% high[c])	23.7	26.5	0.30
Norepinephrine (% high[c])	21.5	27.9	0.02
Epinephrine (% high[c])	23.5	27.4	0.17
DHEA-S (% low[c])	22.7	28.9	0.04
HDL cholesterol (% low[c])	26.5	22.7	0.17
Other covariates			
Number of waves in "poor" or "not so good" health[b] (mean)	0.47 (0.68)	0.82 (1.06)	—
Number of waves with any functional difficulties[b] (mean)	0.46 (0.68)	1.44 (1.35)	—
Spouse in poor health in any wave[b] (%)	2.6%	8.8%	—

[#] p-value for comparison between NE and elderly cohorts.
[a] M = mean, S.D. = Standard deviation.
[b] Measures are based on two waves for the NE and four waves for the elderly.
[c] High/low is defined based on the value of the top/bottom quartile of the distribution for the entire sample.

conducted, examining the stability of this latter association, because it ran contrary to expectations and previous research (Seeman et al., 2002) and because the number of women reporting low emotional support was very small ($n=26$). Indeed, when "low" emotional support was defined less restrictively (i.e, lowermost 33% or 50% vs. lowermost 12% (1996) or 25% (1999) in original scoring), the relationship with AL was not robust; the effect changed sign and the effect for women was not significant.

Table 3
Individual regression models for social indicators and allostatic load, adjusting for age and sex only

Social indicators	Near elderly main effects models ($N=531$)	Sex interaction models[a]		Elderly main effects models[a] ($N=419$)
		Men	Women	
	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)
Marital status[b]				
1a. Married at baseline and throughout survey period[c]	0.01 (0.95)	−0.42 (0.13)[d]	0.32 (0.18)[d]	−0.07 (0.72)
1b. Married at baseline—but divorced, separated, or widowed subsequently[c]	0.46 (0.23)			−0.12 (0.60)
Family ties[b]				
2a. Number waves low ties with immediate family	0.11 (0.38)			0.01(0.86)
2b. Number waves high ties with immediate family	0.08 (0.58)			−0.05 (0.56)
3a. Number waves low ties with other relatives	0.07 (0.50)	0.29 (0.04)[d]	−0.17 (0.24)[d]	0.03 (0.59)
3b. Number waves high ties with other relatives	0.08 (0.57)			−0.02 (0.86)
4a. Number waves low ties with non-relatives	−0.0003 (0.99)			0.01 (0.89)
4b. Number waves high ties with non-relatives	0.03 (0.86)			−0.29 (0.005)
Kids only[b]				
5a. Number waves living with children	−0.09 (0.31)			0.09 (0.08)
5b. Number waves weekly contact with non-resident children	−0.04 (0.65)			−0.03 (0.62)
Social activity				
6. Number waves with no social activities	−0.08 (0.48)			−0.04 (0.59)
Emotional support[b]				
7a. Number waves low emotional support	−0.02 (0.90)	0.26 (0.27)[d]	−0.39 (0.15)[d]	0.12 (0.27)
7b. Number waves high emotional support	0.08 (0.50)			−0.01 (0.90)
8a. Low emotional support in any wave	−0.06 (0.80)	0.42 (0.16)[d]	−0.63 (0.06)[d]	0.22 (0.22)
8b. High emotional support in any wave	0.12 (0.42)			0.08 (0.62)
9. Low emotional support in any wave (entered alone)	−0.09 (0.68)	0.37 (0.21)	−0.66 (0.04)	0.19 (0.26)
Negative interactions[b]				
10a. Number waves family/friends are critical	0.18 (0.07)	—	—	0.09 (0.23)
10b. Number waves people make too many demands	—[e]	—	—	−0.0005 (0.99)
11. Family/friends are critical in any wave	0.29 (0.03)	—	—	0.15 (0.38)

[a] Coefficients are shown separately by sex only if the sex interaction was significantly different from zero at the 0.05 significance level. There were no significant differences among the elderly so only "main effects" models are shown.

[b] Separate models are indicated by numbers while indicators included as a group in a given model are indicated by separate letters (e.g., Model 1 includes 2 indicators for marital status 1a and 1b).

[c] Reference group includes those who were not married at baseline (1996 for NE and 1989 for elderly).

[d] The sex interaction was significant for this indicator but not significant for the other indicator included in the model (e.g., Model 1: significant for 1a (married) but not 1b (divorced/separated/widowed group)). Therefore, the sex interaction model includes an interaction term for the indicator with significant sex difference but only a main effect term (for both sexes combined) for the indicator where the interaction was found to be non-significant (i.e., "divorced/separated/widowed" variable in Model 1).

[e] Not available for NE.

Table 4
Multivariate regression models for near elderly and elderly cohorts, including social indicators and covariates simultaneously

Social indicators	Near elderly ($N=531$)		Elderly ($N=419$)	
	Coefficient (std. error)	*p*-value	Coefficient (std. error)	*p*-value
Marital status				
Married throughout survey period	—		0.01 (0.20)	0.97
Men[a]	−0.47 (0.29)[b]	0.10	—	
Women[a]	0.28 (0.24)[b]	0.24	—	
Divorced, separated, or widowed after baseline	0.44 (0.39)	0.26	−0.08 (0.23)	0.73
Ties with other relatives				
♯ Waves with low social ties	—		0.04 (0.08)	0.60
Men[a]	0.16 (0.14)	0.25	—	
Women[a]	−0.12 (0.15)	0.42	—	
♯ Waves with high social ties	0.02 (0.16)	0.92	0.11 (0.12)	0.36
Ties w/non-relatives (close friends & neighbors)				
♯ Waves with low social ties	−0.03 (0.15)	0.84	−0.04 (0.09)	0.70
♯ Waves with high social ties	−0.003 (0.16)	0.98	***−0.30 (0.11)***	***0.01***
Emotional support				
Low emotional support	—		0.13 (0.20)	0.52
Men[a]	0.08 (0.31)	0.80	—	
Women[a]	***−0.65 (0.33)***	***0.05***	—	
Negative interactions				
Family or friends are critical in any wave	0.20 (0.14)	0.13	0.08 (0.17)	0.66
Other covariates				
Men (reference = Women)	***5.28 (1.96)***	***0.007***	***−0.57 (0.19)***	***0.002***
Age	—		0.03 (0.02)	0.19
Men[a]	−0.003 (0.02)[b]	0.86	—	
Women[a]	***0.09 (0.02)***[b]	***<0.001***	—	
Ethnicity (reference = Hakka)				
Fukien	−0.004 (0.19)	0.98	***0.59 (0.26)***	***0.02***
Mainlander	0.35 (0.32)	0.27	0.47 (0.29)	0.11
Male respondent or husband's education (years)	—		0.01 (0.02)	0.61
Men[a]	0.02 (0.02)	0.49	—	
Women[a]	***−0.04 (0.02)***	***0.05***	—	
Number of waves with difficulty meeting expenses	0.02 (0.10)	0.83	−0.08 (0.09)	0.35
Number of waves in "poor" or "not so good" health	—		0.11 (0.08)	0.20
Men[a]	***0.56 (0.15)***[b]	***<0.001***	—	
Women[a]	0.01 (0.16)[b]	0.95	—	
Number of waves with any functional difficulties	0.09 (0.12)	0.45	0.09 (0.07)	0.22
Spouse in poor health in any wave	−0.41 (0.42)	0.33	−0.14 (0.27)	0.60
R^2	0.12		0.10	
Adjusted R^2	0.08		0.07	

Note: Results that reach the 0.10 significance level are shown in bold italics.
[a] Where significant sex interactions were found, separate parameter estimates are presented for men and women (rather than the less interpretable main and interaction coefficients). The coefficient shown for women (reference group) reflects the main effect, while that for men equals the sum of the main and interaction effects.
[b] Difference between coefficient for men and women is significant at the 0.05 level.

Discussion

The analyses presented here examined whether social relationships and support are related to patterns of biological dysregulation as measured by a summary index of AL. Our general hypothesis was that individuals who enjoy higher levels of social integration and emotional support would exhibit lower AL. More frequent negative interactions with others were expected to be associated with increased levels of AL. We found only modest support for these hypotheses. Among the NE Taiwanese, the presence of a spouse between 1996 and 2000 was associated with lower AL in 2000 among men (but not women). Among the elderly Taiwanese of both sexes, ties with close friends and/or neighbors were found to be significantly related to lower AL. The perceived quality of these social relationships did not show consistent associations with AL.

Our findings linking marriage to lower AL in the NE Taiwanese men, and ties with friends/neighbors to lower AL in the elderly Taiwanese, are consistent with previous research relating greater social integration and positive social relationships to lower AL (Seeman et al., 2002). Parallel to the US data, presence of a spouse among elderly Taiwanese was unrelated to AL while ties with others were associated with lower AL. The fact that marital status was unrelated to AL among the elderly Taiwanese is also consistent with results indicating that non-familial ties, but not marital status, are a significant predictor of mortality risks at older ages (Seeman et al., 1987; Seeman et al., 1993). Recently, similar patterns of association have also been reported for older Taiwanese (Beckett et al., 2002). The fact that marital status was more strongly related to AL among NE men (but not women) is consistent with research suggesting that men may enjoy greater health benefits than women from being married (Seeman, 1996; Burg & Seeman, 1994; Taylor, 2002).

There are several possible reasons for the relatively modest evidence linking aspects of social integration to levels of AL. One possible factor is selection. Those included in the analyses represent the survivors who were available in 2000 to provide outcome data on AL. To the extent that the less socially integrated are more likely to die earlier, the remaining cohort may disproportionately represent those with higher levels of integration as well as a subgroup of those who are most "resistant" to the negative health impact of their relatively impoverished social environments. Several factors, however, argue against the likelihood that such selection accounts for the modest findings. First, the NE group would be considerably less subject to such mortality selection; still they, like the elderly, do not show consistent associations between social conditions and AL. Second, similar selection effects would presumably be operating in other longitudinal studies which have shown significant relationships between social factors and AL at older ages (Seeman et al., 2002).

A more likely explanation for the generally weak findings may relate to the cultural context of this Taiwanese study—a context whose differences from Western culture were outlined in our Introduction. In capsule form, the argument holds that the normative emphasis in Asian cultures on a collective versus an individualistic view of the self and social connectedness has important consequences for the psychological and emotional aspects of social interaction. As Kitayama et al. (1995, p. 440) have argued, "the development and organization of emotional processes and experience, with all their biological underpinnings, may be influenced… by the systems of meaning in which the self, others and social events… are made personally significant." Thus, the Asian emphasis on one's role in a larger social whole may result in different definitions of "good" or "positive" social relationships. In the Asian case, particular interactions may be defined in terms of fulfillment of one's role within a larger social context (e.g., meeting one's obligations or doing what is expected), but in the Western perspective in terms that simply reflect well on one's performance in social interaction (Markus & Kitayama, 1991; Markus, Mullally, & Kitayama, 1997). Thus, in Western society the focus may be more centrally on the self in evaluating what is a "positive" social interaction, while in Asian cultures the focus may tend to be more outward (e.g., "Did I fulfill my role obligations as part of a larger whole?"). If so, available measures of social networks and support may not provide adequate assessment of relevant aspects of the social environment, resulting in weaker observed relationships.

More specifically, measures used in this study represent items developed for use in Western populations. While use of these items in other cultures carries the advantage of allowing for more direct comparison of findings, these Western-based measurement tools may not adequately assess the fundamental relevant aspects of the social environment in other cultures. To the extent that such items have a singularly "self-referent" focus (e.g., "How often do others make you feel loved or cared for?"), they may not capture the most relevant features of the social environment in Taiwan. Likewise, for measures of social integration, the focus on "frequency of contact" or identification of persons "one feels close to" may be more accurate indicators for identifying significant others in a Western context. By contrast, in the Asian context, feelings of social integration may have more to do with the range and status of the persons with whom one has relationships (i.e., with the number, and type of "roles" one has). Notably, the one measure that performed most similarly in the Taiwan and US contexts was marital status, a measure perhaps least subject to cultural definitional differences of the kind discussed above. Overall, although the present analyses showed relatively few statistically significant associations with biological risk, the general trends were consistently in the expected direction, suggesting that the underlying relationships may well be comparable to those observed in US populations. With more culturally attuned measurement of salient experiences in the Taiwanese context, we might well see stronger relationships between exposure to more positive social experiences and lower AL.

There are several additional limitations of this study that should be acknowledged. First, the lack of strictly comparable measurements for the social indicators over the various survey waves may have introduced additional measurement error with respect to the longitudinal tracking of social conditions over time. Such measurement error may have contributed further to weaker associations with AL. Previous research, however, has indicated that different measures of general social conditions demonstrate similar patterns of association with health outcomes, including AL (Seeman et al., 2002; Seeman & Crimmins, 2001), suggesting that measurement of social conditions over time is unlikely to be a primary explanation for the observed pattern of findings. Another limitation of the current analyses relates to the assessment of AL, which includes assessments for some, but not all, major physiological regulatory systems. To the extent that missing components (e.g., markers of inflammation or parasympathetic activity) are significantly impacted by social conditions, the present analyses may underestimate the links between such social conditions and physiological risk profiles. Again, however, previous research using this same measure of AL has shown relationships to social conditions (Seeman et al., 2002; Singer & Ryff, 1999).

Despite these caveats, the current analyses offer an instructive counterpoint to studies of US populations. Only marital status in the NE men and ties with close friends/neighbors among the elderly were significantly related to lower AL, though other measures of social conditions generally showed the expected, albeit non-significant, trends. The lack of significant associations for other measures of social integration and for the perceived quality of these social relationships clearly merits further attention in light of evidence linking such conditions to physiological functioning in Western societies. Are such social conditions more weakly related to physiology in the context of a society that places greater emphasis on social relationships and obligations? And if so, does this reflect the general dearth of individuals in the highest risk groups? Or, alternatively, might a higher level of social integration in Taiwan and comparable societies also carry heavier burdens of social obligations that could in turn exact a physiological toll?

Existing data from a variety of studies (largely based in Western social contexts) have clearly documented the fact that social conditions can have significant impacts on physiological functioning and health outcomes. The fact that these effects appear to be less evident in the Taiwanese context highlights the value of such cross-cultural comparisons as a means of enhancing our understanding of the complex linkages between social conditions and health and, in this case, pointing to the need for additional research focusing on the possibly different aspects of the social environment that may affect health and aging in Asian vs. Western cultural contexts. Cross-cultural differences in social norms, for example, may affect not only the structural characteristics of people's social worlds but also their qualitative experiences of those worlds. Before we can hope to develop effective policies and/or interventions relating to aspects of the social environment, we need a more complete understanding of which features of the social environment might be targets for risk assessment and interventions. More immediately, research is needed on the question of whether or not contextual, normative influences on social experience affect the patterns of association between features of these social worlds and the physiological substrates of health.

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