Social Support and Cumulative Physiological Dysregulation among Chinese at Advanced Ages: Preliminary Findings from the CLHLS

Ting Li[1], Yang Yang[1, 2], Xiao-Ming Shi[3], Zhao-Xue Yin[3], and Yi Zeng[4, 5]

Abstract: The health effects of social support in old age and the underlying biological mechanisms are not well known in non-western populations. This study examined the associations between social relationship and an index of cumulative biological dysregulation (Allostatic load, AL) in a unique sample of people at advanced age (N=499, average age=93) from the 2008-09 wave of the Chinese Longitudinal Healthy Longevity Survey. Logistic regression analyses revealed that while few correlates commonly examined in U.S. based studies are significantly related to AL, social support is strongly related to AL. Structural social support in terms of number of connections was negatively related to AL for males but not for females, and appraisal support in terms of perceived quality of social relationship had a strong negative association with AL for both sexes. These findings highlight the importance of maintaining a high volumne of good social relationships for old people to achieve healthier aging.

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[1]Carolina Population Center and Lineberger Comprehensive Cancer Center, University of North Carolina at Chapel Hill
[2]Department of Sociology, University of North Carolina at Chapel Hill
[3]Division of Chronic Disease Control and Community Health, Chinese Center for Disease Control and Prevention
[4]Center for the Study of Aging and Human Development and the Geriatric Division of School of Medicine, Duke University
[5]Center for Study of Healthy Aging and Development Studies, National School of Development, Peking University

Introduction

The idea that social embeddedness has positive impacts on various health outcomes and adult mortality has been well documented in the literature and validated in populations across different societies and cultures (Broadhead, et al. 1983, Kaplan, Cassel and Gore 1977, Seeman 1996). A growing body of research has recently emerged that intends to elucidate the biological mechanisms underlying such widely recognized relationship (Taylor, Repetti and Seeman 1997, Uchino, Cacioppo and Kiecolt-Glaser 1996). Along this line of research, a number of biological parameters across different systems have been employed to investigate the potential pathways through which social environment transmit its effects to aging related health outcomes. Studies of individual regulatory systems show evidence that favorable social environment tended to prevent the disorder of a number of biological parameters, e.g. blood pressure, cortisol and lipids (Ewart, et al. 1991, Gerin, et al. 1992, Kamarck, Manuck and Jennings 1990, Seeman and McEwen 1996). This provides some basis for the hypothesis that the "cognitive-emotional process of social experience likely involves simultaneous impacts on multiple biological regulatory systems" (Seeman, et al. 2004a) and the construct of allostatic load (AL) as an index of cumulative biological dysregulation.

However, the concept of AL proposed by McEwen and Stellar (1993) does not merely reflect a sum of multiple physiological risks, but a cumulative biological cost resulting from attempts to adapt to one's daily life challenges. AL was initially derived from the term allostasis which refers to the process whereby an organism maintains its internal stability by changing biological parameters to cope with environmental demands (Juster, McEwen and Lupien 2010, McEwen 1998, Sterling and Eyer 1988). AL then represents the chronic "wear and tear" when allostatic responses are frequently activated, such that the biological parameters are chronically out of normal operating ranges. In summary, AL is the long term price paid by the body during the process of achieving repeated short term protections from challenges (Lupien, et al. 2006). Meanwhile, AL had been found to be an effective predictor for various health outcomes including mortality (Goldman, et al. 2006b, Gruenewald, et al. 2006, Karlamangla, Singer and Seeman 2006, Seeman, et al. 2004b, Seeman, et al. 2001), cognitive decline (Goldman, et al. 2006a, Karlamangla, et al. 2002, Seeman, et al. 1997), and physical functioning decline (Karlamangla, et al. 2002, Seeman, et al. 2001). To the extent that AL embodies both multi-system and chronic developmental perspectives, it is a favorable candidate for explaining the biological pathway linking social experience and health outcomes (Lupien, et al. 2006, Seeman, et al. 2004a).

While there is some evidence for the link between AL and a number of social environment characteristics (Glei, et al. 2007, Seeman, et al. 2004a, Seeman, et al. 2002, Singer and Ryff 1999), the role of AL as a pathway linking social factors and health outcomes is not entirely clear. One important reason is that only limited data are available allowing simultaneous assessment of both social relationship and AL in the same study population. In fact, the hypothesized role of AL in this regard has only been tested in very few populations, and only one of them is nonwestern (the Taiwanese elderly) (Seeman, et al. 2004a). In addition, the associations between many features of social relationship and AL are shown to be relatively modest or weak, especially among older (Seeman, et al. 2002) and nonwestern populations (Glei, et al. 2007, Seeman, et al. 2004a).

The recent wave (2008-09) of the Chinese Longitudinal Healthy Longevity Survey (CLHLS) provides an opportunity to evaluate the relationship between social environment and physiological dysregulation. The

CLHLS population sample is unique in that it contains the largest number of oldest old (85+) including a big proportion of nonagenarians and centenarians (Zeng 2008, Zeng, et al. 2001). The subsample we used in this study has an average age of 93. To our knowledge, AL or the multi-system dysregulation has not been constructed or investigated in mainland Chinese population or/and population at such old ages. To this end, our study intends to fill the gap of AL study in Chinese oldest old and provide additional information on the association between social relationship and AL in a new social cultural context of nonwestern aging population.

Both aging and sociocultural factors could modify the social relationship-AL association. Some studies show that such association is less prominent at older ages (Seeman, et al. 2004a, Seeman, et al. 2002). The aging effect was hypothesized to be associated with the selective survival process where individuals in a less favorable social environment may die earlier and the remaining survivors become an assembly of those with good social environment or those less sensitive to the deleterious effects of unfavorable social environment. Alternatively, people at advanced age who have fewer social connections (Carstensen 1992, Sun and Liu 2008) and often need instrumental help could be more vulnerable to the poor quality of their social environment. Regarding the cultural effect, Chinese people who place much more attention on the family role in social interactions were expected to be more affected by the relationship with close family members, e.g. spouse and children (Glei, et al. 2007). However, early studies based on the elder Taiwanese population failed to find a strong association between familial ties and the physiological dysregualtion (Glei, et al. 2007, Seeman, et al. 2004a). All these issues are worth exploring in this newly added sample.

Finally, the original 2008 CHLHS and the additional biomarker sample questionnaires enable us to evaluate the profile of social relationship in a multi-dimensional and comprehensive way. Following early convention, we characterize social relationship in three aspects: the structural, functional, and appraisal components of supportive relationships (Antonucci 1990, Chen and Silverstein 2000, Oxman and Hull 1997, Penninx, et al. 1997). The structural component, often operationalized as the number of social ties a person has, reflects the degree to which he/she is socially integrated. The functional component, indicating help from instrumental, financial and other forms, reflects the actual support one has received. And the appraisal support, a more subjective evaluation of the relationship, represents the degree of satisfaction one has with the relationship. While all of the three dimensions were found to have certain influence on certain health outcomes (Chen and Silverstein 2000, Cornman, et al. 2003, Penninx, et al. 1997), the appraisal support was hypothesized to be more effective (Cassel 2006, Cobb 1976) in its role of stress buffering (Kessler and McLeod 1985, Wethington and Kessler 1986). However, such hypothesis is only validated in selected studies with selected health measures such as mental health (Cornman, et al. 2003).

In sum, in this study we intend to examine the association between social relationship and AL among a sample of Chinese oldest old. Besides testing the role of AL as the pathway that links social environment and health outcomes, we will explore whether the three characteristics of social relationship have similar or heterogeneous effects on the physiological dysregulation in this sample with both aging and cultural effects involved.

Data and Methods

Data

Data for this study come from a subset of the 2008-09 wave of the Chinese Longitudinal Healthy Longevity Survey (CLHLS). The CLHLS was initiated in 1998 as the first nationwide longitudinal survey on the determinants of healthy longevity with the largest sample of oldest old from a developing country. Details on the study design have been described elsewhere (Zeng 2008). The blood (n=2029) and urine (n=732) samples were first collected in the 2008-09 wave survey for willing participants. We included only 499 participants in this study, which have valid measures on all biomarkers that are used to construct AL. Unfortunately, most of the participants in the final sample were newly recruited in the CLHLS and thus no longitudinal information were available, but the sample still provide sufficient information for us to explore the basic pattern of associations between social relationship measures and cumulative multi-system dysregualtion.

Variables

Allostatic Load

Based on the available data, we utilize 9 biomarkers that have been used in early studies to construct AL (Juster, et al. 2010). They are systolic and diastolic blood pressure (indices of cardiovascular reactivity) (Seeman, et al. 1997), pulse rate (reflecting overall heart health), BMI (indicating cardiovascular risk influenced by metabolic factors) (Crimmins, et al. 2003), serum high-density lipoprotein (HDL) and the ratio of HDL to the total cholesterol (markers known to influence the development of atherosclerosis) (Seeman, et al. 2002), triglycerides (functioning as an important source of energy and as a transporter of dietary fat) (Juster, et al. 2010), fasting glucose (defined as part of insulin resistance related to stress hormones) (Seplaki, et al. 2004), and C-reactive protein (CRP) (a measure of chronic inflammation). These measures cover multiple biological systems from the domain of cardiovascular to metabolic and immune functions. The biological parameters of neuroendocrine system are not included due to the lack of data. However, early studies using similar sets of biomarkers without the neuroendocrine measures still show valid results related to the concept of AL (Crimmins, et al. 2007, Crimmins, Kim and Seeman 2009, Langelaan, et al. 2007, Lindfors, Lundberg and Lundberg 2006, Merkin, et al. 2009).

The operationalization of AL is based on an algorithm developed by Seeman et al. (1997). It counts the number of biological parameters for which the participant's value falls into the highest-risk quartile. For systolic blood pressure, pulse rate, triglycerides, fasting glucose, and CRP, the top quartile is considered as the high risk group, and for HDL and the ratio of HDL to total cholesterol, the bottom quartile is considered as unfavorable. Slight modifications are made for diastolic blood pressure and BMI where two-tail cutoffs are used. This is because a considerable proportion of participants (>10%) in this sample have very low values for these two biomarkers that are below the clinical cutoffs for hypotension and severe underweight. Indeed, Seplaki et al. (2005) demonstrated the validity of using two-tails cut points of risk for some biomarkers in comprising AL. To obtain an equal weight across all the biomarkers, we consider top 15% and bottom 10% quantiles as the risk zones for diastolic blood pressure and BMI. See table 1 for the actual values of cut points used for each component of AL.

The derivation of AL based on an empirical approach tends to identify the relative risk of individuals in comparison to the rest of the sample. In many cases, the actual cut points used in AL are lower than the clinical cut points in defining disease conditions. This also reflects the conceptualization of AL that the

co-existence of multiple dysregulations that are relatively less severe could still have a serious impact on overall health.

[Table 1 about here]

Social Relationship Measures

The structural social relationship is primarily described by the degree of social integration which includes four elements: current marital status (1: with spouse present; 0: else), frequent contact with children (1: living with or having frequent visit from at least one child; 0: else), frequent contact with siblings (1: living with or having frequently visit from at least one sibling; 0: else) and participating in social activities (1: playing cards and/or mah-jong or joining organized social activities sometimes; 0:else). A social network index (SNI) (0-4) is constructed as the sum of the above four variables. This index has been tested in previous studies as a more effective measure of social integration in predicting various health outcomes than each of its sub-elements alone (Berkman and Syme 1979, Ertel, Glymour and Berkman 2008). In regression analysis, we test the effects of both the four individual variables and the SNI on AL. In addition, living arrangement is a uniquely important indicator for the social relationship structure of the older people in China and thus is also included in the analysis. Information on living arrangement is obtained directly from the CLHLS questionnaire. We use a categorical variable to indicate four types of arrangement: living alone (reference group), living with children and with or without other relatives, living with relatives except children, and living in a nursing home.

The functional social relationship is indicated by two variables. The first one measures instrumental support derived from the survey question "when you are sick, who usually takes care of you" (Zeng, et al. 2010). It is grouped into three categories: nobody (reference group), family members and other helpers (friends, social services and caregivers). The second one measures financial support concerning if participants receive money from others. The variable also has three categories: own and spouse only (reference group), receiving financial support from children and other relatives, and additional help from government sources only.

Finally, the appraisal social relationship is assessed by three measures. The perceived quality of marital relationship is coded as 1 if currently with spouse present and reporting the relationship as good (from the CLHLS original questionnaire), and 0 otherwise. The perceived quality of relationship with children is coded as 1 if currently having at least one child alive and reporting children being filial (from the additional biomarker sample questionnaire), and 0 otherwise. The perceived quality of neighboring relationship is coded as 1 if reporting having harmonious neighborhood (also from the additional biomarker sample questionnaire), and 0 otherwise. We also created a summary index, the social relationship quality index (SRQI), which sums up the above three variables and we test the three individual measures separately as well as the summary index in the regression analysis.

Control Variables

The control variables include age, sex, residential area (rural vs. urban), household education (no schooling vs. 1 more years schooling), insufficient financial support for daily expenses (yes vs. no), occupation before retirement (farmers vs. others), smoking in the past 5 years (yes vs. no), excessive drinking (having at least 200 g of liquor or 400 g of beer per day vs. not heavy drinker) and regular

exercise (yes vs. no). Besides these demographic and health behavior variables, we also include the current health status indicators, i.e., ADLs and Frailty Index (see Gu et al.(2009) for the details of variable constructions), to account for the possible inverse causality between social relationship and health outcomes. Last but not least, we add two variables to capture the personality of participants which may influence the individual's ability to seek social connections and cope with stress. The first one indicates if the participant has introverted character (yes vs. no) and the second one asks if the participant often gets angry (yes vs. no).

The sample characteristics for the social relationship measures as well as the control variables are presented in table 2.

[Table 2 about here]

Statistical analysis

Ordered logit regressions are applied to examine the associations between independent variables, including social relationship and other control measures, and AL which is grouped into five categories: 0, 1, 2, 3 and 4+. We also considered treating AL as continuous variable and performed linear regression and ANOVA analysis. These two sets of results are largely consistent. Due to the skewness of AL as a continuous variable, we present the results from ordered logit regressions only.

We include each domain of the three social relationship measures individually in models 1-5 and then combine them in models 6-7 to test their separate and collective effects on AL. The first 6 models control for age, sex and residential area only and the last model includes all control variables. Sex differences are examined by testing the interaction terms between sex and the social relationship variables. Only significant interaction terms are maintained in the model and the odds ratio reported in this case are separated by sex. Otherwise the odds ratios are for both sexes combined.

Results

The overall population has a mean AL score of 2.21 (sd. 1.48). Results from preliminary regression analyses of control variables show that being female and living in rural area have on average higher AL scores but the differences are not statistically significant (see Fig.1 for the distribution of AL by sex). The higher AL score among females is likely due to the fact that the average age for females is older than males in the sample. There is no significant age trend associated with AL in the population either, which is consistent with the finding from Crimmins et al. (2003) that AL increases with age but gradually levels off at old age. While socioeconomic status is proved to have strong effects on physiological dysregulation among western populations (Szanton, Gill and Allen 2005), no significant association between the socioeconomic variables and AL is found in this study. Furthermore, neither the health or health behavior related variables nor the characteristics of personality turn out to be strong predictors of AL. Despite of being non-significant, maintaining regular exercise, getting angry less frequently and having non-introverted character correspond to a lower level of system dysregulation. Interestingly, the variables that are consistently and significantly related to AL are all those measuring social relationship. These results are summarized in table 3.

[Figure 1 about here]

Model 1 and model 2 examined the association between the structural support and AL. Model 1 included the 4 individual variables consisted in the social network index while model 2 entered the social network index. Consistently in the two models, living arrangement has a weak association with AL. Compared to living alone, living with children is associated with a lower AL, but this relation is not statistically significant. Surprisingly, living in a nursing home has a stronger and significant correlation with a lower AL. With regard to the individual social integration variables, only current marital status appears significant. Presence of a spouse is significantly associated with a low AL for males but not for females. As indicated by model 2, the social network index has a strong correlation with AL. Men seem to benefit from greater social integration, whereas women who maintain more social connections show more severe system dysregulation.

Model 3 suggests that none of the functional social support measures, such as receiving instrumental help and receiving financial help, is significantly related to AL.

Model 4 and model 5 test the association between the measures of appraisal social support and AL. Model 4 which includes the individual relationship quality measures demonstrates that having good marriage and harmonious neighborhood are weekly associated with a lower AL, whereas having filial children has non-significant impact. However, the social relationship quality index as the sum of the above three variables turns out to be a stronger predictor of the AL in model 5. This may be because including individual measures simultaneously in the model reduces the statistical power of the analysis. It may also suggest that having one type of good quality of social relationship can compensate the absence of another type of good quality relationship.

All these associations are quite robust when combining the three domains of social relationship measures in model 6. This, to some extent, implies that these characteristics of social relationship have additive effects on AL. The presence of other control variables in model 7 does not alter the previously identified associations either and further suggests that the social relationship variables are the most consistent predictors for the cumulative physiological dysregulation among this old Chinese population.

[Table 3 about here]

Discussion

The analyses presented in this study explored the profile of AL, a summary index of biological dysregulation across multiple systems, among a population of Chinese at advanced age. One major surprising finding is that while no socioeconomic and health behavior variables exhibit significant association with AL, as suggested by U.S. based studies, the measures describing one's social environment show strong associations to AL. These results suggest that the hypothesized relationship between social support and multi-system dysregulation based on western populations holds in this old Chinese population in a drastically different culture, and provides additional support to the role biology plays in the process by which social relationship affects health and aging. Specifically, we found that good appraisal social relationship corresponds to a lower AL for both sexes combined, but structural social relationship tends to influence men and women in opposite directions.

Our finding that staying married tends to be beneficial for men but not for women is consistent with early studies (Seeman, et al. 2004b). We further discover that the sex differences in the association between

social connection and AL are not limited to the spousal tie but to the summary index of social integration across several domains. While this confirms the hypothesis that men may enjoy greater health benefits than women from being married (Berkman and Syme 1979, Burg and Seeman 1994, Seeman and McEwen 1996, Taylor 2002), it also suggests a specific detrimental effect of social ties on women's health. In fact, quite of a few previous studies have reported that a high degree of social integration may lead to a high mortality rate for women in selected age groups (Berkman 1985, Orth-Gomer and Johnson 1987, Schoenbach, et al. 1986, Shumaker and Hill 1991). One possible explanation considers the gender differences in the roles of social interactions. Compared to men, women are more likely to be social support providers, the role of which requires strong emotional and physical engagement (Flaherty and Richman 1989, Kessler, McLeod and Wethington 1985). A large social network not only provides greater opportunities for support coupled with more demands and depletion of resources (Shumaker and Hill 1991), but also increases the chances of encountering negative events (e.g. criticism, conflict)(Rook 1984). These detrimental effects associated with being a care provider, thus, result in higher physiological and psychological costs for women (Shumaker and Hill 1991, Shye, et al. 1995). Such effects could be even stronger among Chinese women, given that the cultural norm in China (like that in other Asian countries) places more emphasis on the obligations involved in social interactions and leads to a greater pressure in the role of care giving (Seeman, et al. 2004a). Moreover, women are demonstrated to be more emotionally involved in life events that occur to someone in her social network who is considered important other than their focal members (Kessler and McLeod 1984). This further increases women's vulnerability to undesirable life events of their social contacts (Kessler, et al. 1985, Shye, et al. 1995).

It is also the norm in the Chinese culture to emphasize more on the familial role in social interactions. Therefore, the social relationships oriented toward family ties are expected to be more significantly related to various health outcomes. Nevertheless, except for marital tie, the family related measures do not show stronger associations with AL, if there is any. The early studies based on the older Taiwanese population also failed to identify the importance of family ties (Seeman, et al. 2004a). The reason may be that the connections with family in all aspects are much more prevalent in Chinese society than in the west and thus the sensitivity of this kind of relationship to the dependent variable is low. On the other hand, living in a nursing home and receiving help from non-family members show positive relationship with a lower AL. A few early studies based on the CLHLS data also identified beneficial effects of living in a nursing home on subsequent mortality risk (Sun and Liu 2008), self-reported quality of life (Zhou and Qian 2008) and subjective well-being (Li and Wu 2008). It is hypothesized that nursing homes may provide an environment in which the elderly can share common concerns and avoid potential intergenerational conflicts with children and thus leads to better physiological and psychological outcomes (Zhou and Qian 2008). These results in general suggest the importance of community support for the elderly. However, because the proportions of living in a nursing home and receiving help from non-family members are small in our sample; these relationships are subject to future examinations.

The major limitation of this study is that all the results are based on cross-sectional data and thus no causal inference can be directly made. The relative small sample size may limit the power of statistical analysis. Furthermore, the insignificant relationship between functional social support and AL could be attributed to the fact that the measures we used in the study only reflect whether support is received rather than the amount of actual support received. The latter could be more influential for the health outcomes. Finally, the biological parameters that are used to construct AL and the measures of social relationships are all different from previous studies. Therefore, caution needs to be taken when interpreting these

results as reflecting aging or sociocultural influences. More studies using similar data should be conducted to corroborate the findings.

Table 1: Biomarker and Allostatic Load

Variable (N=499)	Mean (SD)	Cut Point
Biomarkers, Mean (SD)		
Fasting glucose (mg/dl)	98.20 (30.45)	>=105.05
HDL cholesterol (mg/dl)	50.19 (12.36)	<=41.31
Ratio of HDL to total cholesterol	0.33 (0.12)	<=0.27
Triglycerides (mg/dl)	105.31 (69.91)	>=117.70
Body mass index	19.68 (4.94)	>=25.2 or <=15
Systolic blood press (mm Hg)	137.25 (26.98)	>=155
Diastolic blood press (mm Hg)	79.02 (14.79)	>=98 or <=60
Pulse rate	75.58 (10.08)	>=82
C-reactive protein (mg/dl)	46.10 (79.62)	>=41.91
Allostatic Load (AL)	Mean (SD) or %	
Continuous	2.26 (1.52)	
Categorical		
0	11.62	
1	21.84	
2	27.25	
3	19.84	
>=4	19.44	

Table 2: Sample Characteristics: CLHLS (2008)

Variable	Mean or % (N=499)
Demographics and Health Behaviors	
Age, Mean (SD)	93.10 (12.12)
Sex (Female)	72.8%
Residence (Rural)	72.6%
Education (1+ year schooling)	27.5%
Insufficient financial support	23.7%
Occupation (Farmers)	87.4%
Smoked in the past 5 years (Yes)	16.2%
Heavy drink (Yes)	2.0%
Regular exercise (Yes)	18.4%
Getting angry frequently (Yes)	4.8%
Introverted character (Yes)	12.6%
ADLs (impared)	22.0%
Frailty index (0-1), Mean (SD)	0.19 (0.15)
Social Support	
Living Arrangement	
Alone	17.4%
Children with or without others	63.3%
Others without children	17.8%
Nursing home	1.4%
Social Connection	
Stay in marrige	15.0%
Frequent contact with children	91.4%
Frequent contact with siblings	25.5%
Participate in social activities	19.8%
Social network index (0-4)	
0	5.8%
1	54.5%
2	26.3%
3	9.0%
4	4.4%
Instrumental Support	
Nobody	1.8%
Family members	92.6%
None famliy members	5.6%
Financial Support	
Own and spouse only	3.8%
Support from family member	94.6%
Support from government and other sources	1.6%

Table 2 (cont.)

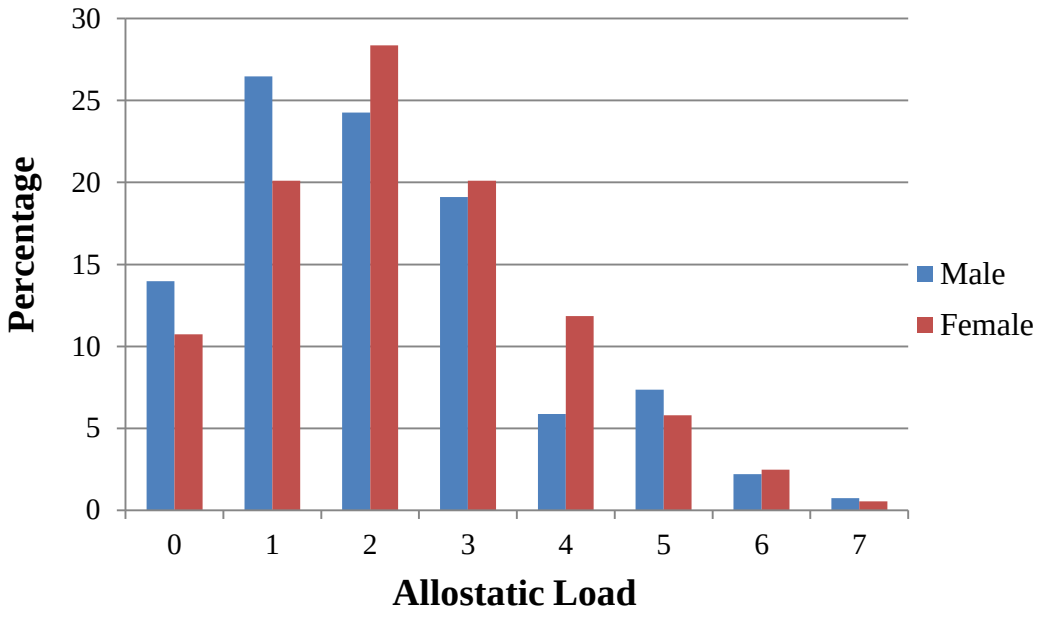
Percieved Quality of Social Relationship	
Good marrage	13.4%
Filial children	80.2%
Harmonious neigboughhood	82.6%
Social relationship quality index (0-3)	
0	8.6%
1	17.2%
2	63.5%
3	10.6%

Table 3: Ordered logit regression models for social relationship indicators and allostatic load

N=499		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Covariates		Odds Ratio	Odds Ratio	Odds Ratio	Odds Ratio	Odds Ratio	Odds Ratio	Odds Ratio
Living Arrangement (ref: alone)								
Children with or without others		0.75	0.76				0.76	0.68
Others relatives without children		1.04	0.96				0.99	0.93
Nursing home		0.22**	0.21**				0.25*	0.25*
Social Connection								
Stay in marriage	Male	0.39**						
	Female	1.44						
Frequent contact with children		1.37						
Frequent contact with siblings		1.12						
Participate in social activities		1.17						
Social network index (0-4)	Male		0.67**				0.69**	0.67**
	Female		1.36**				1.40**	1.38**
Instrumental Support (ref: nobody)								
Family members				0.95			1.21	1.43
Non-famliy members				0.54			0.63	0.71
Financial Support (ref: own and spouse only)								
Family members				1.03			0.71	0.66
Government and other sources				1.88			1.53	1.45
Percieved Quality of Social Relationship								
Good marrage					0.53*			
Filial children					0.97			
Harmonious neigboughhood					0.67*			
Social relationship quality index (0-3)						0.77**	0.78**	0.79**
Control Variables								
Age		0.99	0.98	0.99	0.98	0.99	0.99	0.99
Sex (Female=1)		1.19	0.51*	1.53*	1.37	1.45*	0.50*	0.58
Residence (Rural=1)		1.25	1.30	1.19	1.23	1.26	1.25	1.16
Education (1+ year schooling=1)								1.35
Insufficient financial support (Yes=1)								1.02
Occupation (Farmers=1)								1.13
Smoked in the past 5 years (Yes=1)								0.73
Heavy drink (Yes=1)								0.54
Regular exercise (Yes=1)								0.80
Getting angry frequently (Yes=1)								1.62
Introverted character (Yes=1)								1.48
ADLs (impared=1)								2.48
Frailty index								0.68
Model fit (AIC)		1580.7	1571.7	1585.1	1578.4	1576.6	1573.5	1582.1

* p<0.1, ** p<0.05, *** p<0.01

Figure 1 Distribution of allostatic load by sex



Reference

Antonucci, T. C. (1990). Social Support and Social Relationships. In: Binstock, R. H. and L. K. George (ed.). *Social Support and Social Relationships*. San Diego, CA: Academic Press: 205-27.

Berkman, L. F. (1985). The relationship of social networks and social support to morbidity and mortality. In: Cohen, S. and S. L. Syme (ed.). *The relationship of social networks and social support to morbidity and mortality*. New York: Academic: 241-62.

Berkman, L. F. and Syme, S. L. (1979). Social networks, host resistance, and mortality: a nine-year follow-up study of Alameda County residents. *American Journal of epidemiology* 109(2):186-204.

Broadhead, W. E., Kaplan, B. H., James, S. A., Wagner, E. H., Schoenbach, V. J., Grimson, R., Heyden, S., TIBBLIN, G., and Gehlbach, S. H. (1983). The epidemiologic evidence for a relationship between social support and health. *American Journal of epidemiology* 117(5):521-37.

Burg, M. M. and Seeman, T. E. (1994). Families and health: The negative side of social ties. *Annals of Behavioral Medicine*.

Carstensen, L. L. (1992). Social and emotional patterns in adulthood: support for socioemotional selectivity theory. *Psychology and aging* 7(3):331.

Cassel, J. (2006). The contribution of the social environment to host resistance. *American Journal of epidemiology* 104(2):107-23.

Chen, X. and Silverstein, M. (2000). Intergenerational social support and the psychological well-being of older parents in China. *Research on aging* 22(1):43-65.

Cobb, S. (1976). Presidential Address-1976. Social support as a moderator of life stress. *Psychosomatic medicine* 38(5):300-14.

Cornman, J. C., Goldman, N., Glei, D. A., Weinstein, M., and Chang, M. C. (2003). Social Ties and Perceived Support. *Journal of Aging and Health* 15(4):616-44.

Crimmins, E. M., Johnston, M., Hayward, M., and Seeman, T. (2003). Age differences in allostatic load: an index of physiological dysregulation. *Experimental gerontology* 38(7):731-34.

Crimmins, E. M., Kim, J. K., Alley, D. E., Karlamangla, A., and Seeman, T. (2007). Hispanic paradox in biological risk profiles. *Journal Information* 97(7).

Crimmins, E. M., Kim, J. K., and Seeman, T. E. (2009). Poverty and biological risk: The earlier "aging" of the poor. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* 64(2):286.

Ertel, K. A., Glymour, M. M., and Berkman, L. F. (2008). Effects of social integration on preserving memory function in a nationally representative US elderly population. *Journal Information* 98(7).

Ewart, C. K., Taylor, C. B., Kraemer, H. C., and Agras, W. S. (1991). High blood pressure and marital discord: Not being nasty matters more than being nice. *Health Psychology* 10(3):155.

Flaherty, J. and Richman, J. (1989). Gender differences in the perception and utilization of social support: Theoretical perspectives and an empirical test. *Social Science & Medicine* 28(12):1221-28.

Gerin, W., Pieper, C., Levy, R., and Pickering, T. G. (1992). Social support in social interaction: A moderator of cardiovascular reactivity. *Psychosomatic medicine* 54(3):324-36.

Glei, D. A., Goldman, N., Chuang, Y. L., and Weinstein, M. (2007). Do chronic stressors lead to physiological dysregulation? Testing the theory of allostatic load. *Psychosomatic medicine* 69(8):769-76.

Goldman, N., Turra, C. M., Glei, D. A., Lin, Y. H., and Weinstein, M. (2006a). Physiological dysregulation and changes in health in an older population. *Experimental gerontology* 41(9):862-70.

Goldman, N., Turra, C. M., Glei, D. A., Seplaki, C. L., Lin, Y. H., and Weinstein, M. (2006b). Predicting mortality from clinical and nonclinical biomarkers. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* 61(10):1070-74.

Gruenewald, T. L., Seeman, T. E., Ryff, C. D., Karlamangla, A. S., and Singer, B. H. (2006). Combinations of biomarkers predictive of later life mortality. *Proceedings of the National Academy of Sciences* 103(38):14158-63.

Gu, D., Dupre, M. E., Sautter, J., Zhu, H., Liu, Y., and Yi, Z. (2009). Frailty and mortality among Chinese at advanced ages. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences* 64(2):279.

Juster, R. P., McEwen, B. S., and Lupien, S. J. (2010). Allostatic load biomarkers of chronic stress and impact on health and cognition. *Neuroscience & Biobehavioral Reviews* 35(1):2-16.
Kamarck, T. W., Manuck, S. B., and Jennings, J. R. (1990). Social support reduces cardiovascular reactivity to psychological challenge: A laboratory model. *Psychosomatic medicine* 52(1):42-58.
Kaplan, B. H., Cassel, J. C., and Gore, S. (1977). Social support and health. *Medical care* 15(5):47-58.
Karlamangla, A. S., Singer, B. H., McEwen, B. S., Rowe, J. W., and Seeman, T. E. (2002). Allostatic load as a predictor of functional decline: MacArthur studies of successful aging. *Journal of clinical epidemiology* 55(7):696-710.
Karlamangla, A. S., Singer, B. H., and Seeman, T. E. (2006). Reduction in allostatic load in older adults is associated with lower all-cause mortality risk: MacArthur studies of successful aging. *Psychosomatic medicine* 68(3):500-07.
Kessler, R. C. and McLeod, J. D. (1984). Sex differences in vulnerability to undesirable life events. *American Sociological Review*:620-31.
Kessler, R. C. and McLeod, J. D. (1985). Social support and mental health in community samples.
Kessler, R. C., McLeod, J. D., and Wethington, E. (1985). The costs of caring: A perspective on the relationship between sex and psychological distress. *Social support: Theory, research, and applications*:491-506.
Langelaan, S., Schaufeli, W. B., van Doornen, L. J. P., Bakker, A. B., and van Rhenen, W. (2007). Is burnout related to allostatic load? *International journal of behavioral medicine* 14(4):213-21.
Li, D. and Wu, T. C. Z. (2008). An exploration of the subjective well-being of the Chinese oldest-old. *Healthy Longevity in China*:347-56.
Lindfors, P., Lundberg, O., and Lundberg, U. (2006). Allostatic load and clinical risk as related to sense of coherence in middle-aged women. *Psychosomatic medicine* 68(5):801-07.
Lupien, S. J., Ouellet-Morin, I., Hupbach, A., Tu, M. T., Buss, C., Walker, D., Pruessner, J., and McEwen, B. S. (2006). Beyond the stress concept: Allostatic load--a developmental biological and cognitive perspective.
McEwen, B. S. (1998). Stress, adaptation, and disease: Allostasis and allostatic load. *Annals of the New York Academy of Sciences* 840(1):33-44.
McEwen, B. S. and Stellar, E. (1993). Stress and the individual: mechanisms leading to disease. *Archives of internal medicine* 153(18):2093.
Merkin, S. S., Basurto-Dávila, R., Karlamangla, A., Bird, C. E., Lurie, N., Escarce, J., and Seeman, T. (2009). Neighborhoods and cumulative biological risk profiles by race/ethnicity in a national sample of US adults: NHANES III. *Annals of epidemiology* 19(3):194-201.
Orth-Gomer, K. and Johnson, J. V. (1987). Social network interaction and mortality:: A six year follow-up study of a random sample of the swedish population. *Journal of chronic diseases* 40(10):949-57.
Oxman, T. E. and Hull, J. G. (1997). Social support, depression, and activities of daily living in older heart surgery patients. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences* 52(1):P1.
Penninx, B. W. J. H., Van Tilburg, T., Kriegsman, D. M. W., Deeg, D. J. H., Boeke, A. J. P., and van Eijk, J. T. M. (1997). Effects of social support and personal coping resources on mortality in older age: the Longitudinal Aging Study Amsterdam. *American Journal of epidemiology* 146(6):510-19.
Rook, K. S. (1984). The negative side of social interaction: impact on psychological well-being. *Journal of personality and social psychology* 46(5):1097.
Schoenbach, V. J., Kaplan, B. H., Fredman, L., and Kleinbaum, D. G. (1986). Social ties and mortality in Evans County, Georgia. *American Journal of epidemiology* 123(4):577-91.
Seeman, T., Glei, D., Goldman, N., Weinstein, M., Singer, B., and Lin, Y. H. (2004a). Social relationships and allostatic load in Taiwanese elderly and near elderly. *Social Science & Medicine* 59(11):2245-57.
Seeman, T. E. (1996). Social ties and health: The benefits of social integration. *Annals of epidemiology* 6(5):442-51.

Seeman, T. E., Crimmins, E., Huang, M. H., Singer, B., Bucur, A., Gruenewald, T., Berkman, L. F., and Reuben, D. B. (2004b). Cumulative biological risk and socio-economic differences in mortality: MacArthur studies of successful aging. *Social Science & Medicine* 58(10):1985-97.
Seeman, T. E. and McEwen, B. S. (1996). Impact of social environment characteristics on neuroendocrine regulation. *Psychosomatic medicine* 58(5):459-71.
Seeman, T. E., McEwen, B. S., Rowe, J. W., and Singer, B. H. (2001). Allostatic load as a marker of cumulative biological risk: MacArthur studies of successful aging. *Proceedings of the National Academy of Sciences* 98(8):4770.
Seeman, T. E., Singer, B. H., Rowe, J. W., Horwitz, R. I., and McEwen, B. S. (1997). Price of adaptation--allostatic load and its health consequences: MacArthur studies of successful aging. *Archives of internal medicine* 157(19):2259.
Seeman, T. E., Singer, B. H., Ryff, C. D., Love, G. D., and Levy-Storms, L. (2002). Social relationships, gender, and allostatic load across two age cohorts. *Psychosomatic medicine* 64(3):395-406.
Seplaki, C. L., Goldman, N., Glei, D., and Weinstein, M. (2005). A comparative analysis of measurement approaches for physiological dysregulation in an older population. *Experimental gerontology* 40(5):438-49.
Seplaki, C. L., Goldman, N., Weinstein, M., and Lin, Y. H. (2004). How are biomarkers related to physical and mental well-being? *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* 59(3):B201-B17.
Shumaker, S. A. and Hill, D. R. (1991). Gender differences in social support and physical health. *Health Psychology* 10(2):102.
Shye, D., Mullooly, J. P., Freeborn, D. K., and Pope, C. R. (1995). Gender differences in the relationship between social network support and mortality: a longitudinal study of an elderly cohort. *Social Science & Medicine* 41(7):935-47.
Singer, B. and Ryff, C. D. (1999). Hierarchies of life histories and associated health risks. *Annals of the New York Academy of Sciences* 896(1):96-115.
Sterling, P. and Eyer, J. (1988). Allostasis: a new paradigm to explain arousal pathology. *Handbook of life stress cognition and health*:629-49.
Sun, R. and Liu, Y. (2008). The More Engagement, the Better? A Study of Mortality of the Oldest Old in China. *Healthy Longevity in China*:177-92.
Szanton, S. L., Gill, J. M., and Allen, J. K. (2005). Allostatic load: a mechanism of socioeconomic health disparities? *Biological research for nursing* 7(1):7-15.
Taylor, S. E. (2002). *The tending instinct*: Times Books New York.
Taylor, S. E., Repetti, R. L., and Seeman, T. (1997). Health psychology: what is an unhealthy environment and how does it get under the skin? *Annual review of psychology* 48(1):411-47.
Uchino, B. N., Cacioppo, J. T., and Kiecolt-Glaser, J. K. (1996). The relationship between social support and physiological processes: a review with emphasis on underlying mechanisms and implications for health. *Psychological bulletin* 119(3):488.
Wethington, E. and Kessler, R. C. (1986). Perceived support, received support, and adjustment to stressful life events. *Journal of Health and Social behavior*:78-89.
Zeng, Y. (2008). Introduction to the Chinese Longitudinal Healthy Longevity Survey (CLHLS). *Healthy Longevity in China*:23-38.
Zeng, Y., Cheng, L., Chen, H., Cao, H., Hauser, E. R., Liu, Y., Xiao, Z., Tan, Q., Tian, X. L., and Vaupel, J. W. (2010). Effects of FOXO genotypes on longevity: a biodemographic analysis. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* 65(12):1285.
Zeng, Y., Vaupel, J. W., Zhenyu, X., Chunyuan, Z., and Yuzhi, L. (2001). The healthy longevity survey and the active life expectancy of the oldest old in China. *Population: an English selection*:95-116.
Zhou, M. and Qian, Z. (2008). Social Support and Self-Reported Quality of Life: China's Oldest Old. *Healthy longevity in China: demographic, socioeconomic, and psychological dimensions* 20:357.