# ABSTRACT

Title of Dissertation: THE HEALTH IMPLICATIONS OF STRESS AMONG ASIAN AMERICANS IN THE US AND CHINESE IN CHINA: THE EFFECTS OF PERCEIVED STRESS AND CAREGIVING STRESS ON CARDIOVASCULAR RISK FACTORS

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Prior research suggests that stress plays a role in the etiology and progression of cardiovascular disease (CVD). To lend a more accurate depiction of the associations between stress and CVD risk factors, this dissertation used a comprehensive approach to conceptualizing stress by assessing two dimensions of stress: perceived stress and caregiving stress. The objective of this dissertation was to investigate the associations between multiple dimensions of stress and the risk factors of CVD. This dissertation also explored the potential mechanisms that underlie the relationships between stress and CVD risk factors.

In Paper 1 (Chapter 3), we assessed the associations between perceived stress and hypertension across varying levels of social support and social network among 530 Chinese, Korean and Vietnamese Americans. Results indicated that individuals with high perceived stress were 61% more likely to have hypertension compared to

those with low levels of perceived stress (Odds Ratio (OR): 1.61, 95% Confidence interval (CI): 1.15, 2.46). Social support had a direct beneficial effect on hypertension, irrespective of whether individuals were under stress.

In Paper 2 (Chapter 4), we used five waves of longitudinal data from the China Health and Nutrition Survey to examine the association between parental caregiving and blood pressure among 2,586 Chinese women. We found that parental caregivers were associated with higher systolic (β-coefficient (β) = 1.16; $p \leq 0.01$) and diastolic blood pressure ($\beta = 0.75$; $p \leq 0.01$) compared with non-caregivers across multiple waves.

In Paper 3 (Chapter 5), we investigated the relationship between caregiving trajectory and Metabolic Syndrome (MetS) among 1,636 Chinese women. Three caregiving trajectories were identified by using group-based trajectory analysis. Results showed that 'rising to high-intense' caregivers (OR = 1.90; 95% CI: 0.90, 4.00) and 'stable low-intense' caregivers (OR = 1.56; 95% CI: 1.06, 2.29) were associated with higher risk of MetS compared with non-caregivers.

This dissertation is innovative in its examining the associations of multiple dimensions of stress with CVD risk factors among Asian subgroups. Findings from the proposed study will be used to develop future stress management interventions, and incorporating culturally and linguistically appropriate strategies into community outreach and education to decrease cardiovascular disease risk within the Asian population.

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# Dedication

*To my family and friends, past and present.*

To Hongwei Lu and Zhiying Wei, my parents and my inspiration. Thank you for making countless sacrifices for the family and taking care of my daughter and grandparents.

# Acknowledgements

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# Chapter 1: Introduction

## 1.1 Background and rationale

There is an alarming increase in morbidity and mortality from cardiovascular disease (CVD) among Asians in the U.S. (1, 2). Recent empirical studies have revealed an increase in the prevalence of the risk factors of CVD, such as hypertension, in Asian Americans (3, 4). According to data from the National Health and Nutrition Examination Survey, about one-quarter (25.6%) of Asian Americans aged over 20 years had hypertension during 2011-2012 (5).

Hypertension has been increasingly prevalent in China as well (6). According to national data from the "Survey on the Status of Nutrition and Health of the Chinese People", the prevalence of hypertension was 5.1% in 1959, rising to 7.7% in 1979, 13.6% in 1991, and 18.8% in 2002 (6). A recent study found that 41.9% of the Chinese aged between 35-70 years old had hypertension between 2005 and 2009 (7). Among those hypertensive participants, 41.6% were aware, 34.4% treated, and only 8.2% controlled of hypertension (7).

Prior research suggests that stress in various forms plays a significant role in the etiology and progression of cardiovascular disease. Perceived stress has been reported to be associated with hypertension, although literature show mixed results (8-12). Caregiving are also believed to increase the risk of cardiovascular disease (13-15). Plausible pathophysiological mechanisms linking stress to cardiovascular risk factors include effects through sympathetic nervous system and through inflammatory response (16).

There are several notable research gaps existing in previous literature. First, a substantial number of studies have examined the relationship between traditional modifiable risk factors and

hypertension. However, studies addressing psychosocial aspects of hypertension and related risk factors have been limited. Second, much of the evidence of the association between stress and hypertension derives from cross-sectional studies, making it difficult to rule out the possibility of reverse causation. Third, existing studies mainly focus on a single conceptualization of stress. Few studies examined the effect of multiple forms of stress on hypertension. However, stress is a complex multidimensional construct that is challenging to operationalize. Differences in stress measures across studies may contribute to mixed findings in the literature. A more comprehensive approach to conceptualizing stress could lend a more accurate depiction of associations with health. Fourth, social support and social network are important determinant of health, yet understanding of their contribution to the relationship between stress and hypertension is limited. Many studies have focused on the relationship between hypertension and social support, or stress and hypertension, but few have examined the inter-relationship between stress, social relationship, and hypertension. Fifth, there is a lack of studies among Asian Americans. Asian Americans are one of the fastest growing racial/ethnic group in the United States (17). Research have suggested that high proportion of Asian Americans have CVD risk factors. Early studies investigating CVD risk factors among Asian Americans tended to focus on aggregated AAPIs (18, 19). However, these populations are extraordinarily diverse with respect to country of birth, socioeconomic status, time since immigration, language spoken, religion and other characteristics that may affect heath (20). Lastly, little research exists that attempts to understand the impact of parental caregiving on CVD risk factors among Chinese in China. Nowadays, the demographic changes to China's age structure are astonishing. The proportion of the population aged 65 and older in China increased by 216% from 1953 to 2010 (21). The increased life expectancy among older Chinese has also introduced new burdens on the family. Adult children

shoulder greater responsibility in caring for their aging parents with chronic illness compared to the past. However, it is unclear how Chinese balance the competing demands and structural constraints of family and work while maintain their physical health in the process of fulfilling their filial responsibilities (22). Therefore, it is important to explore the health consequences of caregiving among Chinese.

The goal of this dissertation is to explore the associations between multiple dimensions of chronic stress and the risk factors of CVD as well as investigate the potential mechanisms that underlie the relationships between stress and CVD risk factors among Asian.

### 1.1.1 Literature Review: Chapter 3 (Paper 1)

Hypertension is a major risk factor for the development of cardiovascular disease (CVD), and a main cause of morbidity and mortality worldwide (23). About 1 of every 3 (29%) American adults have high blood pressure, and only half (52%) of people with hypertension have their condition under control (23). Complications from hypertension including heart attack and stroke are leading causes of death and disability (24, 25). Hypertension costs the nation $46 billion each year, which includes the cost of healthcare services, medications to treat high blood pressure, and missed days of work (26).

Asian Americans are one of the fastest growing racial/ethnic groups in the United States (27). As a rapidly growing minority population in the U.S., Asian American subgroups have been found to have high prevalence of hypertension. According to data from the National Health and Nutrition Examination Survey, about one-quarter (25.6%) of Asian Americans aged over 20 years had hypertension during 2011-2012 (5). There is a lack of studies that observe the prevalence of hypertension in Asian American subgroups, however, local data reflects the

hypertension prevalence was different across various Asian American subgroups. In a cross-sectional study conducted among four Asian groups in southeastern Michigan, the prevalence of hypertension was 29.5% in Chinese, 30.0% in Filipino, 21.9% in Hmong, and 9.6% in Vietnamese Americans (28). Kim et al found that the overall prevalence of hypertension in Korean Americans (32%) living in Maryland was much higher than that in their white counterparts (24%) and in their counterparts in Korea (22%) (29). According to the 2003-2010 U.S. death records, Asian subgroups, including Chinese, Korean, Vietnamese, Japanese, Filipino and Asian Indians, had a higher proportion of mortality attributable to hypertension compared to non-Hispanic whites (30).

The modifiable risk factors of hypertension include unhealthy diet, physical inactivity, obesity, too much alcohol, tobacco use and certain socioeconomic factors (31). Prior studies have shown that modifiable risk factors of hypertension significantly differed among Asian subgroups (32-34). Ancheta et al investigated modifiable cardiovascular risk factor profiles as a function of Asian ethnicity by using the sample of Asian American women in northeast Florida (34). The results showed that Filipino American women had a higher prevalence of obesity compared to all other Asian American women subgroups, while the Chinese women had a lower prevalence of obesity and the least number of risk factors. Regarding to the socioeconomic status, the Vietnamese participants and Cambodian groups had more participants with less education than the Chinese and Filipino groups. In general, Filipino participants (41%) had $\geq 4$ risk factors compared to 21% Cambodian, 13% Vietnamese and 10% Chinese (34). Heterogeneity in hypertension risk factors may result from cultural and socioeconomic differences and health care disparities (35). The disparities may come from the lack of health insurance, limited access to healthcare, and lack of culturally–sensitive disease prevention strategies etc. (36). Modifiable

hypertension risk factors significantly differed among Asian subgroups supporting the conclusion that Asian American cannot be categorized as one group.

**Perceived stress**. Stress can influence the pathogenesis of physical disease by exerting direct effects on biological processes or indirect effects on behavioral patterns (37). Early studies have shown that the primary biological pathway linking emotions to disease is hormone (38). Excessive discharge of certain hormones have been implicated in the pathogenesis of cardiovascular disease and diseases involving the immune system including cancer, infectious diseases, and autoimmune diseases (38). Behavioral changes may also occur as adaptations to stressors. People exposed to stressors or perceived themselves as under stress tend to engage in poor health behaviors, such as smoke more, drink more alcohol, exercise less, eat unhealthy, and sleep less (39, 40).

There are three distinctive perspectives to assess the role of stress in the risk of disease (41). The biological perspective focuses on activation of specific physiological systems that have been shown to be modulated by both psychologically and physically demanding conditions. The environmental perspective focuses on assessment of environmental events or experiences that are objectively associated with substantial adaptive demands. The psychological perspective focuses on individuals' subjective evaluation of their abilities to cope with the demands posed by specific events or experiences.

The psychological stress perspective places emphasis on the organism's perception and evaluation of the potential harm posed by objective environmental experiences (41). Perceived stress addresses how an individual appraises the stress in his or her own environment (41). While environmental measures of stress are objective and easier to measure, they cannot address the issue that stressful events elicit varying responses from individuals. Personality factors such as a

strong commitment to self, a sense of meaningfulness and an internal locus of control have been identified as factors that predict illness onset due to stressful life events (42).

Research on appraised stress originated in 1966 with Richard Lazarus's 'transactional model of stress' (43). Lazarus argued that an appraisal of a stimulus as threatening or benign, occurs between stimulus presentation and stress reaction (43). The central concept of appraised stress is that a given event or situation is perceived in separate ways by different people, and the perceptions are the main determinants of effects on behaviors and on health status. Over the times, Richard Lazarus and Sheldon Cohen contributed most significantly to the current understanding of appraised stress (37, 43-45). Many questionnaires have been developed to measure appraised stress including the Ways of Coping Checklist published in 1980 by Lazarus (46), the Hassles and Uplifts Scales published in 1981 by Lazarus (47), and the Perceived Stress Scale (PSS) published in 1983 by Cohen (37).

Immigration is considered to be intensely stressful (48, 49). Studies have shown that most common difficulties which Chinese immigrants experienced include language barriers, adjusting to an unfamiliar environment, differences between Chinese and American cultures, and problems relating to children who are often more acculturated than their parents (49). Chinese immigrants may also struggle to find meaningful work, experience problems communicating with mainstream society, and have issues negotiating the cultural conflicts emerging within their hometown (49). Prior evidence have revealed various stressful immigrant experiences contributed to mental health-related problems among Korean immigrants, such as family violence, alcoholism, juvenile delinquency, alienation of the elderly, marital and inter-generational conflicts, and other mental disorders (50, 51). Same as Chinese and Korean Americans, studies have indicated that Vietnamese immigrants often experience great stress (52,

53). In addition to facing the usual physiological and emotional upheavals, Vietnamese immigrants must learn to negotiate between various multicultural environments, and must deal with additional challenges such as racial discrimination, language barriers, and adaptation as an immigrant (53). It is common that immigrants change their lifestyle to cope with the increased stress (54). These lifestyle changes, such as diet, have been found to increase vulnerability to developing cardiovascular disease (54, 55).

Perceived stress has been consistently reported to be associated with increased cardiovascular risk. A meta-analytic review of the association of perceived stress and incident CHD showed that high perceived stress was associated with a risk ratio of 1.28 for incident CHD by combining results from 6 large prospective observational cohort studies (56). The mechanisms linking perceived stress to adverse cardiovascular outcome include increased activity of hypothalamic pituitary axis (57), increase sympathetic outflow (58) or altered behaviors causing insulin resistance and central obesity (59).

**The role of social support and social isolation**. The importance of social relationship in the maintenance of health and well-being has drawn the attention of researchers across many behavioral and medical disciplines. Dating back to Durkheim's classical work linking social context with the risk for suicide, a large body of literature has shown the engagement with social life through network ties can protect us against illness, enhance coping with stress and illness (60). Social relationship encompasses many different conceptualizations, such as social integration, social networks, and social support. It is difficult to include all aspects of social relations in one empirical study. Therefore, this study focuses on the lack of social integration (social isolation) and social support because they were most frequently examined in previous research and can contribute to the understanding of social relationship and health.

Social support refers to the various types of support (i.e., assistance/help) that people receive from others and is generally classified into four major categories: instrumental, informational, emotional, and appraisal assistance (61). Emotional support refers to the things that individuals offer to make others feel loved and cared for, that bolster their sense of self-worth; such support frequently takes the form of non-tangible types of assistance. By contrast, instrumental support refers to the distinct types of tangible help that individuals may provide. Informational support represents a third type of social support and refers to the help that individuals may offer through the provision of information. A large body of evidence shows that social support improves physical and mental health (62-67). For example, obesity and social support may be closely interrelated. Studies have shown that obese persons had significantly lower levels of support in their family and peer relationships (68, 69) and those who are obese were highly stigmatized and socially isolated (70).

Social support has been demonstrated to be associated with a reduction in stress (71). Specifically, healthy interpersonal relationships may protect one from the potentially pathogenic effects of a stressful event. Prior literature has also shown that social support and perceived stress are associated with health promoting behaviors (66, 72, 73). Social support can help individuals manage their weight and may help buffer against the distress associated with weight-based perceived stress and health problems (60, 74).

Abundant evidence suggests that low social support is a risk factor for the development of coronary heart disease (CHD) in healthy individuals, and low social support also worsens the prognosis of patients with established CHD (75-77). Barth et al. conducted a systematic review and meta-analysis study, and they found that there is an impact of low functional social support on the prevalence of CHD in etiologic studies (RR, range, 1.00-2.23) (75). The results also show

that lower functional support led to higher cardiac and all-cause mortality (pooled RR, range, 1.59-1.71) (75).

Social integration is the extent to which an individual participates in a broad range of social relationships (e.g. marital status, number of close friends and relatives, religious or other group affiliations) (78). Issues of gender, marital status, family position and context, and socioeconomic status have been shown to affect social isolation (79). Change in socioeconomic status, such as employment status, has been correlated with social isolation. In general, women have more extensive and varied social networks than do men. However, if one spouse is chronically ill, married couples spend more time together and less time with networks and activities outside the home (80). In addition, language differences and traditional living style may impede social adaptation. Immigrants are less able to engage in support networks, given their long working hours, low-paying jobs, lack of health insurance, and change in family life-styles and living arrangement (79). Prior research by Logan et al. found that Chinese and Korean immigrants worked significantly more hours than those who worked in the mainstream in New York (81). The difference in hours, however, can be considered as an advantage for immigrants because they are able to work longer hours to make up for lower pay. An important fact affecting the relationship between social integration and health among immigrants is the size of the immigrant community (82). As suggested by Murphy et al., the risk of mental health problems increased by reducing size of the immigrant group (83). One explanation for this could be that the smaller groups failed to provide the same social and cultural support as the bigger groups, leaving the immigrants more vulnerable for cultural pressure from the host community (82).

The health impact of social isolation has been shown in numerous empirical studies of diverse populations. An increasing body of research has found that social isolation is

significantly associated with specific disease etiology such as CHD (84, 85), depression (86), memory loss (87), as well as decreased general health status in older adults (88), and overall mortality (89, 90). A study shows that patients with CHD or other chronic conditions had significantly worse prognosis if they experienced social isolation (84). Furthermore, results from the meta-analysis by Steptoe et al. show a 1.5 fold (95% CI 1.2-1.9) increased risk of coronary heart disease among adults experiencing social isolation (91).

Modification of health behaviors may further contribute to the health effects of social isolation. Socially isolated individuals, compared to those more socially engaged, are less likely to have access to multiple sources of information to foster healthy behaviors, gain access to health care, or minimize stressful or hazardous situations (86). Social engagement can promote or constrain various socially transmissible behaviors among network members such as tobacco and alcohol assumption, diet, weight control, and exercise (92, 93).

In this study, social isolation was assessed by a composite measure of four types of social connections: marital status, intimate contacts (relatives and close friends), church membership, and membership in other community organizations. Studies generally have found that married adults were less likely to experience health problems and less likely to engage in risky health behaviors compared with unmarried adults, whether the unmarried were never married, divorced, separated, or widowed (93-97). There are two major theories explaining why married adults have better health status: marriage protection and marriage selection (94). Marriage protection is the theory that married adults have more advantages in terms of economic resources, social and psychological support, and support for healthy lifestyles. Marital selection is the theory that healthier people get married and stay married, whereas less healthy people do not marry or are more likely to become separated, divorced, or widowed (94).

Empirical evidence has shown the relationship between family and friends connections and health outcomes. Family support offers a secure base through-out one's life, which provides important sources of confidence and reduces stress (98). A study conducted by Torres et al. examined the role of self-efficacy, stress, social integration, and family support in health among 179 Latino college students (99). The results show that family support was associated with physical and psychological health among the Latino college students. Fraure-Smith et al. found that patients who had no close friends were more likely to be depressed than those with close friends (100).

Prior literature has suggested that religious commitment plays a role in enhancing illness prevention, coping with illness, and recovery (101-103). In a systematic review of research conducted by Craigie et al, they found that 81% of the relevant studies showed a positive association between religious commitment and health status; while only 15% of studies found a neutral relationship between religious commitment and health status and 4% of studies found a negative association (104). The positive associations have been found among study populations with diverse characteristics and with different experimental methods. The mechanism by which religious involvement exerts an effect on health outcome could be attendance at religious services may influence attendees' adherence to the norms of religious groups that discourage unhealthy behaviors.

Individuals with fewer organizational participation may also be less able than others to buffer the physiological and health impacts of social life challenges (92). It has been suggested that socially isolated individuals are deprived of opportunities for emotional support and instrumental coping assistance, and the deficiencies in these coping resources may in turn increase physiological arousal and lead to a variety of mental disorders such as anxiety and

depression through compromised physiological reactivity to stressor and impaired immune function (105).

**Perceived stress and hypertension**. Based on evidence from previous literature, it shows that perceived stress is positively associated with blood pressure in general (Table 1.1). Among the 13 studies investigated the relationship between the perceived stress and blood pressure, 7 of them used validated perceived stress measures, and 6 used non-validated measures. Overall, more studies using validated measures of perceived stress reported positive association between perceived stress and blood pressure (4 out of 7). Among studies that used non-validated measures, 4 studies reported a positive association, and 2 studies reported no association. However, the lack of a validated perceived stress questionnaire makes generalizing and comparing results very challenging.

There are few quantitative studies that investigated the association between perceived stress and hypertension among Asian Americans. Logan et al. explored the relationship between psychological stress and arterial stiffness among Korean Americans (106). The study used a convenience sample of 102 Korean Americans aged between 21 to 60 years from North Carolina. Perceived stress was measured by 10-item PSS. The results revealed that SBP and DBP were not significantly related to perceived stress. This study had several potential limitations. The sample was relatively small, homogeneous, and recruited from a limited geographical region. All participants were recruited from churches, and their level of stress may be different from other Korean Americans who are not affiliated with religious organizations. In addition, people may be reluctant to share their personal information with researchers in Korean culture.

Table 1.1 Summary of studies on the relationship between perceived stress and Hypertension

| **Author (year)** | **Study type** | **Population** | **Stress assessment tool** | **Outcome assessment** | **Covariates** | **Major findings** |
|---|---|---|---|---|---|---|
| Gallo 2014 | Cross sectional | 5513 Hispanic/Latino | 10 item PSS | Objective; Hypertension status; | Age, sex, Hispanic/Latino background, nativity/immigration, language of interview, income, and education, BMI, physical activity, smoking, and alcohol consumption. | No association |
| Wiernik 2013 | Cross sectional | 122 816 French adults aged 30 years and older | 4 item PSS | Objective; Hypertension status; measured 3 times; the mean of the latter 2 measures | Age, sex, living status, smoking status, alcohol intake and regular physical activity | Positive association OR 1.06 [1.03-1.09] |
| Gebreab 2012 | Cross sectional | 5301 African American between the ages of 21 and 94 | 8 item the Global Perceived Stress Scale (GPSS) | Objective; Hypertension status; | Age, income, smoking, physical activity, diet. | Positive association OR 1.04 [1.01-1.08] |
| Logan 2012 | Cross sectional | 102 Korean Americans aged 21–60 years | 10 item PSS | Objective; Systolic, diastolic, and mean arterial blood pressure; measured twice; the mean of the two measures | none | No association |
| Huang 2011 | Cross sectional | 307 Chinese aged between 18 and 70 years | 14 item-PSS | Objective; Mean SBP and DBP; 24h ambulatory blood pressure monitoring | Age, sex, hypertension duration, presence of diabetes, dyslipidemia, smoking status, BMI, cholesterol, low-density lipoprotein-cholesterol etc. | Positive association Systolic BP: r = -0.43, P < 0.05; Diastolic BP: r = -0.40, P <0.01 |
| Wright 2011 | Longitudinal follow-up (6 | 170 police officer and non-police | 14 item-PSS | Objective; Mean SBP and DBP; | age | Positive association Standardized |

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| | years) | officer | | measured 3 times; the mean of the three measures | | β:<br>DBP: 0.16 (p = 0.04)<br>SBP: 0.11 (p = 0.14) |
| Ginty 2011 | Cross sectional | 100 undergraduates | PSS | Objective; Mean arterial pressure; measured several times | none | No association |
| Moyo 2010 | Cross sectional | 64 full-time school teachers | Non-validated PSS, PS evaluated using Likert four-point scale | Objective; SBP and DBP; measured 3 times | none | No association |
| Rod 2009 | Longitudinal follow-up (10 years) | 11966 Danish adults; Caucasians | Non-validated PSS 2 item Q that addressed level of PS and frequency of PS | Self-reported use of antihypertensive medication; subjective | sex, age, education, marital status | Participants with high stress were more likely to use anti-hypertensive medication; OR 1.39 [1.05-1.84] |
| Koizumi 2009 | Cross sectional | 806 Japanese in rural Japan | Non-validated PSS 1 item Q on PS, measured as extremely high, high, medium, or low | Objective; SBP and DBP | Age, BMI, heart disease, ECG, smoking, creatinine, and hemoglobin | No association |
| Kario 2002 | Cross sectional | 134 women | Non-validated PSS 1 item Q on PS, 0= low stress to 10 = high stress | Objective; ambulatory BP level | none | Work stress may increase ambulatory BP levels throughout the day, while home stress may induce additional sympathetic activation at home. |
| James 2001 | Cross sectional | 91 women (38.5% White; 31.9% Black; 17.6% Hispanic; | Non-validated PSS 1 item Q on PS, 0= low stress to 10 = high stress | Objective; SBP and DBP; measured 5 times; the mean of the three | none | Work stressed women had significantly higher systolic pressure (P<0.01) than home stressed |

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| | | 12.1% Asian) | | measures | | women |

**Social support and Hypertension.** Social support may directly affect health or act as a buffer against stressors that are deleterious of health (89, 107). Numerous studies have found that greater levels of social support are associated with lower blood pressure or lower incidence of hypertension (table 1.2) (108-112). However, few studies examined the relationship between social support and hypertension among Asian Americans. Lee et al. investigated the impact of structural and functional support on cardiovascular reaction following immigrant stress recall provocation among first-generation Chinese immigrants (108). 150 Chinese immigrants were recruited in New York Chinatown area. Participants recalled a recent post-immigration stress-provoking situation. Blood pressures were taken during adaptation, stressor task, and recovery period. They found that a higher level of perceived emotional support was associated with an increase of SBP by 0.34 mmHg reactivity to stress ($p < 0.02$).

Table 1.2 Summary of studies on relationship between social support and Hypertension

| **Author (year)** | **Study type** | **Population** | **Social support measure** | **Outcome assessment** | **Covariates** | **Major findings** |
|---|---|---|---|---|---|---|
| Clark 2003 | Cross section | 64 black college volunteers | 6-item Sarason Social Support Scale | Objective; SBP and DBP | age, socioeconomic status, family history of cardiovascular disease and hypertension, caffeine and alcohol intake, recreational drug use, and use of birth control medication, BMI | No significant main effect between social support and BP. High social support was related to less marked blood pressure changes under conditions of low perceived racism; high social support was associated with exaggerated blood pressure changes under conditions of high perceived racism |
| Tomaka 2006 | Cross section | 755 southern New Mexico seniors | Non-validated questions about | Subjective; hypertension status | Age | Belonging support negatively associated with hypertension |

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| | | | family and belonging social support | | | |
| Rodriguez 2008 | Cross section | 81 non-Hispanic black | The CARDIA Study Social Support Scale | Objective; Nondipping: defined as a decrease of <10% in the ratio between average awake and average asleep systolic BP | Age; gender; 24-hou systolic BP | Social support was inversely associated with nondipping (OR = 0.27, P = 0.04) |
| Bell 2010 | Cross sectional | 5593 non-Hispanic black, non-Hispanic white, and Mexican American adults | Non-validated questions about emotional support, financial support, and marital status | Objective; hypertension status; calculated average BP, excluding the first measurement | Age, race/ethnicity, gender, income, education, insurance, general health status, diabetes, obese, physical inactivity | none |
| Lee 2012 | Cross sectional | 59 Chinese immigrants | Interpersonal Support Evaluation List | Objective; SBP and DBP | None | None |
| Lee 2015 | Cross sectional | 150 Chinese immigrants | Interpersonal Support Evaluation List | Objective; SBP and DBP; measured 4 times | Age, waist circumferences, gender, history of hypertension | A higher level of perceived emotional support was associated with an increase in SBP reactivity to stress ($\beta$ = 0.34, $p < 0.02$) |

**Social isolation and hypertension.** Several studies have shown that a fewer social network is associated with higher blood pressure (BP) levels (table 1.3) (15, 113-116). Shankar et al. examined the impact of social isolation on hypertension using data from the English Longitudinal Study of Aging (ELSA) (116). The sample included 7666 participants aged 50 years or over living in England. Social isolation index was computed incorporating marital status; frequency of contact with friends, family, and children; and participation in social activities. The results showed that increases in social isolation were associated with small,

significant increases in both systolic and diastolic blood pressure (SBP: β = 0.40, 95% CI, 0.07 - 0.74; DBP: β = 0.31, 95% CI, 0.11 - 0.51; mmHg).

Another study investigated the association between a person's social network and hypertension risk in older adults in Spain (114). This cross-sectional study included 3483 subjects who representative of the non-institutionalized Spanish population aged 60 years or more. The social network was evaluated by questions relating to marital status, cohabitation status, visits by relatives apart from those with whom they lived, and the frequency of contacts with friends or neighbors. The study found that the hypertension risk in married individuals and those living with others was less than in those who were unmarried (OR = 0.79; 95% CI, 0.61 – 0.94) or who lived alone (OR = 0.75; 95% CI, 0.61 – 0.93). Men who saw their friends frequently were more likely to be aware of hypertension (OR = 0.75; 95% CI, 0.61 – 0.93).

Table 1.3 Summary of studies on relationship between social isolation and Hypertension

| **Author (year)** | **Study type** | **Population** | **Social isolation measure** | **Outcome assessment** | **Covariates** | **Major findings** |
|---|---|---|---|---|---|---|
| Gump 2001 | Cross sectional | 120 healthy adult: African Americans (N = 60); White (N = 60) | Social interactions four items from Diary of ambulatory behavioral states | Objective; SBP and DBP; 6 days' ambulatory blood pressure monitor | Physical activity, posture, temperature comfort, alcohol consumption, caffeine, meal consumption | SBP and DBP was significantly lower during social interactions with one's partner ($p < 0.01$) |
| Redondo-Sendino 2005 | Cross sectional | 3483 Spanish population aged 60 years or more | Non-validated questions about marital status, cohabitation status, visits by relatives apart from those with whom they lived, and frequency of contacts with friends or neighbors | Objective; hypertension status; measured 6 times; Awareness of hypertension; subjective | Age, education, physical activity, BMI, smoking, alcohol, and frequency of medical visits | In older adults, low level of social integration increased the risk of hypertension |
| Grant 2009 | Cross sectional | 10,308 London-based civil | Social isolation index created from adapted | Objective; SBP and DBP; measured 3 | none | Social isolation was associated with slower post |

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| | | servants | version of the Close Persons Questionnaire | times; mean of the 3 measures | | task recovery of systolic blood pressure. ($p = 0.049$) |
| Troxel 2010 | Cross sectional | 224 African American | Social Network Index | Objective; The average ratio of night/day mean arterial pressure (MAP) across the 48h assessment period; ambulatory blood pressure | Age, sex, education, ethnicity, BMI, smoking status, alcohol use, general health | Less socially integrated ($\beta = -0.26$, $P<0.05$) and those with fewer daily contacts ($\beta = -0.34$, $P<0.01$) had higher night/day MAP ratios |
| Shankar 2011 | Cross sectional | 7666 participants in England | Non-validated social isolation index | Objective; SBP and DBP; measured three times; the mean of the last two measures | Age, gender, limiting long-standing illness, depression, and marital status-adjusted health | Increases in social isolation were associated with significant increases in both SBP and DBP; SBP: $\beta = 0.40$ [0.07 - 0.74]; DBP: $\beta = 0.31$ [0.11 - 0.51] |

**The buffering effect of social support and social integration**. Prior studies have shown that high level of social support and social integration act as a buffer for the adverse impact of stress on cardiovascular functions (117, 118). The potential mechanism that social support may buffer the effects of immigration stress on health could be that social support may facilitate immigrants' adaptation to the host society (119). Research show that emotional and instrumental support from family and friends is important to immigrants' adaptation and acculturation (120). Lee et al. examined the relationship between acculturative stress and mental health symptoms and the role of social support among Korean international students (N = 74) living in the Pittsburgh area (120). They found that social support buffered the effect of stress on mental symptoms. Among students with high levels of social support, the symptom score increased by 0.47 as the acculturative stress increased by one level ($\beta = 0.47$, $p = 0.04$); while among students

reporting low levels of social support, the symptom score increased by 0.67 as the acculturative stress increased by one ($\beta = 0.67$, $p < 0.01$).

### 1.1.2 Literature Review: Chapter 4-5 (Paper 2-3)

**Hypertension in China.** Cardiovascular disease (CVD) is the first cause of death worldwide and in China (121). Hypertension is one of the most important risk factors of CVD, accounting for about 45% of CVD morbidity and mortality (6). Evidence has shown that hypertension is increasingly prevalent in China (6). According to national data from the "Survey on the Status of Nutrition and Health of the Chinese People", the prevalence of hypertension was 5.1% in 1959, rising to 7.7% in 1979, 13.6% in 1991, and 18.8% in 2002 (6). A recent study found that 41.9% of the Chinese aged between 35-70 years old had hypertension between 2005 and 2009 (7).

Regional differences in the prevalence of hypertension within China have been observed in prior literature (6, 122). Hypertension is less common in southern China compared to northern China, where diet and exercise pattern are substantially different (122). In addition, the prevalence of hypertension is lower in rural than urban areas, which has been suggested to be related to higher levels of physical activity and lower levels of overweight (123).

The economic transition in China has provoked remarkable changes in lifestyle involving overconsumption of dietary fat and reduction in physical activity, which have contributed to the increase in body weight (124). In the last two decades, the rate of obesity has tripled in developing countries (125). Considering the rapid increased prevalence of obesity over the recent years, the obesity-related illnesses including hypertension, maybe worsening at a dramatic rate in China (126).

**Metabolic syndrome in China**. Metabolic syndrome (MetS) is considered a worldwide epidemic (127). MetS is characterized by a cluster of metabolic risk factors including hyperglycemia/insulin resistance, obesity, elevated blood pressure and dyslipidemia (127-129). According to the National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III) definition, MetS is present if three or more of the following five criteria are met: waist circumference over 40 inches (men) or 35 inches (women), blood pressure over 130/85 mmHg, fasting triglyceride (TG) level over 150 mg/dl, fasting high-density lipoprotein (HDL) cholesterol level less than 40 mg/dl (men) or 50 mg/dl (women) and fasting blood sugar over 100 mg/dl (130). MetS is important, because: 1) it identifies patients who are at high risk of developing atherosclerotic cardiovascular disease and type 2 diabetes (T2D); 2) by considering the relationships between the components of metabolic syndrome, we may be able to better understand the pathophysiology that links them with each other and with the increased risk of CVD; 3) it facilitates epidemiological and clinical studies of pharmacological, lifestyle and preventive treatment approaches (129).

China is currently experiencing rapid economic, social and cultural changes. The accelerated pace of nutrition transition and great changes in people's lifestyle may contribute to increased prevalence of MetS (128). The MetS was defined based upon the updated NCEP-ATPIII for Asian Americans (131) as presenting 3 or more of the following components: 1) waist circumference $\geq$ 90 cm for men $\geq$ 80 cm for women; 2) triglycerides $\geq$ 1.7 mmol/L; 3) HDL < 1.03 mmol/L for men or <1.30 mmol/L for women; 4) blood pressure $\geq$ 130/85 mmHg or current use of antihypertensive medication; and 5) fasting glucose $\geq$ 5.6 mmol/L. According to the China Health and Nutrition Survey in 2009, the age-standardized prevalence of MetS was 21.3% based on the definition of updated NCEP ATPIII (128). High blood pressure was the most

frequent component in men and high waist circumference was the most frequent component in women. MetS was associated with older age, being a woman, living in urban region and with central obesity (128). The study found that compared to men, women was 40% more likely to have MetS (OR = 1.37, 95% CI: 1.16 – 1.61) (128). The great increase in prevalence of MetS in women older than 60 years might be due to their postmenopausal status which is associated with increase of central obesity (132)

**Caregiving**. Providing care to aging family members is an increasing phenomenon in our society. In the U.S., about 42.1 million family caregivers provided care to an adult with limitations in daily activities at any given point in time, and about 61.6 million provided care at some time during the year (133). Research shows that the average U.S. caregiver is a 49 year old woman who works outside the home and spends nearly 20 hours per week providing unpaid care to her mother nearly five years (133). Almost two-thirds of family caregivers are female (65%). More than eight in ten are caring for a relative or friend age 50 or older (133). The average out-of-pocket spending for caregivers who were caring for someone who was age 50 or older was $5,531 in 2007 (133). About 37% of caregivers reduced their work hours or quit their job in 2007 (134). A recent analysis estimates that the lifetime income-related losses sustained by family caregivers who leave the workforce to care for a parent are about $283,716 for men to $324,044 for women (133).

**Caregiving in China.** Caring for older people is viewed as a family's responsibility and is reinforced by law in China. In 1996, a law was implemented to ensure the economic and social rights of the older people. The law emphasized the role of adult children in providing physical care and financial assistance to the elderly. Traditionally, Chinese are influenced by Confucianism, which promotes the belief of filial piety (135). In addition, Chinese endorse

collectivist values that encourage individuals to make sacrifices to satisfy the group achievement (135). The values of Confucianism and collectivism impose Chinese the duty of care of older people on family members. The proportion of adult children providing caregiving on a daily basis is higher in China (57.1%) compared to those in western countries (33.3%) (136, 137).

**Caregiving stress and Health**. Caregiving is considered as a type of chronic stress, because caregivers consistently have higher levels of self-reported stress and stress-related biomarkers than noncaregivers (138-140). In addition, perceived stress, biomarkers, and physical symptoms are worse in persons engaged in more stressful caregiving situations, such as caregiving for more years (141).

Studies of caregiving and health decline have mixed results (142-144). There are long-term positive effects of caregiving on the caregivers. Evidence has shown that caregiving can bring some positive outcomes to family caregivers, include a sense of satisfaction for a variety of reasons, such as observing improvements in the care recipient, fulfilling an obligation, or caring for a loved one (145); provision of a heightened sense of purpose and meaning (146); and provision of an opportunity for adult children to frequently and intimately intergenerational bonds (147). The extent of the caregiver involvement in activities of daily living (ADLs) such as bathing, clothing, and feeding or caregiver's deficits in ADLs has been found to be related to positive reactions or caregiver rewards (148, 149).

There are also negative effects of caregiving on the caregivers (150). Prior study explored the relationship between physical care and satisfaction among middle-aged daughters caring for physically impaired mothers in late life, and found that the level of satisfaction decreased as the amount of physical care increased. Existing research consistently shows that adults who provide care exhibit greater levels of burden, anxiety, depression, and poor self-rated health than adults

who are not caregivers (151-155). Liu et al examined the impact of parental caregiving on self-rated health among Chinese women. They found that caregivers had consistently worse self-rated health status than non-caregiver (22).

The effect of caregiving on health can be direct. It is well established that caregivers consistently report higher levels of stress, strain, and depression and lower levels of subjective well-being and quality of life than non-caregivers (156-158). Caregivers often provide ADLs and instrumental activities of daily living (IADL) such as money management and transportation. Pearlin and colleagues' (1990) influential work suggests that ADL and IADL responsibilities are among the most prevalent and stressful experiences of caregiving (159). According to the statistics from National Alliance for Caregiving and AARP, caregivers reported having difficulty finding the time for one's self (35%), managing emotional and physical stress (29%), and balancing work and family responsibility (29%) (160). Caregivers reported they did not go to the doctor because they put their family's needs first (67% said that is a major reason), or they put the care recipient's needs over their own (57%). More than half (51%) said they did not have time to take care of themselves and almost half (49%) said they were too tired to do so (160).

Despite several studies on psychological outcomes, the evidence is limited regarding to the association between caregiving and physical health. Regarding subjective health rating, the key findings from National Alliance for Caregiving and American Association of Retired Persons (AARP) show that almost three in four caregivers said being a caregiver had no effect on their health. And those reported caregiving had made their health worse tended to be lower income, women, age 50+, provide higher levels of care, and live with the person they provide care for (159). 25% of caregivers described their health as excellent, 30% indicated their health is very good, and 28% mentioned their health is good. About 17% considered their health as fair

or poor, and this number is higher than general U.S. population (one in ten considered their health is fair or poor) (159). In a meta-analysis study conducted by Vitaliano and colleagues, results also show that global self-rated health was worse in caregivers than non-caregivers (155).

The findings of studies that use objective physiological measures or disease incidence are not as consistent as subjective health ratings. Some studies indicate that caregivers have higher rates of health problem than non-caregivers, such as hypertension (161), plasma lipid disorders (162), obesity (163), deteriorated immunity (164), and coronary heart disease (13). Lee et al. conducted a prospective study in 54,412 women from the Nurses' Health Study. They found that caring for non-ill children 21 hours or more per week and caring for non-ill grandchildren 9 hours or more per week (vs. no caregiving) were associated with an increased risk of coronary heart disease (relative risks (RR) were 1.59 and 1.55, respectively) (13). Another prospective study was conducted as part of the Nurses' Health Study among 54,412 women. Results show that caregiving for disabled or ill spouse for $\geq$ 9 hours per week was associated with increased risk of coronary heart disease (RR, 1.82; 95% CI, 1.08-3.05) during 4 years of follow-up (165). Mausbach et al. investigated the potential protective role of coping self-efficacy on the relationship between caregiving stress and circulating concentration of IL-6 among 62 elderly Alzheimer's caregivers. The study found that when self-efficacy was low, the log (IL-6) increased by 0.43 as caregiving stress score increased by 1 ($\beta = 0.43$, $p < 0.05$; stress score range = 0-12) (166). Another prospective study examined the relationship between caregiving demands among older spousal caregivers and 4-year all-cause mortality. Results show that participants who were providing care and experiencing caregiver strain had mortality risk that were 63% higher than non-caregiving controls (RR = 1.63; 95% CI: 1.00 – 2.65) (167). However, some other studies suggest contradictory conclusions. For example, Fredman et al conducted a

prospective study and found that older caregivers who provide high intensity care (more than 24 hours per week) had slower declines in mobility and reduced mortality risk than non-caregivers; however, this association reversed when activity levels were not taken into account (142).

The effect of caregiving on health can also be indirect. For example, studies have consistently shown that caregiving is associated with the lack of time for other family members, lower marital quality, and decreased involvement in social activities (168-170). O'Reilly found that increasing care provision was associated with fewer social contacts, outings, and holidays. Caregivers were 1.79 times less likely to get out of the house at least once a week (95% CI: 1.0-3.2) compared to non-caregivers. And the study also found caregivers were 1.71 times less likely to have had a holiday last year (95% CI: 1.0-2.9) (168). In addition, caregivers often experience financial burdens as a result of becoming a caregiver (171, 172). Because caregivers often devote significant attention to their care recipients and invest a sizeable proportion of their time to care, caregivers may have to quit their jobs that may induce financial strain. Caregiving also may require using personal finances toward providing food, clothing, transportation, housing, and utility fees for their care recipients (173). In sum, the consequences of acquired strains and economic burdens may indirectly lead to declining health among caregivers.

**Caregiving stress and hypertension**. Previous research shows inconsistent evidence regarding the relationship between caregiving stress and blood pressure. Some studies suggest no association exists between caregiving and hypertension. Doshi et al. compared antihypertensive use and ambulatory blood pressure among 69 black female caregivers and 86 non-caregivers. They found that caregivers and non-caregivers were comparable in their anti-hypertensive drug use and blood pressure even after adjusting for potential confounders, such as age, education, marital status, co-morbidities, tobacco use, alcohol use, and insurance type etc. (174) An earlier

cross sectional study examined the effects of caregiving stress and social support on cardiovascular functioning among 36 family caregivers of Alzheimer's disease victims and 34 controls. The results revealed that the effect of social support on blood pressure were the same among caregivers and noncaregivers (175).

Some other studies indicate that the provision of care can increase the risk of hypertension. A cohort study used the Health and Retirement Study (HRS) to examine the association between spousal caregiving and the risk of incident hypertension (176). 5708 respondents aged 50 and over were followed up to 8 years. After adjusted for demographic, socioeconomic and health factors, current caregiving (defined as assisting a spouse with instrumental or basic activities of daily living (I/ADLs) 14+ hours/week) significantly predicted hypertension incidence (RR = 1.36, 95% CI: 1.01, 1.83). For long-term caregivers (defined as providing ≥ 14 hours/week of care at two consecutive biennial surveys), there was significant increased risk of hypertension onset compared to non-caregivers (RR = 2.29, 95% CI: 1.17, 4.49). A study in Japan reported that hypertension was significantly related to caregiver status even after adjusting for potential confounders, such as exercise, yearly health checkup experiences, age related stress, quality of sleep and coping plans (177). King et al. found that caregivers and non-caregivers showed comparable ambulatory blood pressure levels when they measured in the clinic and at work settings. However, caregivers demonstrated a significant increase in systolic blood pressure levels following work when they were in the presence of the care recipient (178). A recent cross-sectional study examined the impact of caregiving on blood pressure and other health indicators among 149 caregivers and 149 sex and age matched non-caregivers. The prevalence of high blood pressure was significantly higher among caregivers than non-caregivers. After adjusting for related sociodemographic and health factors, high blood

pressure remained significantly more prevalent among female caregivers than female non-caregivers (179).

Data on the impact of caregiving on caregivers' health among Chinese are limited. Existing published studies have mostly examined the subjective health outcomes, such as self-rated health, quality of life and mental health problems (22). Liu et al conducted a prospective study to examine the impact of parental caregiving on self-rated health among Chinese women. They found that caregivers had consistently worse self-rated health status than non-caregiver (22). Ho et al. investigated the impact of caregiving on the health status and quality of life among primary informal caregivers of elderly care recipients in Hong Kong through a cross sectional study (180). They found compared to non-caregivers, caregivers had significantly increased risk for reporting worse health, poorer QOL, more doctor visits, anxiety and depression, and weight loss (180).

## 1.2 Objectives/research questions

The overarching goal of this dissertation will be to explore the associations between multiple dimensions of chronic stress and the risk factors of CVD as well as investigate the potential mechanisms that underlie the relationships between stress and CVD risk factors among Asian. Specifically, the three specific aims and associated research questions and hypotheses are as follows:

**Specific Aim 1 (Paper 1)**. To assess the relationship between perceived stress and hypertension across varying levels of social support and social isolation among Chinese, Korean and Vietnamese Americans in the U.S.

a. Is there an association between perceived stress and hypertension among Chinese, Korean, and Vietnamese Americans?
b. Is there an association between social support and hypertension among Chinese, Korean, and Vietnamese Americans?
c. Is there an association between social isolation and hypertension among Chinese, Korean, and Vietnamese Americans?
d. Is the relationship between perceived stress and hypertension different with social support status? (effect modification)
e. Is the relationship between perceived stress and hypertension different with social isolation status? (effect modification)

**Specific Aim 2 (Paper 2).** To examine the influence of parental caregiving on women's blood pressure trajectories in China.

a. Is the caregiving status associated with hypertension trajectories among Chinese women?
b. Is the intensity of caregiving associated with hypertension trajectories among Chinese women?

**Specific Aim 3 (Paper 3)**. To examine the association between caregiving trajectory and MetS among Chinese women.

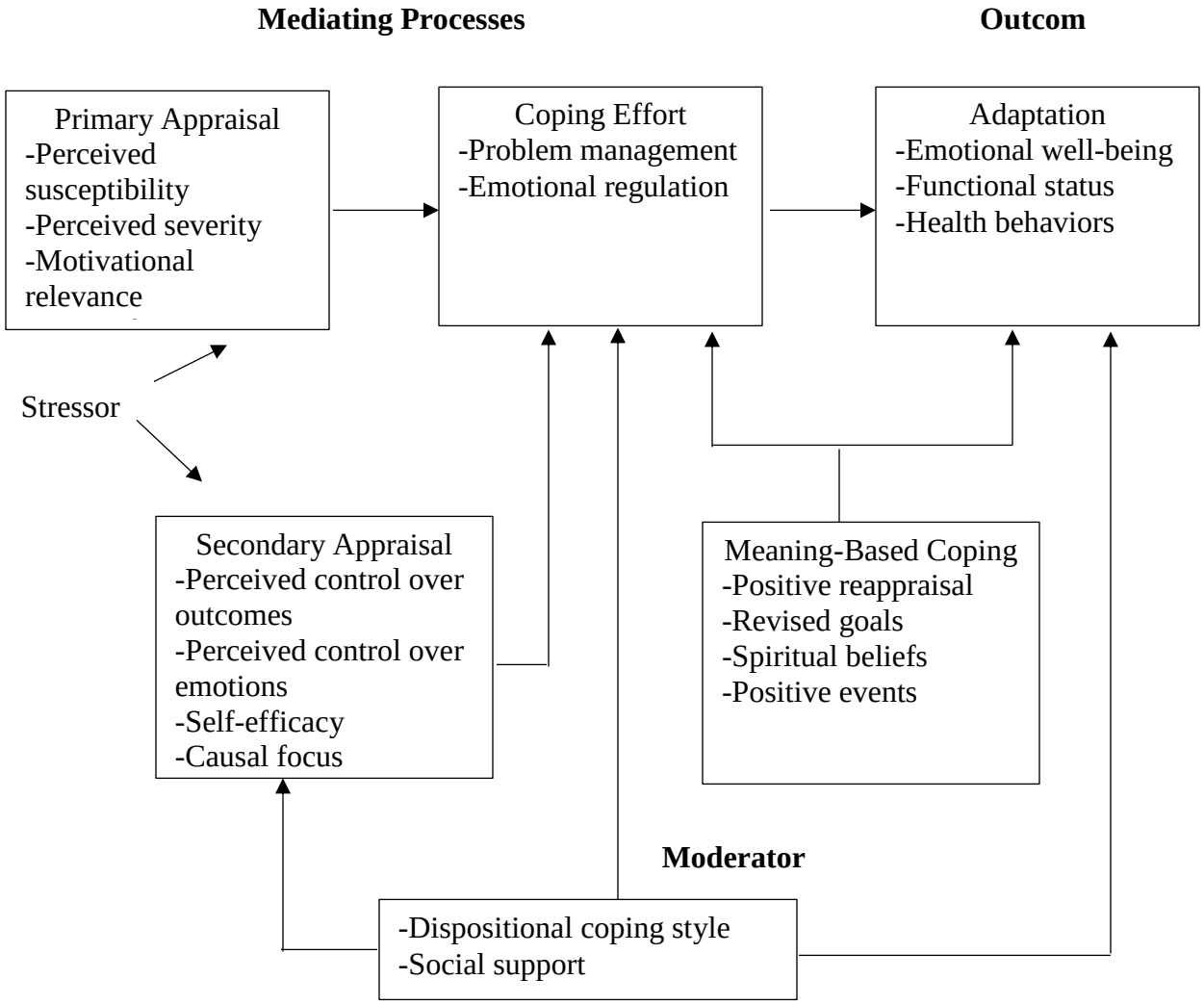
a. Do multiple caregiving trajectories exist in the three waves of data?
b. Is the caregiving trajectores associated with MetS?
c. Is the caregiving trajectores associated with individual MetS component?

## 1.3 Theoretical/conceptual framework and hypothesis

In 1985, Cohen and Wills introduced two mechanisms in which social support might contribute to health (107). The main effect model proposes that social resources have a beneficial effect by providing positive experience and stability in life situation, irrespective of whether persons are under stress or not (89, 107). For example, social support may have direct physiological and immunological benefits by enhancing the expression of negative feelings (181). The supportive-expressive group therapy approach emphasizes providing support in helping patients face and deal with their disease-related stress (182). The stress-buffering hypothesis predicts that social support will have stronger positive effects on adjustment and physical well-being when a stressor becomes more intense or persistent (107). A possible mechanism by which social support may benefit physical well-being is the promotion of active coping behaviors such as adherence to recommended health behaviors (183).

The Transactional Model of Stress and Coping is a framework for evaluating the process of coping with stressful events and adaptation outcomes (184). The impact of an external stressor is mediated by the person's appraisal of the stressor and the person's psychological, social, and cultural resources (185). When faced with a stressor, a person evaluates the potential threat (primary appraisal) and the ability to alter the situation and manage negative emotional reactions (secondary appraisal) (184). Prior studies have provided support for the premise that reactions to stress may affect health status through physiological process of the endocrine, immune, and nervous systems (186, 187). Figure 1.1 illustrates the interrelationships among the concepts of the Transactional Model of Stress and Coping

**Figure 1.1 Diagram of the Transactional Model of Stress and Coping**



## 1.4 Innovation and significance

**Chapter 3 (Paper 1)**. An important limitation of existing research is that studies of the inter-relationship between perceived stress, social support, and hypertension are scare, particularly among Asian Americans. Asian Americans are the fastest growing ethnic group in the U.S. (30) It is predicted that there will be more than 40.6 million Asian Americans by the year 2050 (188). However, studies of the effect of perceived stress on hypertension in Asian Americans are very rare. There is also a dearth of research on the relationship between social support and hypertension among Asian Americans. Prior research has shown that older Chinese immigrants may seek less support from their westernized children in order to reduce conflicts (189). It is possible that a lower level of social support among Asian Americans could be a reason for a high prevalence of hypertension.

Early studies investigating CVD risk factors among Asian Americans tended to focus on aggregated AAPIs (18, 19). However, these populations are extraordinarily diverse with respect to country of birth, socioeconomic status, time since immigration, language spoken, religion and other characteristics that may affect heath (20). Therefore, perceived stress and hypertension prevalence attributed to AAPIs as an aggregate can obscure the heterogeneity in stress and hypertension among Asian subgroups. In our study, we will focus on three of the largest Asian American populations: Chinese, Koreans, and Vietnamese. This will highlight the importance of identifying differences in health effects of perceived stress among disaggregated AAPI subgroups to help health professionals prioritize which subgroups need the most urgent intervention in terms of stress management.

This study advances our understanding of stress and hypertension by highlighting the importance of social support and social isolation on the relationship between perceived stress and hypertension among Asian Americans. To our best knowledge, this is the first study examining the synergetic effect of social support, social isolation and perceived stress on hypertension among Asian Americans. In addition, this study focuses on three of the largest Asian American populations: Chinese, Koreans, and Vietnamese. This will highlight the importance of identifying differences in health effects of perceived stress among disaggregated AAPI subgroups to help health professionals prioritize which subgroups need the most urgent intervention in terms of stress management. Moreover, instead of using subjective measurements of health such as self-rated health, our study used objective measure of hypertension as our outcome. Three blood pressure readings were taken at the time of the survey for increased accuracy.

**Chapter 4 and 5 (Paper 2 and 3).** The literature on the effect of caregiving stress on cardiovascular health reported mixed results. And the conclusions have been based mainly on cross-sectional studies and thus difficult to assess the underlying causal relationship. Nonetheless, the change of physiological status usually does not take place suddenly but is likely a gradual, interactive, and cumulative process. Therefore, prospective studies and experimental studies that employ more robust methodology are necessary to confirm the existence and validity of a relationship between caregiving stress and blood pressure. Even for the research estimating cross-sectional associations of hypertension among caregivers, most of the studies were conducted in a sample of only Alzheimer's caregivers and its results may not be generalizable to the general caregivers.

In addition, the assessments of caregivers' health in most previous studies have been largely subjective, rather than collecting objective data. Although objective measures and subjective measures should essentially reflect the same thing, there is ample evidence in previous literature of large disparities between the two health measures in even very high quality surveys (190). Taylor et al. examined the relationship between self-reported and clinical measurements for high blood pressure in a random population sample. They found self-reported of current high blood pressure showed high specificity (98%), but the sensitivity was moderate (49%). And agreement between current self-report and clinical measures was also moderate (kappa 0.55) for high blood pressures (191). The results support that there are major differences between the self-reported measures and the actual clinical measurements.

Little research exists that attempts to understand the impact of parental caregiving on cardiovascular health among Chinese. Nowadays, the demographic changes to China's age structure are astonishing. The proportion of the population aged 65 and older in China increased by 5% from 1953 to 2010 (21). The increased life expectancy among older Chinese has also introduced new burdens on the family. Adult children shoulder greater responsibility in caring for their aging parents with chronic illness compared to the past. However, it is unclear how Chinese balance the competing demands and structural constraints of family and work while maintain their physical health in the process of fulfilling their filial responsibilities (22). Therefore, it is important to explore the health consequences of caregiving among Chinese.

Paper 2 makes important contributions to the literature of health implications of parental caregiving among Chinese women. To our knowledge, this study provides one of the first comprehensive longitudinal analyses of the association between parental caregiving and hypertension trajectories among Chinese women. In addition, we used objective measure of blood pressure. In

most previous studies, the assessment of caregivers' health has been largely subjective, rather than collecting objective data. There is ample evidence in previous literature of large disparities between the objective and subjective health measures in even very high quality surveys (190). In addition, this study examined the trajectory of hypertension change by incorporating multiple measures of caregiving. Furthermore, the study used prospective design instead of cross sectional design. The prospective study design employs robust methodology that is necessary to confirm the existence and validity of a relationship between caregiving stress and blood pressure.

Paper 3 advances our understanding of parental caregiving and cardiovascular risk factors among Chinese in China. Only a handful of previous studies have attempts to understand the health impact of parental caregiving in this population. As a rapid demographic change to China's age structure, it is important to explore the health consequences of caregiving among Chinese. In addition, we used group-based trajectory analysis to explore the caregiving trajectories. The trajectory analysis is a useful statistical technique for capturing the essential features of the underlying complex reality of the longitudinal caregiving data, with added advantage of being simple to interpret.

# Chapter 2: Methods

The following chapter contains additional detailed information about the epidemiological methods, in addition to what is presented in Chapters 3-5.

## 2.1 Study design and data source

### 2.1.1 Study design and data source: Chapter 3 (Paper 1)

The study design of the paper 1 was secondary analysis of a cross sectional study. The study used data from a randomized community trial titled as "Lay Health Worker Model to Reduce Liver Cancer Disparities in Asian Americans" in the Washington D.C. Metropolitan area from April 2013 to March 2014. The project was funded by the National Institute of Health, and aimed to promote liver cancer prevention for Chinese, Korean, and Vietnamese Americans through outreach, screening, education, and training.

*Recruitment procedures*

A total of 600 Asian Americans adults, 18 years of age and older were drawn from the community. Considering that it was a hard-to-reach population, a non-probability sampling was used. The connections with local community-based organizations (CBOs), Hepatitis B Initiative of DC (HBI-DC) and the Asian American Healthcare Center (AAHC), and other links through the community advisory board were used as the main sources for obtaining recruitment locations. First, print advertisements in local Chinese, Korean, and Vietnamese newspapers and local Asian grocery stores describing the study were placed. Those who called us were screened for the eligibility and were invited to the study. Second, lay health workers (LHWs), who were trained about hepatitis B announced upcoming screening events in their community. Most participants

were recruited by word of mouth through LHWs. Our research team and LHWs attended these screening events to recruit potential participants. Third, church and temple leaders were contacted to arrange recruitment days in which church and temple members were recruited to participate in the study on the spot. All recruitment occurred in Maryland and Northern Virginia.

*Eligibility criteria*

We recruited participants on a voluntary basis if they were foreign born Chinese, Korean, and Vietnamese Americans 18 years of age and older who resided in the target area; who were not aware of hepatitis B infection; who would stay in the targeted area in the next 2 years; 4. Who were willing to give written consent to participate in the study?

*Data collection procedures*

After obtaining the informed consent for pre-test, screening test, and blood banking, all the participants were asked to complete a self-administered questionnaire in English, Chinese, Korean, or Vietnamese, with the assistance of a bilingual interviewer when necessary. The questionnaire contained items on demographics, health status, acculturation, health care accessibility and utilization, health behaviors, perceived stress, social networks and social support among other topics. Research team members measured height, weight, waist and hip circumferences, and blood pressure for each participant. Participants were seated and three readings of blood pressure were taken at 5 minutes intervals in the right arm using the OMRON HEM 907 blood pressure monitor.

*Detailed information on selected measures*

**Perceived stress**. Perceived stress was measured using the Perceived Stress Scale (PSS). The PSS is a measure of the degree to which situations in one's life are appraised as stressful. Items were designed to tap how unpredictable, uncontrollable, and overloaded respondents find

their lives (37). The scale also includes several direct queries about current levels of experienced stress. Response categories are a 5-point Likert scale ranging from never to very often. There are 14-item (PSS-14), 10-item (PSS-10), and four-item (PSS-4) versions of the PSS scale. All three versions have been shown to have satisfactory reliability and validity (39) . The Cronbach's alphas for the 14-item, 10-item, and 4-item versions were 0.89, 0.91, and 0.82, respectively. These results indicate that the items in the scales are highly homogeneous and that 82-91% of the variance is true score variance, with the remainder due to error variance. The Spearman Brown split-half reliability coefficient was acceptable for all three versions of the PSS (0.86, 0.90, and 0.87, respectively) (192).

In this study, the 10-item version was administered to assess the degree to which participants appraised their current stress level. Leung et al. examined the psychometric properties of the PSS-10 scale among Chinese cardiac patients who were also smokers (193). Hong et al. examined the reliability and validity of the Korean version of the PSS-10 scale. They found that PSS-10 had good reliability with a Cronbach's alpha of 0.75. For the concurrent validity, moderate relationships were found between a negative response to stress and depression ($r = 0.42$, $p < 0.001$) and quality of life ($r = -0.45$, $p < 0.001$). A positive response to stress had moderate significant correlations with depression ($r = 0.30$, $p < 0.001$) and quality of life ($r = -0.36$, $p < 0.001$).

The PSS-10 includes easy-to-understand questions about participants' stressful thoughts or feelings related to situations in their lives within the last month:

1. How often have you been upset because of something that happened unexpectedly?
2. How often have you felt that you were unable to control the important things in your life?

3. How often have you felt nervous and "stressed"?
4. How often have you dealt successfully with irritating life hassles?
5. How often have you felt that you were effectively coping with important changes that were occurring in your life?
6. How often have you felt confident about your ability to handle your personal problems?
7. How often have you felt that things were going your way?
8. How often have you found that you could not cope with all the things that you had to do?
9. How often have you been able to control irritations in your life?
10. How often have you felt that you were on top of things?

Each item is rated on a 5-point Likert scale ranging from Never (0) to Very Often (4). A total PSS score is calculated by reverse-scoring the six positive items (item 4, 5, 6, 7, 9, and 10) and then summing scores for all 10 items. PSS scores can range from 0 to 40. The higher score indicates more perceived stress. As the PSS is not a diagnostic instrument there is no cut-off point. Cronbach's alpha for the scale with our data is 0.77.

**Social isolation**. Social isolation was measured using Berkeman and Syme's Social Network Index (SNI). This measure is a self-reported questionnaire for use in adults aged 18–64 years old that is a composite measure of four types of social connections: marital status (married vs. not); sociability (number and frequency with close relatives and close friends); church membership (yes vs. no); and membership in other community organizations (yes vs. no) (194). The SNI allows researchers to categorize individuals into four levels of social connection: socially isolated (individuals with low intimate contacts—not married, fewer than six friends or

relatives, and no membership in either church or community groups), moderately isolated, moderately integrated, and socially integrated (194). The SNI considers both the number and the relative importance of social ties across these four network categories and combines this information into a single summary measure (ranging from 0 to 4). In Berkman's weighting system (1979), an index of intimate contacts (marital status, friends and relatives) is given nearly four times the weight as group membership and twice the weight of church membership. Measures of social integration have an impressive track record of forecasting poor health, particularly mortality (60, 194). However, the construct validity of measures of social integration is less well documented. For example, measures of social integration were not closely linked to psychological distress in most samples (195). However, social integration does appear to be related to extroversion, positive affect and positive health practices (196).

The main questions for the SNI include:

1. What is your present marital status? (married, living with a partner, separated, divorced, remarried, widowed, never been married)
2. How many living children? (none, 1 or 2, 3-5, 6 or more)
3. Apart from your children, how many relatives do you have with whom you feel close? (none, 1 or 2, 3-5, 6-9, 10 or more)
4. How many of these friends do you have? (none, 1 or 2, 3-5, 6-9, 10 or more)
5. How often do you go to religious meetings or services (i.e. churches, temples, etc.)? (never or almost never, twice a month to once a year, once a week, more than once a week)
6. How many hours each week do you participate in volunteer or other community groups? (None, 1-2 hours, 3-5 hours, 6-10 hours, 11-15 hours, 16 or more hours)

In the current study, four network categories were developed to reflect differences in type and extent of social contact: married (no = 0; yes = 1); close friends and relatives (0-2 friends and 0-2 relatives (including children) = 0; all other scores = 1); group participation (no = 0; yes = 1); participation religious meetings or services (never or almost never = 0; greater than or equal to once or twice a month = 1). Scores were summed: 0 or 1 being the most isolated category (socially isolated); 2 (moderately isolated), 3 (moderately integrated), or 4 (socially integrated) formed the other three categories of increasing social connectedness. The procedure by which this index was developed and the precise description of methods used to score it are available elsewhere (65, 194, 197).

**Social support**. Social support was measured using the Duke-UNC Functional Social Support Questionnaire (DUFSS). The DUFSS measures the amount and type of perceived functional social support. The original instrument included 14 items, grouped into 4 subscales: quantity of support, confidant support, affective support, and instrumental support. A shortened 8-item version of the DUFSS includes two subscales: confidant support (having someone to talk to, social with, receive advice from) and affective support (being shown love and affection). The responses are on 5 point Likert scale, ranging from 5 (as much as I would like) to 1 (much less than I would like). A total score is calculated by summing all the responses. The 8-item DUFSS has moderate internal consistency. For the confidant support scale of DUFSS-8, the average item-remainder correlation was 0.62; for the affective support scale, the correlation was 0.64 (198). At between one and four weeks, the final reliability coefficient for test-retest was 0.66 (198). For validity, there was no significant correlation between either of the subscales and gender, marital status, age, employment status, education, or socioeconomic status. Living situation was significantly correlated with each of the subscales. There was a significant

correlation between race and social support, reflected by scores on the scores on the confidant support (198). The confident support and affective support scales were each significantly correlated with social activity measures, including a social contacts subscale of a social activities questionnaire and two measures of social function from a health profile questionnaire (198). The psychometric validity of the Korean version of the DUFSS was previously reported to be satisfactory (Cronbach's alpha = 0.89).

In this study, we used 8 item DUFSSQ to measure social support, which contains items relating to the perceived functional elements of social support:

1. I have people who care what happens to me.
2. I get love and affection.
3. I get chances to talk to someone about problems at work or with my housework.
4. I get chances to talk to someone I trust about my personal or family problems.
5. I get chances to talk about money matters.
6. I get invitations to go out and do things with other people.
7. I get useful advice about important things in life.
8. I get help when I am sick in bed.

Each item is rated on a 5 point Likert scale ranging from 5 (as much as I would like) to 1 (much less than I would like). The 8-item scale yields a single total support score, ranging between 8 and 40. The higher total score reflect higher perceived social support. Cronbach's alpha for this scale with our data is 0.94.

2.1.2 Study design and data source: Chapter 4 (Paper 2)

The study design of the paper 2 was secondary data analysis of a longitudinal study with five waves of data collection. This was a retrospective analysis of 2,586 women using five waves of data from the Ever-Married Women Survey component of the China Health and Nutrition Survey (2000, 2004, 2006, 2009, and 2011).

The China Health and Nutrition Survey (CHNS) is a large-scale longitudinal survey conducted by the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention (199). The CHNS data involves nine large provinces across a wide geographic region with a range of economic and demographic variation, covering approximately 56% of population in China. The age and gender distribution in the CHNS is slightly older than that of the national China census in 2009, which includes approximately 3% more individuals aged 60 and older and 3% fewer children and adolescents.

The CHNS was not designed to be representative of China but to be randomly selected and to capture a range of economic and demographic circumstances (200). The CHNS provided data from randomly selected households in nine provinces—Liaoning, Shandong, Henan, Heilongjiang, Jiangsu, Hubei, Hunan, Guizhou and Guangxi. A multistage, random cluster process was used to draw the sample in each of the provinces. Counties and cities in each province were stratified by income (low, middle and high) and a weighted sampling scheme was used to randomly select four counties and two cities in each province.

The analytic sample in this study will use Ever-Married Women (EMW) Survey, which is a component of the CHNS and provides a unique opportunity to assess detailed information on the socioeconomic, behavior, and family contexts of women caregivers in China. The EMW only

includes ever married women aged 18 and 52 years, which precludes generalization of the findings to women of other ages and those who never married. However, the EMW has some major strength: first, the survey provides detailed information on parental caregiving; second, the longitudinal design allows observing participants at several time-points and building causal associations. Therefore, this study can capture a portion of life course for adult Chinese women who fulfill the caregiving demands.

### 2.1.3 Study design and data source: Chapter 5 (Paper 3)

The study design of the paper 3 was secondary analysis of a longitudinal study with three waves of data collection. This was an analysis of 1,636 women using three waves of data from the Ever-Married Women Survey component of the China Health and Nutrition Survey (2004, 2006, and 2009). One of the limitations in this study design is that the outcome information (MetS) was only available at wave III. This limited our ability to calculate the risk of MetS since the cases with MetS at baseline were not able to be excluded from the denominator.

## 2.2 Assessment of potential Bias

### 2.2.1 Selection Bias

Selection bias occurs when a systematic error in the ascertainment of study subjects results in a tendency toward distorting the measure expressing the association between exposure and outcome (201). The important analogue of selection bias in the context of cohort studies is differential losses to follow up, that is, whether individuals who are lost to follow up over the course of the study are different from those who remain under observation up to the event or termination of the study. The CHNS data is an open cohort. The response rates and attrition were

very complex to determine with this survey since the participants who left in one survey year may have moved back in a later year. If the response rate was defined based on those who participated in previous survey rounds remaining in the current survey, the response rates were 88% at individual level and 90% at household level. If the response rate was defined based on those who participated in 1989 and remained in the last round of survey, the response rates were 63% at individual level and 69% at household level (200). To reduce the loss to follow up rate, the research team piloted new strategy that implemented in 2009. The interviewers returned to the communities during the Spring Festival to attempt to locate families and individuals they previously missed, since many migrant farmers who work in other areas would return to their home during the Spring Festival.

Selection bias can also arise from missing data. We treated the dependent variable as missing at random and removed records having missing values in any variables used in the analysis. However, it is possible that this assumption is not reasonable, and that relationships between the independent variables and outcomes are different among nonresponders. We conducted sensitivity analysis to compare the distributions of characteristics between the excluded sample with missing values and the final analysis sample. The results were presented in Table 3.6 for paper 1, Table 4.4 for paper 2, and Table 5.4 for paper 3.

### 2.2.2 Information Bias

Information bias in epidemiologic studies results from either imperfect definition of study variables or flawed data collection procedures (201). Both "lay health worker" study (paper 1) and CHNS study (paper 2 and paper 3) took quality assurance measures to minimize misclassification of exposure and outcome. First, the two studies have standard protocols for

training the field staff for data collection, data entry, and how to properly check and clean the data. Second, both surveys employed objective measures and gold standard diagnostic techniques for ascertainment of outcomes. In paper 1 and paper 2, we used objective measures of blood pressure instead of self-reported outcomes. Three readings of blood pressure were taken by the trained research staffs. In paper 3, biomarkers were used to define MetS. All blood samples were analyzed in a national central lab in Beijing with strict quality control. However, we acknowledge participants may have inaccurate recall of past exposure and inaccurate answers to certain socially sensitive questions, such as smoking and alcohol use.

### 2.2.3 Confounding bias

Confounding refers to a situation in which a noncausal association between a given exposure and an outcome is observed as a result of the influence of a third variable (or a group of variables) (201). The essential nature of confounding is: the confounding variable is causally associated with the outcome; and noncausally or causally associated with exposure; but is not an intermediate variable in the causal pathway between exposure and outcome. The identification of potential confounders is based on a prior knowledge of the dual association of the possible confounder with the exposure and the outcome. Multivariate analysis is a method to estimate the main association of interest while controlling for one or more confounding variables. In this dissertation, each study included assessment of potential confounding variables based on previous literature, such as sociodemographic variables (age, education, employment status, marital status) and health behavior factors (alcohol drinking and smoking status). We acknowledge residual confounding may exist in each study, either because some information was

not collected in the survey (dietary history), or the categories of the confounders controlled are too broad, resulting an imperfect adjustment.

## 2.3 Assessment of potential interaction effects

Effect modification describes a situation in which two or more risk factors modify the effect of each other with regard to the occurrence or level of a given outcome (201). Approaches to testing for effect modification include stratified tests (e.g Breslow-Day, Wald) or regression-based tests of interaction. In the studies, the potential moderators were selected based on prior literature. Potential moderations were examined by including the corresponding interaction terms in the regression models. The stratified analysis was conducted if the interaction term was significant.

# Chapter 3: The association between perceived stress and hypertension among Asian Americans: does social support and social network make a difference?

To be submitted for publication

**ABSTRACT**

**Background**: There are several proposed mechanisms that point to the negative effects of stress on health. However, the role of social support and social network in the relationship between stress and hypertension, especially in Asian American populations, remains unclear. This study aims to assess the associations between perceived stress and hypertension across varying levels of social support and social network among Asian Americans.

**Methods**: We conducted a cross-sectional study using data on 530 Chinese, Korean and Vietnamese Americans recruited from a liver cancer prevention program in the Washington D.C. – Baltimore metropolitan area.

**Results**: Hypertension prevalence was 29.1%. Individuals with high perceived stress were 61% more likely to have hypertension compared to those with low levels of perceived stress (Odds Ratio (OR): 1.61, 95% Confidence interval (CI): 1.15, 2.46). There was no evidence that social support and social network acted as effect modifiers. Social support had a direct beneficial effect on hypertension, irrespective of whether individuals were under stress. The relationship between perceived stress and hypertension was modified by gender and ethnicity whereby a significant positive association was only observed among male or Chinese participants.

**Conclusion**: Our study highlights the importance of understanding the associations between stress, social support, and hypertension among Asian American subgroups. Findings from the study can be used to develop future stress management interventions, and incorporate culturally and linguistically appropriate strategies into community outreach and education to decrease hypertension risk within the Asian population.

KEYWORDS Hypertension, Asian American, Stress, Social support, Social network

## 3.1 Introduction

Hypertension is a major risk factor for the development of cardiovascular disease (CVD), and a main cause of morbidity and mortality worldwide (23). Asian Americans, a rapidly growing minority population in the U.S., have been found to have a high prevalence of hypertension. According to data from the National Health and Nutrition Examination Survey (NHANES), about one-quarter (25.6%) of Asian Americans 20 years of age and older had hypertension during 2011-2012 (5). While there is a lack of national studies that observe the prevalence of hypertension in Asian American subgroups, local data reveals that significant differences in hypertension prevalence across various Asian American subgroups (29, 30, 202).

Emerging evidence indicates that chronic exposure to psychological stress/stressors plays a central role in the pathophysiology of hypertension and CVD (203, 204). Stress is a complex process and can influence the pathogenesis of physical disease by exerting direct effects on biological processes or indirect effects on behavioral patterns (37). When stress exceeds adaptive capacity, it results in maladaptive processes that negatively impact cardiovascular health (205). Prior evidence suggests that perceived stress contributes to the elevated blood pressure and to the development of hypertension and CVD (56, 206).

Regarding social relationships, a growing body of literature indicates that social support and social isolation can have a direct effect on hypertension (84-86, 89, 90). Prior research suggests that a low level of social support is a risk factor for the development of CVD in healthy individuals (75-77). In terms of social network, several studies have shown that a smaller social network is associated with higher blood pressure levels (113, 114, 207). Social isolation limits the amount of interactions and support that this population needs to maintain a healthy lifestyle. Failure to comply with certain medical recommendations because of social isolation could

increase blood pressure in stressful situations. To the contrary, a large social network and strong social support may attenuate the negative cardiovascular response in situations of stress, thereby avoiding the increase in blood pressure (208).

The positive health benefits of being socially connected are clear; however, very little is known about the mechanisms of social support and social network that underlie the association between stress and hypertension (107). In 1985, Cohen and Wills introduced two mechanisms in which social support may contribute to health: the Main Effect Hypothesis and the Stress-Buffering Hypothesis (107). The Main Effect Hypothesis proposes that social resources have a beneficial health effect by providing positive experience and stability in life situation, irrespective of whether persons are under stress or not (89, 107). The expression of negative feelings, for example, could lead to positive physiological, and concurrent, immunological benefits. The Stress-Buffering Hypothesis predicts that social support will have stronger positive effects on adjustment and physical well-being when a stressor becomes more intense or persistent (107). Unfortunately, there is a lack of studies of the inter-relationship between perceived stress, social support, social network, and hypertension, particularly among Asian Americans.

To bridge the missing gaps in previous literature, this study aims to: (1) assess the relationship between perceived stress and hypertension among Chinese, Korean and Vietnamese Americans in the Washington, DC metropolitan area; (2) test the main effect hypothesis by examining the direct effects of social support and social network on hypertension; and (3) test the stress-buffering hypothesis by assessing the relationship between perceived stress and hypertension across varying levels of social support and social network. Given the high prevalence of hypertension among Asian Americans, utilizing multiple psychosocial measures

allows us to capture the differences in the associations between various psychosocial aspects and hypertension, and to better understand the contributing psychosocial factors to hypertension.

## 3.2 Methods

### Study Population and Recruitment Procedure

We used the baseline survey data collected for the Asian American Liver Cancer Prevention Program (a randomized controlled trial to increase hepatitis B vaccination) for this ancillary study (209). To examine the relationship between perceived stress and hypertension, foreign-born Asian American adults, aged 18 years and older, were recruited from the community in the Baltimore-Washington Metropolitan Area. After obtaining informed consent, all the participants were asked to complete a self-administered questionnaire in English, Chinese, Korean, or Vietnamese, with the assistance of a bilingual interviewer when necessary. While completing the survey, blood pressure was measured three times by the research team at the study site. This study was approved by the Institutional Review Board at Johns Hopkins Bloomberg School of Public Health.

Of the 645 eligible volunteers, 30 did not participate in the program and 15 of those who attended the program did not complete either the survey or the hepatitis B screening. Thus, a total of 600 participants (201 Chinese, 198 Korean, and 201 Vietnamese) completed the screening and survey. We excluded 70 participants who had missing values on the following variables: social support (19), stress (32), social network index (11), education (6), employment (3), body mass index (BMI) (3), smoke (7), binge drinking (7), and self-rated identity (3). The final sample included 530 subjects for descriptive and regression analyses. Compared to the excluded sample (N = 70), women remaining (N = 530) in the analysis sample tended to be more

educated, employed, self-identified very Asian, and more likely to smoke. We addressed this potential selection bias in the discussion section (see Table 3.6 in Appendix).

**Measures**

*Dependent variable*

While participants were seated, three readings of blood pressure were taken at 5-minute intervals in the right arm using the OMRON HEM 907 blood pressure monitor. Based on the American Heart Association (AHA)'s recommendations (210), the mean of the latter two readings were used in the analysis. The following criteria were used to define hypertension in this study: 1. systolic blood pressure (SBP) of 140 mmHg or higher or diastolic blood pressure (DBP) of 90 mmHg or higher; or 2. use of antihypertensive drugs. Participants were considered to be aware of their hypertension status if they answered yes to the question "Have you been told by a doctor or other healthcare professional that you have hypertension or high blood pressure?".

*Independent variable*

**Perceived Stress**. Perceived stress was measured using the 10-item version of Perceived Stress Scale (PSS) which captures how unpredictable, uncontrollable, and overloaded respondents find their lives (37). Response categories are based off a 5-point Likert scale ranging from never (0) to very often (4) (39). PSS scores can range from 0 to 40, with a higher score indicates more perceived stress. Cronbach's alpha for the scale with our data is 0.77. We categorized the PSS score based on the median into low (0-15) and high (16 and above) groups.

**Social Support**. Social support was assessed using the 8-item version of the Duke-UNC Functional Social Support Questionnaire (DUFSS) which measures the amount and type of perceived functional social support. The 8-item version of the DUFSS includes two subscales: 6-item confidant support (including having someone to talk to, trust with, socialize with, receive

advice from, and receive help from) and 2-item-affective support (being shown love and affection). The responses are on 5 point Likert scale, ranging from 5 (as much as I would like) to 1 (much less than I would like). The scale yields a single total support score, ranging between 8 and 40. The higher total score reflects a higher perceived social support. Cronbach's alpha for this scale from our data is 0.94. We categorized the DUFSS score based on the median into low (0-30) and high (31 and above) groups.

**Social Network Index Score.** Social network index was measured using Berkeman and Syme's Social Network Index (SNI). This measure is a composite measure of four types of social connections: marital status (married vs. not); sociability (number and frequency with close relatives and close friends); church membership (yes vs. no); and membership in other community organizations (yes vs. no) (194). The SNI allows researchers to categorize individuals into four levels of social connection: socially isolated, moderately isolated, moderately integrated, and socially integrated (194). The SNI considers both the number and the relative importance of social ties across these four network categories and combines this information into a single summary measure (ranging from 0 to 4). Four network categories were developed to reflect differences in type and extent of social contact: married (no = 0; yes = 1); close friends and relatives (0-2 friends and 0-2 relatives (including children) = 0; all other scores = 1); group participation (no = 0; yes = 1); and participation in religious meetings or services (never or almost never = 0; greater than or equal to once or twice a month = 1). Scores were summed: 0 or 1 being the most isolated category (socially isolated); 2 (moderately isolated), 3 (moderately integrated), or 4 (socially integrated) formed the other three categories of increasing social connectedness. The procedures by which this index was developed and the precise description of methods used to score it are available elsewhere (65, 194, 197).

**Covariates**. Based on existing literature, the following confounders were included in the analysis: age, gender, ethnicity, education, employment status, marital status, body mass index (BMI), smoking, binge drinking, self-rated identity and English speaking. We obtained information on these variables from the self-administered questionnaire mentioned previously. Since age was not linearly related to the outcome based on LOWESS analysis (211, 212), age was categorized into 3 groups: less than 40 years, 40-59 years, and 60 years and over. With regards to education, we categorized participants into three groups: less than high school, high school or some college, college graduate or higher. We collapsed the marital status variable into two categories: married/living with a partner, or others (separated/divorced/widowed/never married). Employment status was dichotomous: employed vs unemployed. BMI was assessed as a continuous variable using anthropometric measure of weight and height, and was defined as body weight (in kilograms) divided by the square of height (in meters). Smoking was grouped as smoke (had smoked at least 100 cigarettes in entire life) vs non-smoke. Binge drinking status was categorized as yes (women had 4 or more drinks on an occasion during the past 30 days; men had 4 or more drinks on an occasion during the past 30 days) vs no (reference level). For the acculturation variables, English proficiency was measured as fluent, well, so-so, poorly, or not at all. Due to the low cell counts, we collapsed this variable into three groups: native/very well, so-so, and poorly/not at all. Self-rated identity was assessed using a single item measure on a 5-point scale: very Asian, mostly Asian, bicultural, mostly westernized, and very westernized. The last three self-rated identity categories were combined into one group: bicultural/westernized.

**Statistical Analysis**

Descriptive statistics calculated included estimating means of continuous variables and proportions of categorical variables. Hypertension status was compared by acculturation and

covariates using the t-test for continuous variables and the Pearson's chi-squared test for categorical variables. The statistical significance was based on a p value less than 0.05.

Age-adjusted logistic regression and multiple logistic regression were performed to assess the association between each psychological measure and hypertension. Potential moderation by social support, social network index, age categories, gender, education, employment status, self-identity, English proficiency, obesity, smoking and binge drinking were examined by including the corresponding interaction term. The potential moderators were selected based on prior literature. The stratified analysis was conducted if the interaction term was significant. The statistical analysis of the study was performed using SAS 9.4 (SAS Institute, Cary, NC).

## 3.3 Results

Participant characteristics are presented in Table 3.1. Of the 530 participants, the majority (63%) were between age of 40 and 59 years. About 58% were female and most of the participants were married (78%). Chinese, Korean, and Vietnamese ethnic composition was about the same, each making up about one third of the sample. About half of the study population received a college education or higher while 18% reported a history of smoking and 17% were binge drinkers. Based on the objective measure of BMI, 31% of the participants were overweight (BMI > 25 $kg/m^2$).

The mean of the perceived stress score in our sample was 15.5 (SD = 5.8). The level of perceived stress varied with ethnicity groups, English proficiency, and social support. A larger proportion of Korean Americans reported high perceived stress compared to Chinese and Vietnamese Americans (64% vs 48% and 45%, $p < 0.01$). In addition, those with high level of

perceived stress tended to receive less social support and rate their English fluency as "poorly/not at all" or "so-so". Regarding social support, 53% of the participants reported low level of social support. The level of social support also differed by gender and English proficiency. Females and individuals who spoke English well tended to receive a high level of social support. For the social network index score, 13% were socially isolated, 22% were moderately isolated, 30% were moderately integrated, and 35% were socially integrated. Socially isolated individuals tended to be less than 40 years or older than 60 years, not married, more Korean than Chinese or Vietnamese Americans, lower educated, not employed, and rated their English fluency as "poorly/not at all".

The overall prevalence of hypertension in this population was 29%. As shown in Table 3.1, those with hypertension tended to be older, male, less educated, higher BMI, rate their English fluency as "poorly/not at all" or "so-so", and have a history of smoking compared to those without hypertension. Perceived stress and social support were significantly associated with hypertension in the bivariate analyses.

Table 3.2 shows age-adjusted models for the association between psychological factors and hypertension. Individuals who had high level of perceived stress were 71% more likely to have hypertension as compared to those with low level of perceived stress (OR: 1.71, 95% CI: 1.15, 2.54) after adjusting for age. Participants with high social support were 51% less likely to have hypertension comparing with those with low social support (OR: 0.49, 95% CI: 0.33, 0.74). However, social network index score was not significantly associated with hypertension after controlling for age.

Table 3.3 reports multivariable adjusted models for the association between psychological factors and hypertension. Age and BMI had the largest confounding effect among

all covariates. After adjusting for other variables, individuals who had a high level of perceived stress were 61% more likely to have hypertension as compared to those with low level of perceived stress (OR: 1.61, 95% CI: 1.15, 2.46). Social support also had a direct impact to hypertension: participants with high social support were 48% less likely to have hypertension comparing with those with low social support (OR: 0.52, 95% CI: 0.33, 0.81). However, social network index score was not significantly associated with hypertension in general. Moderately integrated individuals were 58% less likely to have hypertension than socially isolated individuals (OR: 0.42, 95% CI: 0.19, 0.92). Interactions between perceived stress and social support or social network index were not statistically significant.

There was a significant interaction between perceived stress and gender (Table 3.4), suggesting that perceived stress had a stronger association with hypertension in men than in women. Male participants with high level of perceived stress were 95% more likely to have hypertension compared with those with low level of perceived stress (OR: 1.95, 95% CI: 1.05, 3.60). This association was not significant in women.

The relationships between perceived stress and hypertension also varied by three ethnic groups (Table 3.5). The adjusted model suggests that Chinese participants who had a high level of perceived stress were 278% more likely to have hypertension compared to those with low level of perceived stress (OR: 3.78, 95% CI: 1.13, 6.80). Similar to perceived stress, Chinese participants with high social support were 64% less likely to have hypertension as compared to those who had low social support (OR: 0.36, 95% CI: 0.15, 0.87). Among Korean and Vietnamese groups, no significant difference in hypertension status was found for various psychological measures.

## 3.4 Discussion

Our study is one of the first to examine multiple measures of psychosocial factors in relation to hypertension among Asian Americans overall and by ethnicity. The findings in this study clearly indicate that perceived stress is a strong predictor of hypertension. Our results support the main effect hypothesis that social support had a direct beneficial effect on hypertension, irrespective of whether persons were under stress. However, a stress-buffering effect of social support or social network was not demonstrated in this study. Our findings also suggest the relationship between perceived stress and hypertension was modified by gender. Among Asian American men, those with high level of perceived stress were significantly more likely to develop hypertension compared to those with low level of perceived stress. For women, no association between perceived stress and hypertension was found. In addition, the impact of perceived stress on hypertension may differ by Asian American subgroups as the significant association between perceived stress and hypertension was only observed among Chinese Americans.

The prevalence of hypertension was found to be slightly higher among Asian Americans in our sample (29.1%) compared to the data of NHANES 2011-2012 (25.6%) (5). This is probably because our sample was mostly comprised of a foreign-born population. According to the NHANES data, the prevalence of hypertension was higher among foreign-born (26.1%) individuals compared to those U.S.-born (21.2%) (5). Regarding the disaggregated data, consistent with a study that observed differences in hypertension prevalence among Asian subgroups (202), we found some variations in hypertension prevalence: hypertension prevalence was highest among Vietnamese Americans (33%), followed by Korean (31%) and Chinese Americans (23%).

Another notable finding is the level of perceived stress observed among Asian Americans in this study. The mean of the perceived stress score in our sample was 15.5, which is slightly higher than the mean score reported among Whites in the study by Cohen et al. (15.2) (213). Prior evidence has suggested that immigrant population experienced more psychosocial stress compared to dominant western cultural groups (214). Studies have shown that most common difficulties which immigrants experience include language barriers, adjusting to an unfamiliar environment, differences between Asian and American cultures, and problems relating to children who are often more acculturated than their parents (49). Our study also found that perceived stress was strongly related to acculturation whereby those with perceived low stress tended to rate English as "native fluency/well" or "so-so" (37% native fluency/well vs 35% so-so vs 29% poorly/not at all, $p < 0.01$). In addition, our data suggests that a larger proportion of Korean Americans reported high perceived stress relative to Chinese and Vietnamese Americans (64% vs 48% and 45%, $p < 0.01$). This finding is consistent with previous studies that reveal high levels of psychosocial stress, anxiety, and depression in Korean Americans (51, 106, 215). Potential explanatory factors may include higher rates of under-employment (a better education but lower-prestige jobs); limited ability in English; and a higher concentration in small business located in high-risk minority districts (216).

A strong relationship between perceived stress and hypertension among Asian Americans was concluded in our study. Prior research connecting stress with hypertension has produced mixed findings, with some studies identifying a positive association (11, 12), some showing no correlation (106) while others even demonstrating a negative correlation (217). However, few of these studies were conducted among Asian Americans (106). Logan et al. explored the relationship between perceived stresses and blood pressure among 102 Korean

Americans in North Carolina (106). They found that there was no significant association between perceived stress and SBP/DBP.

The mechanisms by which stress may be linked to hypertension are complex and involve a variety of interrelated physiological and behavioral pathways (218). Early studies have shown that the primary biological pathway linking emotions to disease is hormone (38). Excessive discharge of certain hormones have been implicated in the pathogenesis of cardiovascular disease and diseases involving the immune system including cancer, infectious diseases, and autoimmune diseases (38). Behavioral changes may also occur as adaptations to stressors. People exposed to stressors or with perceived stress tend to engage in poor health behaviors, such as smoking, alcohol consumption, inactivity, unhealthy diets, and poor sleep patterns (39, 40). Additionally, it is believed that immigrants change their lifestyle to cope with the increased stress (54). These lifestyle changes, such as unhealthy diet, have been found to increase vulnerability to developing hypertension (54, 55). Therefore, well-established behavioral risk factors may represent an intermediate stage through which stress increases hypertension risk (91). However, the established risk factors do not account completely for the stress and CVD association. Consistent with earlier studies (219), our study found adjusting for intermediate behavioral health indicators (smoking, binge drinking and BMI) resulted in only a small change in the strength of associations of perceived stress with hypertension.

We found mixed evidence regarding the effects of social relationship on hypertension. In this analysis, social support was significantly associated with hypertension. Similar findings have been reported from Tomaka et al (111). They examined relations between social support and health outcomes in a senior sample from New Mexico. The results show that the odds of hypertension were 24% lower for a one unit increase in the social support score (OR: 0.76, $p <$

0.05). Inconsistent with prior studies (114-116), we found there was no significant association between social network and hypertension. In addition, we observed no difference in the associations between perceived stress and hypertension across various levels of social support or social network. This suggests that the impact of the subjective experience of stress on hypertension was not moderated by social network or social support. But the stress-buffering effect of social support was demonstrated in other studies (109, 120). The findings from these studies highlight the importance of examining the joint contribution of stress and coping resources to hypertension.

The gender discrepancies in the association between stress and hypertension found in our study is consistent with prior research (50, 197). Our results revealed that Asian American men with a high level of perceived stress were significantly more likely to develop hypertension compared to those with a low level of perceived stress. Interestingly enough, there was no association between perceived stress and hypertension among women. The mechanism for these gender differences of stress-related hypertension remains unclear. It has been reported that Asian men experience a more difficult time in adjusting to new cultures compared with Asian women (50). Asian culture had instilled in these men more authority that the impact of stress would be more profound (50). In addition, prior research has observed gender differences in the use of stress coping strategies (220). Women preferred the emotion-focused coping strategy to mobilize their social networks, especially peers, to talk about what was troubling them as a way of releasing stress; while men usually repressed their emotions to either fight or escape (221). Although this stress-buffering effect was not observed in our data, social support has been demonstrated as an effect modifier in other research (109, 120).

Another noteworthy finding is the heterogeneity among Asian subgroups in the associations between psychosocial factors and hypertension. Stratified analyses concluded that the significant associations between perceived stress, social support and hypertension only presented among Chinese participants. This suggests that the negative effect of perceived stress and positive effect of social support on hypertension may be particularly potent among Chinese Americans. Chinese culture emphasizes interdependence and values group consensus more than individual attributes (49). In the current study, we also found the mean of social support score was higher among Chinese (30.2) than Korean (28.1) and Vietnamese Americans (29.0). Future study may elucidate the underlying mechanisms in the heterogeneous associations among Asian subgroups by examining the culturally relevant stress and social support measures.

We acknowledge a few limitations in this study. First, our study was based on cross–sectional data and does not lend itself to causal inference. Future studies using longitudinal data are needed to corroborate our findings. Second, the study used non-probability sampling methods because the target population is a hard-to-reach population; however, our sample composition closely follows the composition of the United States 2010 Census data (222). Therefore, generalizability of the study may not be largely compromised. Third, most of our study population was first generation immigrants because the goal of the parent study was to study hepatitis B. Thus, variability for perceived stress and social support might have been smaller than studies that included more US-born Asian Americans. This might have reduced our ability in detect potential associations between psychosocial factors and hypertension. Fourth, we did not have data on several established risk factors for hypertension that are also related to stress. Physical activity and diet are known to be associated with the risk of hypertension (223, 224), but these information were not available in our data.

Nevertheless, this study advanced our understanding of psychosocial factors and hypertension among Asian Americans. To our best knowledge, this is one of the first studies examining the synergistic effect of perceived stress, functional social support, and structural social support on hypertension among Asian Americans. By using a large sample size, this study focused on three of the largest Asian American populations: Chinese, Koreans, and Vietnamese. This highlights the importance of identifying differences in health effects of perceived stress among disaggregated Asian Americans subgroups. Moreover, as opposed to using self-reported hypertension information, our study used objective measure of hypertension as our outcome. Three blood pressure readings were taken at the time of the survey for increased accuracy. There is ample evidence in previous literature of large disparities between the objective and subjective health measures in even very high quality surveys (190).

The implication of this work is directed towards expanding our understanding of the interrelationship between stress, social support, and hypertension among Asian Americans. It is critical to this discussion that researchers and clinicians understand the fundamental cultural differences that Asian Americans have relative to the general population. At the same time, it is also essential to recognize the diversity that exists within the Asian American culture. Because of this, our study underlines the importance of identifying differences in health effects of stress among disaggregated Asian American subgroups to help health professionals prioritize which subgroups need the most urgent intervention in terms of stress management. Successful interventions to reduce the modifiable risk factors among individuals under stress may prevent the risk of long-term health hazards. In general, findings from the study can be used to develop future stress management interventions, and incorporate culturally and linguistically appropriate

strategies into community outreach and education to decrease hypertension risk within the Asian Americans.

## 3.5 Acknowledgement

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## 3.6 Tables and Figures

Table 3.1. Baseline Characteristics of the Participants (N = 530)

| | Total N = 530 | Non-Hypertensive N = 376 | Hypertensive N= 154 | P-value |
|---|---|---|---|---|
| Age | | | | <0.01 |
| < 40 years | 126 (23.8) | 111 (29.5) | 15 (9.8) | |
| 40-59 years | 335 (63.2) | 227 (60.4) | 108 (70.1) | |
| 60 years and over | 69 (13.0) | 38 (10.1) | 31 (20.1) | |
| Gender | | | | <0.01 |
| Male | 224 (42.3) | 131 (34.8) | 93 (60.4) | |
| Female | 306 (57.7) | 245 (65.2) | 61 (39.6) | |
| Ethnicity | | | | 0.07 |
| Chinese | 177 (33.4) | 137 (36.4) | 40 (26.0) | |
| Korean | 179 (33.8) | 121 (32.2) | 58 (37.7) | |
| Vietnamese | 174 (33.8) | 118 (31.4) | 56 (36.3) | |
| BMI (mean[SD]) | 23.4 (3.4) | 22.6 (3.1) | 25.4 (3.2) | <0.01 |
| Marital status | | | | 0.29 |
| Married | 411 (77.6) | 287 (76. 3) | 124 (80.5) | |
| Not married | 119 (22.4) | 89 (23.7) | 30 (19.5) | |
| Education | | | | <0.01 |
| Less than high school | 68 (12.8) | 40 (10.6) | 28 (18.2) | |
| High school or some college+ | 202 (38.1) | 135 (35.9) | 67 (43.5) | |
| College graduate + | 260 (49.1) | 201 (53.5) | 59 (38.3) | |
| Employment status | | | | 0.77 |
| Employed | 356 (67.2) | 122 (32.4) | 52 (33.8) | |
| Unemployed | 174 (32.8) | 254 (67.6) | 102 (66.2) | |
| Self-rated Identity | | | | 0.07 |
| Very Asian | 304 (57.2) | 205 (54.5) | 99 (64.3) | |
| Mostly Asian | 88 (16.5) | 63 (16.8) | 25 (16.2) | |
| Bicultural/Westernized | 140 (26.3) | 108 (28.7) | 30 (19.5) | |
| English speaking | | | | <0.01 |
| Poorly/not at all | 194 (36.6) | 126 (33.5) | 68 (44.2) | |
| So-so | 207 (39.1) | 143 (38.0) | 64 (41.5) | |
| Native/very well | 129 (24.3) | 107 (28.5) | 22 (14.3) | |
| Smoke | | | | <0.01 |
| Smoker | 94 (17.7) | 51 (13.6) | 43 (27.9) | |
| Non-smoker | 438 (82.3) | 325 (86.4) | 111 (72.1) | |
| Binge drink | | | | 0.31 |
| Yes | 67 (12.6) | 44 (11.7) | 23 (14.9) | |
| No | 463 (82.4) | 332 (88.3) | 131 (85.1) | |
| Perceived Stress | | | | 0.01 |
| Low | 251 (47.2) | 192 (51.1) | 59 (38.3) | |

| | | | | |
|---|---|---|---|---|
| High | 281 (52.8) | 184 (48.9) | 95 (61.7) | |
| Social Network Index Score | | | | 0.84 |
| socially isolated | 67 (12.6) | 46 (12.2) | 21 (13.6) | |
| moderately isolated | 115 (21.6) | 83 (22.1) | 31 (20.1) | |
| moderately integrated | 162 (30.5) | 117 (31.1) | 44 (28.6) | |
| socially integrated | 188 (35.3) | 130 (34.6) | 58 (37.7) | |
| Social support | | | | <0.01 |
| Low | 282 (53.0) | 179 (47.6) | 101 (65.6) | |
| High | 250 (47.0) | 197 (52.4) | 53 (34.4) | |

Table 3.2. Age adjusted logistic regression models of psychological factors and hypertension (N = 530)

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Perceived Stress | | | |
| Low | ref | | |
| High | 1.71 (1.15, 2.54)* | | |
| Social Network Index Score | | | |
| socially isolated | | ref | |
| moderately isolated | | 0.66 (0.33, 1.34) | |
| moderately integrated | | 0.60 (0.31, 1.17) | |
| socially integrated | | 0.65 (0.34, 1.24) | |
| Social support | | | |
| Low | | | ref |
| High | | | 0.49 (0.33, 0.74)* |
| Age | | | |
| < 40 years | ref | ref | ref |
| 40-59 years | 3.52 (1.95, 6.33)* | 3.88 (2.11, 7.12)* | 3.50 (1.94, 6.32)* |
| 60 years and over | 6.18 (3.00, 12.74)* | 6.45 (3.10, 13.39)* | 5.69 (2.76, 11.75)* |

*p<0.05

Table 3.3. Multivariable logistic regression models of psychological factors and hypertension (N = 530)

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Perceived Stress | | | |
| Low | ref | | |
| High | 1.61 (1.03, 2.51)* | | |
| Social Network Index Score | | | |
| socially isolated | | ref | |
| moderately isolated | | 0.51 (0.23, 1.12) | |
| moderately integrated | | 0.42 (0.19, 0.92)* | |
| socially integrated | | 0.52 (0.25, 1.12) | |
| Social support | | | |
| Low | | | ref |
| High | | | 0.52 (0.33, 0.81)* |
| Age | | | |
| < 40 years | ref | ref | ref |
| 40-59 years | 3.04 (1.54, 5.98)* | 3.52 (1.72, 7.22)* | 3.13 (1.59, 6.20)* |
| 60 years and over | 4.32 (1.86, 10.06)* | 4.82 (2.01, 11.52)* | 4.18 (1.79, 9.76)* |
| Gender | | | |
| Male | ref | ref | ref |
| Female | 0.43 (0.26, 0.73)* | 0.44 (0.26, 0.74)* | 0.47 (0.28, 0.80)* |
| BMI (mean[SD]) | 1.28 (1.19, 1.38)* | 1.29 (1.20, 1.39)* | 1.30 (1.21, 1.39)* |
| Education | | | |
| Less than high school | ref | ref | ref |
| High school or some college+ | 0.85 (0.44, 1.65) | 0.86 (0.43, 1.69) | 0.89 (0.46, 1.74) |
| College graduate + | 0.54 (0.26, 1.09) | 0.57 (0.28, 1.17) | 0.56 (0.28, 1.15) |
| Employment status | | | |
| Unemployed | ref | ref | ref |
| Employed | 0.89 (0.54, 1.47) | 0.94 (0.56, 1.56) | 0.85 (0.51, 1.41) |
| Self-rated Identity | | | |
| Very Asian | ref | ref | ref |
| Mostly Asian | 1.05 (0.57, 1.94) | 1.06 (0.57, 1.98) | 1.08 (0.58, 2.02) |
| Bicultural/Westernized | 0.67 (0.38, 1.19) | 0.64 (0.36, 1.15) | 0.70 (0.39, 1.23) |
| English speaking | | | |
| Poorly/not at all | ref | ref | ref |
| So-so | 1.07 (0.63, 1.81) | 1.06 (0.63, 1.81) | 1.09 (0.64, 1.85) |
| Native/very well | 0.57 (0.27, 1.23) | 0.49 (0.23, 1.05) | 0.60 (0.28, 1.30) |
| Smoke | | | |
| Non-smoker | ref | ref | ref |
| Smoker | 1.24 (0.67, 2.29) | 1.30 (0.71, 2.39) | 1.28 (0.70, 2.36) |
| Binge drink | | | |
| No | ref | ref | ref |
| Yes | 0.90 (0.46, 1.77) | 0.95 (0.49, 1.87) | 0.92 (0.47, 1.81) |

*p<0.05

Table 3.4. Logistic regression models of psychological factors and hypertension by gender (N = 530)

| | Male<br>N = 224 | Female<br>N = 306 |
|---|---|---|
| Perceived Stress | | |
| Low | ref | ref |
| High | 1.95 (1.05, 3.60)* | 1.53 (0.78, 3.00) |
| Social Network Index Score | | |
| socially isolated | ref | ref |
| moderately isolated | 0.22 (0.07, 0.71) | 1.22 (0.35, 4.29) |
| moderately integrated | 0.23 (0.07, 0.76) | 0.79 (0.24, 2.66) |
| socially integrated | 0.25 (0.08, 0.82) | 1.03 (0.31, 3.36) |
| Social support | | |
| Low | ref | ref |
| High | 0.50 (0.26, 0.93)* | 0.48 (0.24, 0.94)* |

*$p<0.05$

Adjusted for age, gender, BMI, education, employment status, self-identity, English speaking, smoke and binge drinking

Table 3.5. Logistic regression models of psychological factors and hypertension by ethnicity (N = 530)

| | Chinese N =177 | Korean N = 179 | Vietnamese N = 174 |
|---|---|---|---|
| Perceived Stress | | | |
| Low | ref | ref | ref |
| High | 3.78 (1.13, 6.80)* | 1.03 (0.46, 2.31) | 1.73 (0.84, 3.57) |
| Social Network Index Score | | | |
| socially isolated | ref | ref | ref |
| moderately isolated | 0.28 (0.07, 1.06) | 2.03 (0.26, 16.08) | 0.64 (0.16, 2.53) |
| moderately integrated | 0.29 (0.07, 1.24) | 0.89 (0.11, 6.95) | 0.57 (0.16, 2.03) |
| socially integrated | 0.40 (0.10, 1.65) | 0.94 (0.13, 7.03) | 1.02 (0.28, 3.73) |
| Social support | | | |
| Low | ref | ref | ref |
| High | 0.36 (0.15, 0.87)* | 0.47 (0.20, 1.07) | 0.58 (0.26, 1.29) |

*$p<0.05$

Adjusted for Age, gender, BMI, education, employment status, self-identity, English speaking, smoke and binge drinking

**Appendix**

Table 3.6. Compare characteristics between analysis sample and excluded sample with missing values

| | Analysis sample (n = 530) | Excluded sample (n = 70) | P-Value |
|---|---|---|---|
| Age | | | 0.10 |
| < 40 years | 126 (23.8) | 10 (14.3) | |
| 40-59 years | 335 (63.2) | 46 (65.7) | |
| 60 years and over | 69 (13.0) | 14 (20.0) | |
| Gender | | | 0.72 |
| Male | 224 (42.3) | 28 (40.0) | |
| Female | 306 (57.7) | 42 (60.0) | |
| Ethnicity | | | 0.49 |
| Chinese | 177 (33.4) | 24 (34.3) | |
| Korean | 179 (33.8) | 19 (27.1) | |
| Vietnamese | 174 (33.8) | 27 (38.6) | |
| BMI (mean[SD]) | 23.4 (3.4) | | |
| Marital status | | | |
| Married | 411 (77.6) | | |
| Not married | 119 (22.4) | | |
| Education | | | <0.01 |
| Less than high school | 68 (12.8) | 18 (25.7) | |
| High school or some college+ | 202 (38.1) | 21 (30.0) | |
| College graduate + | 260 (49.1) | 25 (35.7) | |
| Missing | 0 | 6 (8.6) | |
| Employment status | | | <0.01 |
| Employed | 356 (67.2) | 42 (60.0) | |
| Unemployed | 174 (32.8) | 25 (35.7) | |
| Missing | 0 | 3 (4.3) | |
| Self-rated Identity | | | <0.01 |
| Very Asian | 304 (57.2) | 37 (52.9) | |
| Mostly Asian | 88 (16.5) | 11 (15.7) | |
| Bicultural/Westernized | 140 (26.3) | 19 (27.1) | |
| Missing | | 3 (4.3) | |
| English speaking | | | 0.31 |
| Poorly/not at all | 194 (36.6) | 31 (44.3) | |
| So-so | 207 (39.1) | 27 (38.6) | |
| Native/very well | 129 (24.3) | 12 (17.1) | |
| Missing | 0 | | |
| Smoke | | | <0.01 |
| Smoker | 94 (17.7) | 10 (14.3) | |
| Non-smoker | 438 (82.3) | 54 (77.1) | |
| Missing | 0 | 6 (8.6) | |
| Binge drink | | | 0.53 |

| | | |
|---|---|---|
| Yes | 67 (12.6) | 63 (90.0) |
| No | 463 (82.4) | 7 (10.0) |

Table 3.7. Age-adjusted logistic regression models of each factor and hypertension (N = 530)

| | OR (95% CI) |
|---|---|
| Gender | |
| Male | ref |
| Female | 0.32 (0.22, 0.48)* |
| Ethnicity | |
| Chinese | ref |
| Korean | 1.61 (0.99, 2.62) |
| Vietnamese | 1.55 (0.95, 2.52) |
| BMI | 1.31 (1.22, 1.40)* |
| Marital status | |
| Not Married | ref |
| Married | 1.04 (0.64, 1.70) |
| Education | |
| Less than high school | ref |
| High school or some college+ | 0.85 (0.48, 1.53) |
| College graduate + | 0.55 (0.31, 0.99)* |
| Employment status | |
| Unemployed | ref |
| Employed | 1.12 (0.74, 1.70) |
| Self-rated Identity | |
| Very Asian | ref |
| Mostly Asian | 0.92 (0.54, 1.57) |
| Bicultural/Westernized | 0.61 (0.38, 0.98) |
| English speaking | |
| Poorly/not at all | ref |
| So-so | 0.95 (0.62, 1.47) |
| Native/very well | 0.53 (0.30, 0.94)* |
| Smoking | |
| Non-smoker | ref |
| Smoker | 2.45 (1.73, 3.46)* |
| Binge drinking | |
| No | ref |
| Yes | 1.63 (0.93, 2.87) |
| Perceived Stress | |
| Low | ref |
| High | 1.71 (1.15, 2.54)* |
| Social Network Index Score | |
| socially isolated | ref |
| moderately isolated | 0.66 (0.33, 1.34) |
| moderately integrated | 0.60 (0.31, 1.17) |
| socially integrated | 0.65 (0.34, 1.24) |
| Social support | |
| Low | ref |
| High | 0.49 (0.33, 0.74)* |

*$p<0.05$

Table 3.8. Assess potential effect modifications

(a) Stress x social support

| | Estimate | Standard Error | P-value |
|---|---|---|---|
| Perceived Stress | 0.12 | 0.13 | **0.34** |
| Social support | -0.28 | 0.13 | **0.03** |
| Stress x support | -0.04 | 0.13 | **0.77** |

Adjusted for Age, gender, BMI, education, employment status, self-identity, English speaking, smoke and binge drinking

(b) Stress x social network index

| | Estimate | Standard Error | P-value |
|---|---|---|---|
| Perceived Stress | 0.25 | 0.12 | **0.04** |
| Social network index | | | **0.11** |
| socially isolated | ref | ref | ref |
| moderately isolated | -0.08 | 0.21 | 0.16 |
| moderately integrated | -0.43 | 0.21 | 0.04 |
| socially integrated | -0.10 | 0.18 | 0.21 |
| Stress x social network index | | | **0.48** |
| Stress x socially isolated | ref | ref | ref |
| Stress x moderately isolated | 0.12 | 0.21 | 0.56 |
| Stress x moderately integrated | 0.25 | 0.20 | 0.21 |
| Stress x socially integrated | -0.10 | 0.18 | 0.57 |

Adjusted for Age, gender, BMI, education, employment status, self-identity, English speaking, smoke and binge drinking

(c) Stress x gender

| | Estimate | Standard Error | P-value |
|---|---|---|---|
| Perceived Stress | 0.25 | 0.11 | **0.02** |
| Gender | -0.41 | 0.13 | **< 0.01** |
| Stress x support | -0.09 | 0.11 | **0.07** |

Adjusted for Age, BMI, education, employment status, self-identity, English speaking, smoke and binge drinking

(d) Stress x age group

| | Estimate | Standard Error | P-value |
|---|---|---|---|
| Perceived Stress | 0.25 | 0.14 | **0.08** |
| Age | | | **<0.01** |
| < 40 years | ref | ref | ref |
| 40-59 years | 0.25 | 0.17 | 0.14 |
| 60 years and over | 0.59 | 0.23 | <0.01 |
| Stress x social network index | | | **0.82** |
| Stress x < 40 years | ref | ref | ref |
| Stress x 40-59 years | -0.03 | 0.16 | 0.06 |
| Stress x 60 years and over | 0.14 | 0.21 | 0.39 |

Adjusted for gender, BMI, education, employment status, self-identity, English speaking, smoke and binge drinking

(e) Stress x smoke

| | Estimate | Standard Error | P-value |
|---|---|---|---|
| Perceived Stress | 0.20 | 0.13 | **0.12** |
| Smoke | 0.18 | 0.32 | **0.57** |
| Stress x smoke | 0.19 | 0.28 | **0.50** |

Adjusted for Age, gender, BMI, education, employment status, self-identity, English speaking, and binge drinking

(f) Stress x English speaking

| | Estimate | Standard Error | P-value |
|---|---|---|---|
| Perceived Stress | 0.27 | 0.12 | **0.03** |
| Social network index | | | **0.17** |
| Poorly/not at all | ref | ref | ref |
| So-so | 0.26 | 0.16 | 0.16 |
| Native/very well | -0.40 | 0.22 | 0.04 |
| Stress x social network index | | | **0.37** |
| Stress x Poorly/not at all | ref | ref | ref |
| Stress x So-so | -0.23 | 0.16 | 0.16 |
| Stress x Native/very well | -0.17 | 0.20 | 0.40 |

Adjusted for Age, gender, BMI, education, employment status, self-identity, smoke and binge drinking

Table 3.9. Baseline Characteristics of the Participants by Ethnicity (N = 530)

| | Chinese (n = 177) | Korean (n = 179) | Vietnamese (n = 174) | P value |
|---|---|---|---|---|
| Age | | | | 0.01 |
| < 40 years | 57 (32.2) | 35 (19.6) | 34 (19.5) | |
| 40-59 years | 93 (52.5) | 125 (69.8) | 117 (67.2) | |
| 60 years and over | 27 (15.3) | 19 (10.6) | 23 (13.2) | |
| Gender | | | | 0.90 |
| Male | 74 (41.8) | 74 (41.3) | 76 (43.7) | |
| Female | 103 (58.2) | 105 (58.7) | 98 (56.3) | |
| BMI (mean[SD]) | | | | |
| Education | | | | <0.01 |
| Less than high school | 11 (6.2) | 11 (6.1) | 46 (26.4) | |
| High school + | 32 (18.1) | 76 (42.5) | 94 (54.0) | |
| College graduate + | 134 (75.7) | 92 (51.4) | 34 (19.6) | |
| Employment status | | | | 0.08 |
| Employed | 111 (62.7) | 117 (65.4) | 128 (73.6) | |
| Unemployed | 66 (37.3) | 62 (34.6) | 46 (26.4) | |
| Self-rated Identity | | | | <0.01 |
| Very Asian | 58 (32.8) | 160 (89.4) | 86 (48.4) | |
| Mostly Asian | 47 (26.5) | 5 (2.8) | 36 (20.7) | |
| Bicultural/Westernized | 72 (40.7) | 14 (7.8) | 52 (29.9) | |
| English speaking | | | | <0.01 |
| Poorly/not at all | 35 (19.8) | 80 (44.7) | 79 (45.4) | |
| So-so | 65 (36.7) | 69 (38.5) | 73 (42.0) | |
| Native/very well | 77 (43.5) | 39 (16.8) | 22 (12.6) | |
| Smoking | | | | <0.01 |
| Smoker | 18 (10.2) | 46 (25.7) | 30 (17.2) | |
| Non-smoker | 159 (89.8) | 133 (74.3) | 146 (82.8) | |
| Binge drinking | | | | <0.01 |
| Yes | 8 (4.5) | 31 (17.3) | 28 (16.1) | |
| No | 169 (95.5) | 148 (82.7) | 146 (83.9) | |
| Perceived Stress | | | | <0.01 |
| Low | 92 (52.0) | 64 (35.8) | 95 (54.6) | |
| High | 85 (48.0) | 115 (64.2) | 79 (45.4) | |
| Social Network Index | | | | <0.01 |
| Score | | | | |
| socially isolated | 31 (17.5) | 10 (5.6) | 26 (15.0) | |
| moderately isolated | 55 (31.1) | 27 (15.1) | 32 (18.4) | |
| moderately integrated | 42 (23.7) | 57 (31.8) | 62 (35.6) | |
| socially integrated | 49 (27.7) | 85 (47.5) | 54 (30.0) | |
| Social support | | | | 0.11 |
| Low | 87 (49.2) | 106 (59.2) | 87 (50.0) | |
| High | 90 (50.8) | 73 (40.8) | 87 (49.0) | |

# Chapter 4: A longitudinal Assessment of Parental Caregiving and Blood Pressure Trajectories: Findings from the China Health and Nutrition Survey for Women 2000-2011

To be submitted for publication

**ABSTRACT**

**Background:** Few studies have investigated the consequences of caregiving on the objectively measured physiological health outcomes in China. This study used population based longitudinal data to examine the association between parental caregiving and blood pressure among Chinese women.

**Method**: This is a retrospective analysis of 2,586 women using five waves of data from the Ever-Married Women Survey component of the China Health and Nutrition Survey (2000, 2004, 2006, 2009, and 2011). We applied growth curve models to examine trajectories of systolic blood pressure (SBP) and diastolic blood pressure (DBP) associated with parental caregiving among women in China.

**Results**: In multivariable analyses of blood pressure trajectories adjusting for potential confounders, parental caregivers were associated with higher systolic (β-coefficient (β) = 1.16; $p \leq 0.01$) and diastolic blood pressure ($\beta = 0.75$; $p \leq 0.01$) compared with non-caregivers across multiple waves. Caregivers and non-caregivers had similar levels of systolic blood pressure at baseline, but caregivers exhibited relatively higher growth rate over time. Diastolic blood pressure was much higher among caregivers at the baseline measure, and across time relative to non-caregivers. Moreover, low-intensity but not high-intensity caregivers showed higher growth rate compared with non-caregivers for both SBP and DBP.

**Discussion**: Our results demonstrate the negative cardiovascular consequences of parental caregiving among Chinese women. Findings from the study can be used to develop future stress management interventions to decrease hypertension risk within women who provide care to their parents.

## 4.1 Introduction

Cardiovascular disease (CVD) is the most common cause of death in China (121), with hypertension accounting for about 45% of CVD morbidity and mortality (6). While elevated blood pressure is one of the major modifiable risk factors for CVD, accumulating evidence has shown that hypertension is increasingly prevalent in China (6). According to national data from the "Survey on the Status of Nutrition and Health of the Chinese People", the prevalence of hypertension was 5.1% in 1959, rising to 7.7% in 1979, 13.6% in 1991, and 18.8% in 2002 (6). A recent study found that 41.9% of Chinese individuals ages 35-70 years had hypertension between 2005 and 2009 (7). Moreover, the prevalence was higher among men than women (41.9% versus 38.4%, $P < 0.001$),

Caregiving may be a possible explanation for the observed increases in the prevalence of hypertension. Providing care to aging family members is an increasing phenomenon in Chinese society. Nowadays, the demographic changes to China's age structure are astonishing. The proportion of the population aged 65 and older in China increased by 5% from 1953 to 2010 (21). The increased life expectancy among older Chinese has also introduced new burdens on the family. Adult children shoulder greater responsibility in caring for their aging parents with chronic illness compared to the past. The values of Confucianism and collectivism impose on Chinese individuals the duty of care of older people on family members. The proportion of adult children providing caregiving on a daily basis is higher in China (57.1%) compared to those in western countries (33.3%) (136, 137).

Prior research exhibits inconsistent evidence regarding the relationship between caregiving and blood pressure. Some studies indicated that the provision of care could increase the risk of hypertension (177, 178, 225), while others found that caregivers and non-caregivers

were comparable in their blood pressure and anti-hypertensive drug use even after adjusting for potential confounders (174). Data on the impact of caregiving on caregivers' health among Chinese are limited. Existing published studies have mostly examined the subjective health outcomes, such as self-rated health, quality of life and mental health problems (22). Liu et al. conducted a prospective study to examine the impact of parental caregiving on self-rated health among Chinese women. They found that caregivers had consistently worse self-rated health status than non-caregiver (22). Ho et al. investigated the impact of caregiving on health status and quality of life among primary informal caregivers of elderly care recipients in Hong Kong through a cross sectional study (180). The results presented that caregivers had significantly increased risk for reporting worse health, poorer QOL, more doctor visits, anxiety and depression, and weight loss compared to non-caregivers (180). However, little existing research attempts to understand the impact of parental caregiving on blood pressure among Chinese in China.

To fill this important gap, we sought to investigate the influence of parental caregiving on blood pressure trajectories among Chinese women. We hypothesized that caregivers would have higher systolic and diastolic blood pressure over the study period. This study provides unique insights into the blood pressure trajectories among caregivers which can be used to develop future stress management interventions, rooted in in community outreach and education, to decrease cardiovascular disease risk among Chinese caregivers.

## 4.2 Methods

Data source

This study used data from the China Health and Nutrition Survey (CHNS), which is a large-scale longitudinal survey conducted by the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention (199). The CHNS data involves nine large provinces across a wide geographic region with a range of economic and demographic variation. Approximately 56% of the Chinese population resides in these nine provinces. The age distribution in the CHNS is slightly older than that of the national China census in 2009, which includes approximately 3% more individuals aged 60 and older, and 3% fewer children and adolescents. A detailed description of the survey design and procedures has been published elsewhere (199).

The analytic sample in this study used the Ever-Married Women (EMW) Survey, which is a component of the CHNS and provides a unique opportunity to assess detailed information on the socioeconomic, behavioral, and familial contexts of women caregivers in China. The EMW was initiated in 1991 and now includes eight waves of data through 2011 with added respondents and replenished sample in follow-up years. Due to changes in the format of the blood pressure measure, we used a sample of respondents who participated in the 2000, 2004, 2006, 2009 and 2011 waves of the EMW in this study to better ensure comparability of measures. Additionally, we restricted the dataset respondents who provided substantive answers to the variables included in the analysis in all five waves. Individuals (N=6740) were excluded from analyses if they had missing data for the independent variables, dependent variable, covariates, or only had one wave of data (see Figure 1 in Appendix). Cases had two or more than two waves of data were included in the analysis. Compared to the excluded sample (N = 5618), women remaining (N = 2586) in the analysis sample tended to be more educated, married, employed, not have insurance, less

likely to smoke, and less likely to drink alcohol (see Table 4.4 in Appendix). We addressed this potential selection bias in the discussion section. The final analytic sample includes data from 2586 women during the 11 years study period. Among women included in the sample, 1136 (43.9%) were observed for two waves; 721 (28.9%) were observed for three waves; 631 (24.4%) were observed for four waves; and 98 (3.8%) were observed for all five waves of data during the study period.

Measures

*Dependent variable*

Three dependent variables were used in the analysis: systolic blood pressure (SBP), diastolic blood pressure (DBP), and hypertension. Data from all five waves were used to capture the blood pressure trajectories. Blood pressure was measured by trained examiners using a mercury sphygmomanometer according to a standard protocol (226). Measures were collected in triplicate after a ten-minute seated rest. According to the American Heart Association's recommendations, at least two seated blood pressures should be properly taken (210). The mean of the latter two readings were used in the analysis. Hypertension was defined as: 1. SBP of 140 mmHg or higher or DBP of 90 mmHg or higher; or 2. use of antihypertensive drugs. The change of hypertension status was assessed by comparing the baseline data to the final wave of data (see Table 4.5 in Appendix).

*Independent variable*

Caregiving status was examined as a key independent variable predicting blood pressure change. All respondents were asked: "During the past week, did you help your mother with her daily life and shopping?" Response was either yes or no. Comparable questions were asked about respondents' care for their fathers, mothers-in-law, and fathers-in-law, respectively.

Caregiving intensity was defined as the cumulative time spent on caring for parents and parents-in-laws. The respondents were asked: "During the past week, how many hours did you spend taking care of your mother?" Comparable questions were asked about respondents' care for their fathers, mothers-in-law, and fathers-in-law, respectively. We operationalized caregiving duration as "high intensity" (14 or more hours of care per week), "low intensity" (1-14 hours of care per week), and "no care" (reference group). We chose 14 hours as a cut-point to be consistent with prior evidence (227) which suggests that this cut-point had construct validity. Specifically, respondents who provided more than 14 hours/week of care were significantly more likely to report that their care recipient "made too many demands" than either those who provided less than 14 hours/week or no care at all (227).

*Covariates*

The selection of covariates was guided a priori by existing literature. This study included sociodemographic variables (age, education, employment status, and marital status), healthcare access (insurance), and health behaviors (body mass index (BMI), alcohol consumption and smoking status). All the covariates were assessed as the time-varying covariates except for age (baseline). Age was coded as a continuous variable (in years). Education attainment was categorized into 6 groups: none (reference), primary school graduate, lower middle school degree, upper middle school degree, technical or vocational degree, and college degree. Employment status was grouped as working vs. not working (reference). Marital status was coded as married vs. never married/divorced/widowed (reference). Insurance was assessed as yes vs. no (reference). For the health behaviors, alcohol consumption was coded as currently drinking (drink beer or any other alcoholic beverage during the current year) vs. currently not drinking (reference). Smoking status was grouped as currently smoking vs. not currently

smoking (reference). Height was measured without shoes to the nearest 0.1 cm using a portable SECA stadiometer (Seca North America East, Hanover, MD, USA); weight was measured without shoes and in light clothing to the nearest 0.1 kg on a calibrated beam balance. BMI was calculated as body weight (in kilograms) divided by the square of height (in meters).

Statistical Analysis

Descriptive statistics were performed by determining means of continuous variables and proportions of categorical variables to describe the characteristics of the study population at baseline. Baseline sample characteristics were compared by caregiving status and covariates using the t-test for continuous variables and the Pearson chi-square test for categorical variables. The statistical significance was based on the p value less than 0.05.

To assess the relationship between parental caregiving and blood pressure, growth curve models were used to simultaneously estimate intraindividual as well as interindividual blood pressure trajectories, with particular attention paid to the effect of parental caregiving status and parental caregiving intensity. Both age and time (five waves) based preliminary growth curve models were fitted, and time based model provided more robust and statistically significant results. Repeated measures of blood pressure were included in the model estimation. The model has two levels, with repeated measurements of individuals at Level 1 being nested across individuals at Level 2. The Level 1 model captures within-individual change of the outcome variable blood pressure $y_{ti}$ over time. We first fitted a linear change trajectory model of blood pressure ($y_{ti}$) of individual i at time t (wave) as a function of time ($Time_{ti}$). A quadratic term was added to check the nonlinear pattern of blood pressure increase. We used centered time in the quadratic model to avoid multicollinearity and to decrease the probability of errors in the

estimation of regression parameters and standard errors. We further added our key independent variable caregiving status. Thus, the basic level 1 model can be expressed as

$$\overline{Y_{ti}} = \beta_{0i} + \beta_{1i}cTime_{ti} + \beta_{2i}cTime_{ti}^2 + \beta_{3i}caregiving_{ti}$$

The level 2 model captures interindividual difference in change where the coefficients βs in the level 1 model are further modeled as dependent variable. In the level 2 models, $\gamma_{00}$ is the mean intercept of the time trajectory, $\gamma_{10}$ is the mean linear component of the slope of the time trajectory and $\gamma_{20}$ is the mean quadratic component of the slope of the time trajectory. For person i, $u_{0i}$ is the random effect of the intercept term, $u_{1i}$ is the random effect of the linear component of the slope, and $u_{2i}$ is the random effect of the quadratic component of the slope. The three unconditional models of the intercept model$\beta_{0i}$, the linear rate of change $\beta_{1i}$ and the quadratic rate of change $\beta_{2i}$ are listed as below:

$$\beta_{0i} = \gamma_{00} + u_{0i}$$

$$\beta_{1i} = \gamma_{10} + u_{1i}$$

$$\beta_{2i} = \gamma_{20} + u_{2i}$$

Combining the level 1 and level 2 models together, the composite model is presented as:

$$\overline{Y_{ti}} = \gamma_{00} + \gamma_{10}cTime_{ti} + \gamma_{20}cTime_{ti}^2 + \beta_{3i}caregiving_{ti} + (u_{0i} + u_{1i}cTime_{ti} + u_{2i}cTime_{ti}^2 + e_{ti})$$

All statistical analyses were performed by using SAS 9.4. The statistical significance was based on the p value less than 0.05, and the marginal significant was defined as greater than 0.05 and less than 0.1.

## 4.3 Results

Descriptive findings for the baseline characteristics of participants by caregiving status are presented in table 1. The average age of the study sample was 37 years. While most of the study population was married (97.9%) and employed (72%), only 35% of participants reported having health insurance. Regarding the educational attainment, 9.6% did not receive any education, 22.4% had primary school degree, 41.7% had lower middle school degree, 15.1% had upper middle school degree, 11.2% had technical degree or college degree. For the health behaviors, 1.8% of women had a history of smoking and 9.1% were current alcohol drinkers. Compared with non-caregivers, caregivers were more likely to be older, higher educated, to have insurance, and to currently drink alcohol.

Table 2 reports the estimates for the effects of caregiving status on mean levels of blood pressure and blood pressure trajectories with adjustments for socioeconomic status, health care access, and health behaviors. Model 1 and model 4 present differences in levels of blood pressure by caregiving status across the waves with adjustments for baseline age. Results show that caregivers had moderately higher average SBP elevation ($\beta = 0.71$; $p \leq 0.05$) and DBP elevation ($\beta = 0.73$; $p \leq 0.05$) than those who did not provide caregiving for their parents across multiple waves. Both linear and quadratic time effects were significantly positive in SBP ($p < 0.05$), which suggested an accelerated elevation in SBP over time. There was also a significant linear elevation in DBP ($p < 0.05$), but the quadratic time effect for DBP was not significant, so we excluded quadratic slopes in model 4 - 6. Model 2 and model 5 tested the impact of caregiving status on the linear and/or quadratic growth rates in SBP and DPB in addition to initial mean levels of the blood pressures trajectories. The interactions between caregiving status and linear/quadratic time did not vary significant, suggesting a similar growth rates among

caregivers and non-caregivers. Model 3 and Model 6 summarized the full models adjusting all the covariates. In model 3, caregivers had 1.16 mmHg higher SBP compared with non-caregivers after taking other covariates into consideration across multiple waves ($\beta = 1.16$; $p \leq 0.05$). Again, the estimates of time effect show that there was a significant linear increase in SBP ($p < 0.05$) over the five waves. The quadratic effect, suggesting an accelerated elevation in blood pressure over time, was marginally significant in SBP ($p = 0.06$). The interactions between caregiving status and linear/quadratic time did not vary significantly in caregiving status, suggesting a similar growth rates among caregivers and non-caregivers. In model 6, caregivers remained a positive predictor of DBP ($\beta = 0.75$; $p \leq 0.05$). There was a significant time effect in SBP ($p < 0.05$), but the interaction between caregiving status and time was not statistically significant.

Figure 1a and 1b illustrate the effects of parental caregiving status on blood pressure trajectories among Chinese women based on the fully adjusted models with all the other control variables set to their sample means (for continuous variables) or modes (for categorical variables). Figure 1a presents the predicted trajectories of SBP by caregiving status among Chinese women, with no disparity observed for SBP levels between caregivers and non-caregivers at baseline. As women aged, the levels of SBP increased for both groups. However, the growth of SBP among caregivers was slightly precipitous compared with non-caregivers. Figure 1b shows the predicted trajectories of DBP by caregiving status whereby DBP was much higher among caregivers at the baseline, and this disparity was persistent over time.

Table 3 presents findings for the assessment of caregiving intensity on blood pressure trajectories. Model 1 and model 4 examine how levels of blood pressure differed by caregiving intensity across multiple waves with adjustments for baseline age. Results show no significant difference in SBP among high-intensity, low intensity, and non-caregivers. Caregivers who

provide low-intensity care had moderately higher average DBP ($\beta = 0.77$, $p \leq 0.05$) than those who did not provide caregiving for their parents. Both linear and quadratic time effects were significant in SBP ($p < 0.05$), which suggested an accelerated elevation in SBP over time. Model 2 and model 5 tested the impact of caregiving intensity on the linear and/or quadratic growth rates in SBP and DPB in addition to initial mean levels of the blood pressures trajectories. The interactions between caregiving intensity and linear/quadratic time did not vary significant, suggesting a similar growth rates among high-intensity caregivers, low-intensity caregivers and non-caregivers. Model 3 and Model 6 are the full models adjusting all the covariates. In model 3, the SBP was increased by 1.19 mmHg among low-intensity caregivers compared with non-caregivers ($p = 0.07$). In model 6, low-intensity caregivers remained a positive predictor of DBP: those with low-intensity caregiving had 0.80 mmHg higher DBP compared with non-caregivers ($p = 0.02$). However, the SBP and DBP were not significantly different among high-intensity caregivers compared with non-caregivers when other covariates were considered. There was a significant time effect in SBP ($p < 0.05$), but the interaction between caregiving intensity and time was not statistically significant.

Figure 1c and 1d suggest that the parental caregiving intensity affected blood pressure trajectories, and the growth rate of blood pressure was non-linear for SBP but linear for DBP. In figure 1c, the initial SBP was lower in the high-intensity caregiving group compared to the other two groups. However, the high-intensity caregiving group experienced a steeper increase in SBP from 2000 to 2009. The SBP disparity among the three groups reduced over time. Figure 1d shows the predicted trajectories of DBP by caregiving intensity. The figure suggests that the difference in initial diastolic blood pressure was largest among the three groups, and the

difference came to be smaller as year increased. Still, high-intensity caregivers showed the highest DBP in year 2010.

We assessed the change of hypertension by caregiving status from baseline to the final wave of the data (Appendix table 4.4). There was no significant difference in the change of hypertension status between caregivers and non-caregivers.

## 4.4 Discussion

Our study is one of the first to investigate how caregiving burden affects blood pressure trajectories among women in China. The findings from this study clearly indicate that women who provide parental care exhibit higher systolic and diastolic blood pressure compared with non-caregivers over time. In addition, caregiving intensity plays a significant role in the trajectory of blood pressure. Low-intensity but not high-intensity caregivers show higher growth rate compared with non-caregivers for both SBP and DBP.

One of the notable findings of this study is the positive association between parental caregiving status and blood pressure among Chinese women. Caregiving can be considered as a type of chronic stress due to the fact that caregivers consistently experience higher levels of self-reported stress and stress-related biomarkers than non-caregivers (138-140). The mechanisms through which chronic stress may be linked to blood pressure are complex and involve a variety of interrelated physiological, behavioral, and emotional pathways (218). The effect of caregiving stress on blood pressure can be direct: chronic stress can stimulate the sympathetic nervous system (SNS), which may further lead to sustained increase in blood pressure and vascular hypertrophy (228). Evidence has also shown that the effect of caregiving on health can be indirect. Studies have consistently revealed that caregiving is associated with the lack of time for

other family members, lower marital quality, and decreased involvement in social activities (168-170). Moreover, behavioral changes may occur as adaptations to caregiving stress. Caregivers tend to engage in poor health behaviors, such as alter normal patterns of diet, smoking, and alcohol consumption (229). Our data suggest caregivers reported more alcohol drinking than non-caregivers (13,6% vs. 8.4%, $p < 0.05$).

Our results also demonstrate that the predicted blood pressure trajectories were noticeably different between caregivers and non-caregivers. We found that women who provide parental care had similar SBP at initial observed time-point compared with non-caregivers, but the growth rate among caregivers was relatively higher over time. This phenomenon is in line with the wear and tear theory proposed in the caregiving literature (230), which suggests that the accumulation of caregiving demands erodes caregivers' resources and well-being. Consequently, the negative impact of caregiving persist and accrue over time (230). On the other hand, the figure of diastolic blood pressure indicates that the initial difference in diastolic blood pressure was largest between caregivers and non-caregivers, and the difference persisted across time.

The findings also establish a relationship between caregiving intensity and the level of blood pressure across observed time-points. Overall, caregivers who provide parental care for less than 14 hours per week have significantly higher average of blood pressure compared to non-caregivers. Similar findings have been reported in a sample of the Nurses' Health Study, which found that caregiving for disabled or ill spouse for $\geq 9$ hours per week was associated with increased risk of coronary heart disease (RR, 1.82; 95% CI, 1.08-3.05) (165). However, we did not find a significant difference in blood pressure between high-intensity caregivers (greater than 14 hours per week) and non-caregivers. One of the potential explanations could be related to statistical power. Compared to non-caregivers (N = 6430) and low-intensity caregivers (n=671),

the sample size for high-intensity caregivers was much smaller (N = 348). Another possible explanation is due to the healthy caregiver hypothesis. Individuals who are healthier and more capable of providing care are more likely to take on intense caregiving responsibilities. In addition, the trajectory patterns of caregiving intensity reveal that both SBP and DBP over low-intensity caregiving support the adaptation theory, which suggests that the negative impact of caregiving demands occurs early in the caregiving trajectory but then level-off over time as they adjust to the physical challenges of caregiving and settle into their role (231). This corroborates evidence from Lawton et al. that caregiving demands were strongest when caregiving began, and caregiver's quality of life did not change significantly over 1 year (231). This may be due to a variety of adjusting process within the caregiver's life, such as psychologically adapting the role of caregiving and developing the skills to perform the caregiving tasks.

There are several limitations that should be noted in this study. First, we treated the dependent variable as missing at random and removed records having missing values in any variables used in the analysis. Sensitive analysis results show that the characteristics of non-responders differed in education attainment, marital status, insurance status, smoking, and alcohol. Second, the association between caregiving and blood pressure may be confounded with the healthy caregiver hypothesis. This hypothesis suggests that individuals who are healthier and more capable of providing care are more likely to take on caregiving responsibilities (232). In this case, the association might have been underestimated. Third, our ability to generalize results to a population is limited. The EMW only includes ever married women aged 18 and 52 years, which precludes generalization of the findings to women of other ages or those who never married. In addition, the analysis was not weighted since the complex design features were not available in the data. This is a sample design issue that the CHNS research team wished to work

with the State Statistical Bureau and involvement of a more experienced Chinese sampling researcher at the beginning of the project (199). Finally, data limitations prohibited the inclusion of several potentially important variables. For example, there is a lack of information on what type of care that caregivers provided, and thus, we were unable to differentiate caregivers with distinct types/levels of caregiving tasks. This may potentially bias interpretation of the results.

Nevertheless, there are multiple strengths of this study. First, one of the major strengths is the use of a prospective design to establish a clear temporal relationship between caregiving and blood pressure elevation. The change of physiological status usually does not take place suddenly but is likely a gradual, interactive, and cumulative process. Therefore, prospective studies that employ more robust methodology are necessary to confirm the existence and validity of a relationship between caregiving stress and blood pressure. Secondly, an objective measure of hypertension was assessed in the study. In most previous studies, the assessment of caregivers' health has been largely subjective, rather than collecting objective data. There is ample evidence in previous literature of large disparities between the objective and subjective health measures, even in very high quality surveys (190). In this study, three blood pressure measures were taken on-site at the time of the survey for increased accuracy, rather than taking just one measurement. Lastly, this study considered the trajectory of blood pressure change by incorporating various measures of caregiving, including caregiving status and caregiving intensity.

In conclusion, the implication of this study is directed towards expanding our understanding of the relationship between parental caregiving and blood pressure among Chinese women. Women are the undeniable backbone of the caregiving system in China and their contributions to the care of the largest and fast growing elderly population cannot be overstated.

Successful interventions to reduce the modifiable risk factors over the life course among women under caregiving stress, such as alcohol abstinence, may prevent the risk of long-term health hazards. In general, findings from this study will be used to develop future stress management interventions into community outreach and education to decrease cardiovascular disease risk among Chinese women who provide care to their parents.

## 4.5 Tables and Figures

Table 4.1. Baseline Sample Characteristics of the Participants by caregiver status (N = 2586)

| | N (%)/Mean (SD) | | | P value |
|---|---|---|---|---|
| | Total | Caregiver | Noncaregiver | |
| Age (years) | 37.1 (7.1) | 38.3 (7.0) | 36.9 (7.1) | <0.001 |
| Education | | | | |
| None | 248 (9.6) | 24 (7.1) | 224 (10.0) | 0.003 |
| Primary school graduate | 580 (22.4) | 59 (17.5) | 521 (23.2) | |
| Lower middle school degree | 1078 (41.7) | 139 (41.1) | 939 (41.8) | |
| Upper middle school degree | 390 (15.1) | 65 (19.2) | 325 (14.5) | |
| Technical or college degree | 290 (11.2) | 51 (15.1) | 239 (10.5) | |
| BMI ($kg/m^2$) | 23.0 (3.3) | 23.2 (3.3) | 23.0 (3.2) | 0.237 |
| Working | | | | |
| Working | 1856 (71.8) | 239 (70.7) | 1617 (71.9) | 0.642 |
| Not working | 730 (28.2) | 99 (29.3) | 631 (28.1) | |
| Marital Status | | | | |
| Married | 2532 (97.9) | 330 (97.6) | 2202 (98.0) | 0.701 |
| Never married/divorced | 54 (2.1) | 8 (2.4) | 46 (2.0) | |
| Insurance | | | | |
| Yes | 914 (35.3) | 142 (42.0) | 772 (34.3) | 0.006 |
| No | 1672 (64.7) | 196 (58.0) | 1476 (65.7) | |
| Current Smoking | | | | |
| Yes | 46 (1.8) | 7 (2.1) | 39 (1.7) | 0.663 |
| No | 2540 (98.2) | 331 (97.9) | 2209 (98.3) | |
| Current Drinking | | | | |
| Yes | 235 (9.1) | 46 (13.6) | 186 (8.4) | 0.002 |
| No | 2351 (90.9) | 292 (86.4) | 2059 (91.6) | |

Table 4.2. Growth Curve Models for Caregiving Status and Women's Systolic Blood Pressure and Diastolic Blood Pressure in China

| | Systolic blood pressure | | | Diastolic blood pressure | | |
|---|---|---|---|---|---|---|
| | Model 1 Coef. (SE) | Model 2 Coef. (SE) | Model 3 Coef. (SE) | Model 4 Coef. (SE) | Model 5 Coef. (SE) | Model 6 Coef. (SE) |
| Intercept | 92.31 (1.17)*** | 92.19 (1.19)*** | 77.37 (1.66)*** | 63.08 (0.82)*** | 63.07 (0.82)*** | 53.78 (1.45)*** |
| Caregiver | 0.71 (0.42)** | 1.13 (0.56)** | 1.16 (0.55)*** | 0.73 (0.30)** | 0.71 (0.30)** | 0.75 (0.30)** |
| Linear growth rate | | | | | | |
| Time | 0.56 (0.05)*** | 0.59 (0.05)*** | 0.49 (0.07)*** | 0.36 (0.03)*** | 0.38 (0.04)*** | 0.34 (0.04)*** |
| Time*Caregiver | | 0.07 (0.14) | 0.05 (0.14) | | -0.11 (0.09) | -0.10 (0.09) |
| Quadratic growth rate | | | | | | |
| $Time^2$ | 0.03 (0.01)* | 0.04 (0.02)** | 0.03 (0.01)* | | | |
| $Time^2$*Caregiver | | 0.05 (0.04)* | 0.04 (0.04) | | | |
| Covariates | | | | | | |
| Baseline age | 0.60 (0.03)*** | 0.60 (0.03)*** | 0.48 (0.03)*** | 0.34 (0.02)** | 0.34 (0.02)*** | 0.27 (0.02)*** |
| Education | | | | | | |
| None | | | Ref | | | Ref |
| Primary school graduate | | | -0.93 (0.61) | | | -0.69 (0.43) |
| Lower middle school degree | | | -1.05 (0.59)* | | | -0.71 (0.42)* |
| Upper middle school degree | | | -1.05 (0.70) | | | -0.80 (0.49) |
| Technical or college degree | | | -2.77 (0.75)*** | | | -1.10 (0.59)* |
| Working status | | | -0.28 (0.35) | | | 0.07 (0.24) |
| Insurance | | | 0.14 (0.38) | | | -0.13 (0.27) |
| BMI | | | 0.88 (0.05)*** | | | 0.58 (0.04)*** |
| Current Drinking | | | -0.50 (0.51) | | | -0.33 (0.36) |
| Random effects- Variance components | | | | | | |
| Level-1: within-person | 94.93 (4.66)*** | 94.76 (4.73)*** | 67.11 (4.01)*** | 42.70 (1.78)*** | 42.72 (1.78)*** | 31.85 (1.50)*** |
| Level-2: in intercept | 1.31 (0.24)*** | 1.31 (0.25)*** | 0.88 (0.20)*** | 0.40 (0.09)*** | 0.40 (0.09)*** | 0.26 (0.08)*** |
| In linear growth rate | 0.003 (0.01) | 0.01 (0.01) | 0.003 (0.01) | | | |

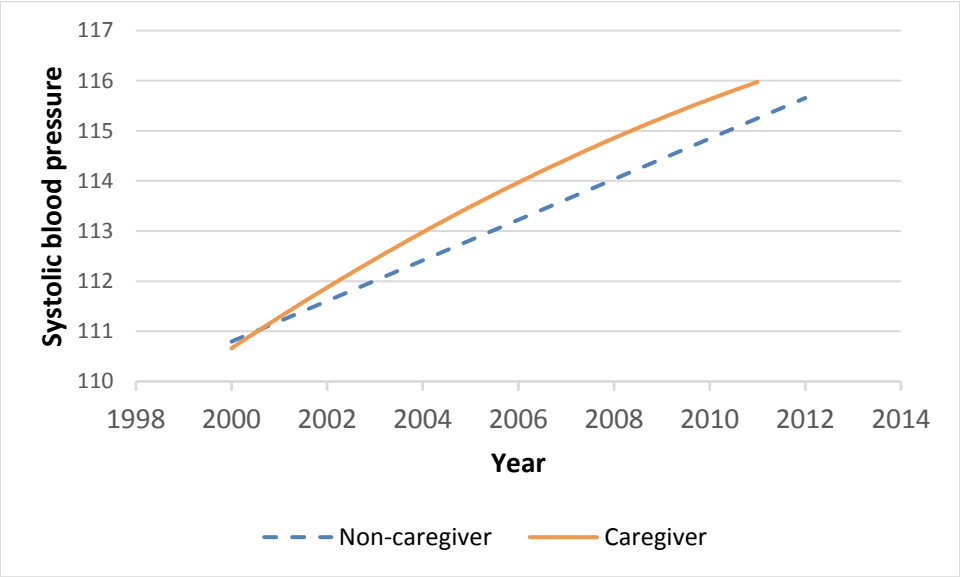
* ≤ 0.1 ** ≤ 0.05 *** ≤ 0.01

Table 4.3. Growth Curve Models for Caregiving Intensity and Women's Systolic Blood Pressure and Diastolic Blood Pressure in China

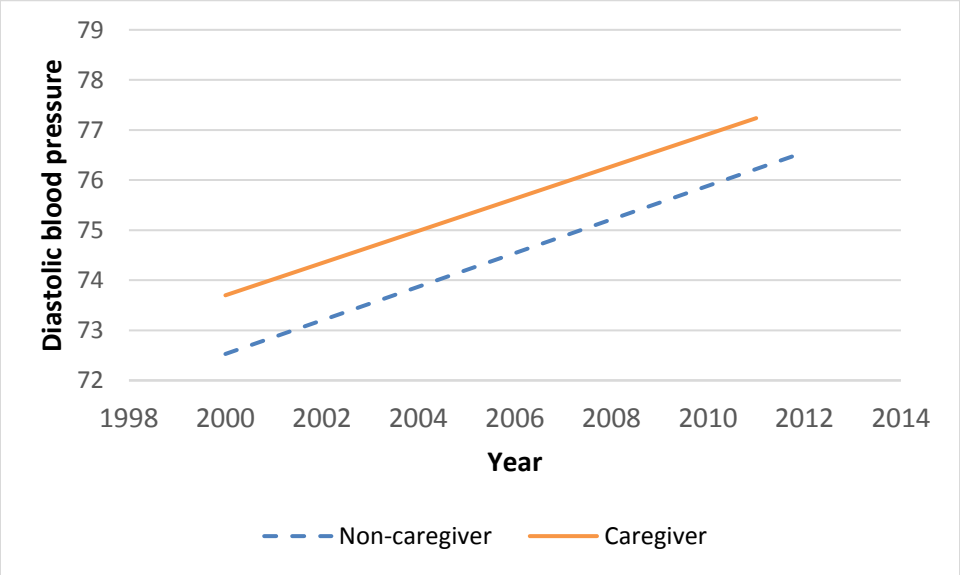
| | Systolic blood pressure | | | Diastolic blood pressure | | |
|---|---|---|---|---|---|---|
| | Model 1 Coef. (SE) | Model 2 Coef. (SE) | Model 3 Coef. (SE) | Model 4 Coef. (SE) | Model 5 Coef. (SE) | Model 6 Coef. (SE) |
| Intercept | 92.34 (1.18)*** | 92.18 (1.19)*** | 77.37 (1.66)*** | 63.08 (0.82)*** | 63.07 (0.82)*** | 52.77 (1.17)*** |
| Caregiving intensity | | | | | | |
| High intensity | 0.50 (0.68) | 1.12 (0.91) | 1.13 (0.90) | 0.69 (0.48) | 0.67 (0.48) | 0.65 (0.48) |
| Low intensity | 0.71 (0.50) | 1.14 (0.67)* | 1.16 (0.66)* | 0.77 (0.35)** | 0.73 (0.36)** | 0.80 (0.35)** |
| Linear growth rate | | | | | | |
| Time | 0.58 (0.05)*** | 0.59 (0.05)*** | 0.49 (0.07)*** | 0.36 (0.03)*** | 0.38 (0.04)*** | 0.34 (0.04)*** |
| Time*High intensity | | 0.03 (0.24) | 0.01 (0.23) | | -0.02 (0.15) | -0.02 (0.15) |
| Time*Low intensity | | -0.10 (0.17) | -0.06 (0.17) | | -0.16 (0.11) | -0.14 (0.11) |
| Quadratic growth rate | | | | | | |
| $Time^2$ | 0.03 (0.01)*** | 0.04 (0.02)** | 0.03 (0.01)** | | | |
| $Time^2$*High intensity | | -0.07 (0.06) | -0.07 (0.06) | | | |
| $Time^2$*Low intensity | | -0.05 (0.05) | -0.03 (0.04) | | | |
| Covariates | | | | | | |
| Baseline age | 0.60 (0.03)*** | 0.60 (0.03)*** | 0.48 (0.03)*** | 0.34 (0.02)*** | 0.34 (0.02)*** | 0.27 (0.02)*** |
| Education | | | | | | |
| None | | | Ref | | | Ref |
| Primary school graduate | | | -0.94 (0.61) | | | -0.70 (0.43) |
| Lower middle school degree | | | -1.07 (0.59)* | | | -0.72 (0.42)* |
| Upper middle school degree | | | -1.08 (0.70) | | | -0.82 (0.49)* |
| Technical or college degree | | | -2.77 (0.76)*** | | | -1.06 (0.53)** |
| Working status | | | -0.28 (0.35) | | | 0.07 (0.21) |
| Insurance | | | 0.12 (0.38) | | | -0.13 (0.27) |
| BMI | | | 0.88 (0.05)*** | | | 0.58 (0.04)*** |
| Drinking | | | -0.47 (0.51) | | | -0.31(0.36) |
| Random effects- Variance components | | | | | | |
| Level-1: within-person | 94.73 (4.66)*** | 94.81 (4.73)*** | 67.04 (4.00)*** | 42.71 (1.78)*** | 42.74 (1.78)*** | 31.79 (1.50)*** |
| Level-2: in intercept | 1.31 (0.24)*** | 1.31 (0.25)*** | 0.89 (0.20)*** | 0.40 (0.09)*** | 0.41 (0.09)*** | 0.26 (0.08)*** |
| In linear growth rate | 0.00. (0.01) | 0.01 (0.01) | 0.003 (0.01) | | | |

* $\leq 0.1$ ** $\leq 0.05$ *** $\leq 0.01$

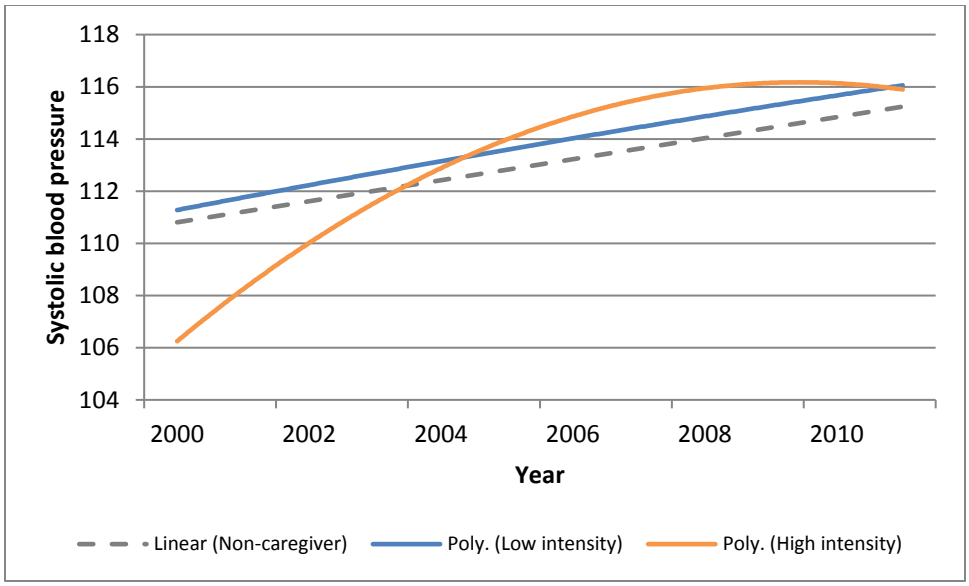
Figure 4.1. Predicted trajectories of Systolic Blood Pressure and Diastolic Blood Pressure by caregiving status and caregiving intensity among Chinese women



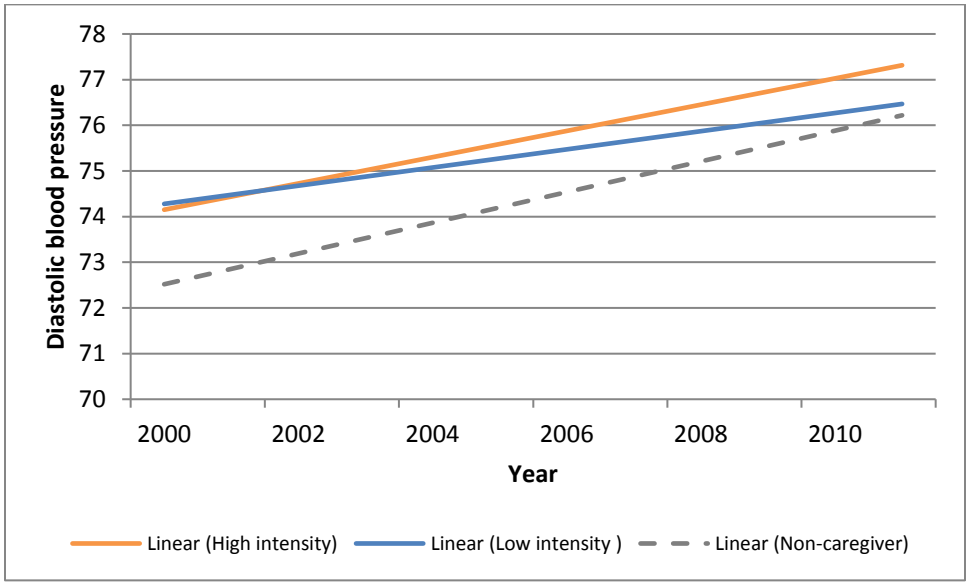

(a) Systolic Blood Pressure by caregiving status




(b) Diastolic Blood Pressure by caregiving status




(c) Systolic Blood Pressure by caregiving intensity




(d) Diastolic Blood Pressure by caregiving intensity

Appendix
Figure 4.2. Sample size flow chart.

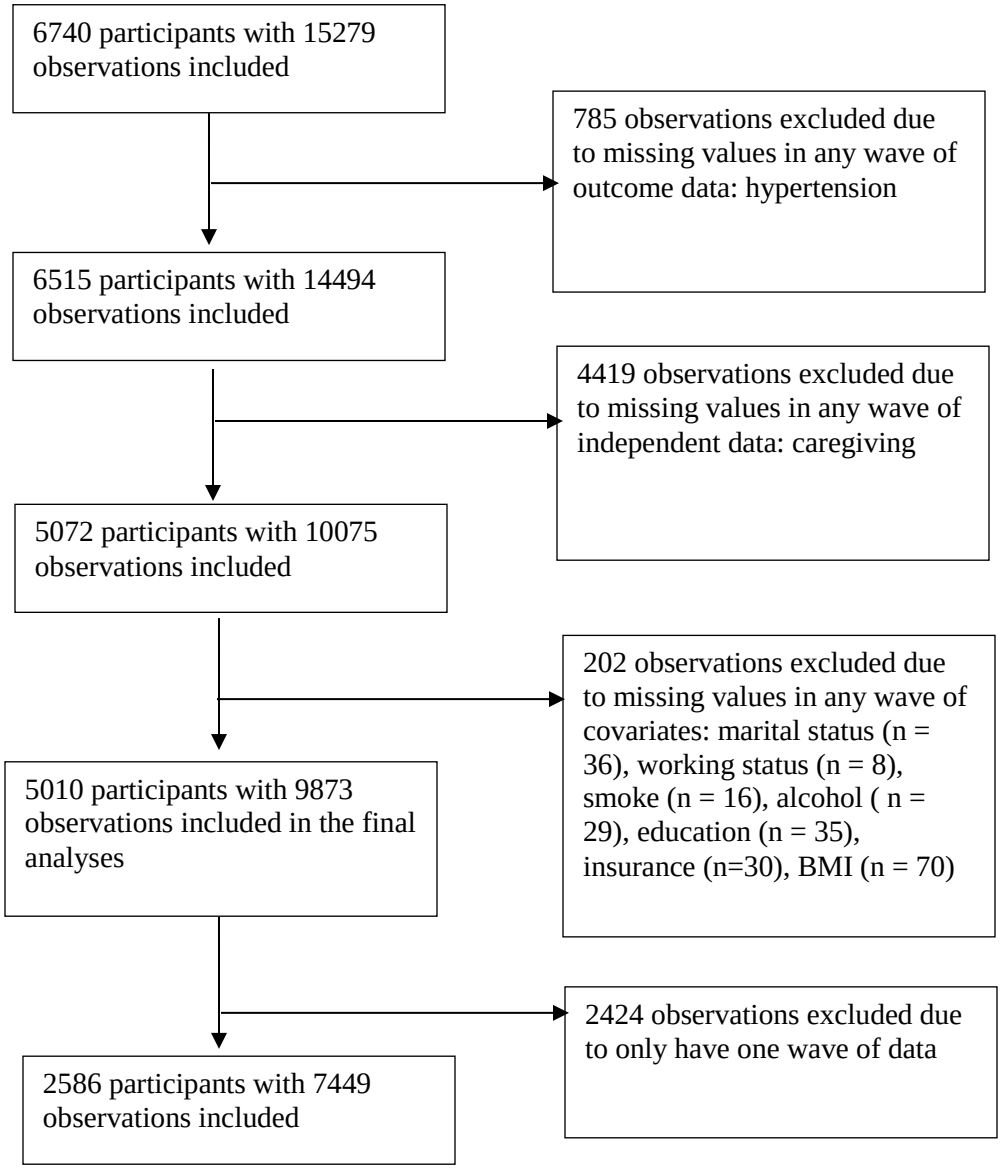


Table 4.4. Compare baseline characteristics between analysis sample and excluded sample with missing values

| | Analysis sample (n = 2586) | Excluded sample (n = 5618) | P-Value |
|---|---|---|---|
| Age (mean ± sd) | 37.1 (7.1) | 37.1 (9.5) | 0.69 |
| Education (n, %) | | | <0.01 |
| None | 248 (9.6) | 753 (13.4) | |
| Primary school graduate | 580 (22.4) | 993 (17.7) | |
| Lower middle school degree | 1078 (41.7) | 1938 (34.5) | |
| Upper middle school degree | 390 (15.1) | 881 (15.7) | |
| Technical or college degree | 290 (11.2) | 950 (17.0) | |
| Missing | 0 | 103 (1.8) | |
| BMI | 23.0 (3.3) | 23.0 (3.4) | 0.94 |
| Working (n, %) | | | <0.01 |
| Working | 1856 (71.8) | 4016 (71.5) | |
| Not working | 730 (28.2) | 1577 (28.1) | |
| Missing | 0 | 25 (0.4) | |
| Marital Status | | | <0.01 |
| Married | 2532 (97.9) | 4809 (85.6) | |
| Never married/divorced | 54 (2.1) | 688 (12.3) | |
| Missing | 0 | 121 (2.1) | |
| Insurance | | | <0.01 |
| Yes | 914 (35.3) | 2406 (42.8) | |
| No | 1672 (64.7) | 3133 (55.8) | |
| Missing | 0 | 79 (1.4) | |
| Smoking | | | <0.01 |
| Yes | 46 (1.8) | 118 (2.1) | |
| No | 2540 (98.2) | 5276 (93.9) | |
| Missing | 0 | 224 (4.0) | |
| Drinking | | | <0.01 |
| Yes | 235 (9.1) | 589 (10.5) | |
| No | 2351 (90.9) | 4734 (84.3) | |
| Missing | 0 | 295 (5.2) | |

Table 4.5. Distribution of hypertension status by caregiving status

| From baseline to the last wave | Total | Caregiver N (%) | Non-caregiver N (%) | P value |
|---|---|---|---|---|
| From non-hypertension to Hypertension | 222 (8.6) | 30 (8.9) | 192 (8.5) | 0.26 |
| From hypertension to non-hypertension | 97 (3.7) | 17 (5.0) | 80 (3.6) | |
| From non-hypertension to non-hypertension | 2152 (83.2) | 271 (80.2) | 1881 (83.7) | |
| From Hypertension to Hypertension | 115 (4.5) | 20 (5.9) | 95 (4.2) | |

Table 4.6. Data distribution

| count | Frequency | Percent | Cumulative Frequency | Cumulative Percent |
|---|---|---|---|---|
| **Have two waves of data** | 1136 | 43.93 | 1136 | 43.93 |
| **Have three waves of data** | 721 | 27.88 | 1857 | 71.81 |
| **Have four waves of data** | 631 | 24.40 | 2488 | 96.21 |
| **Have all five waves of data** | 98 | 3.79 | 2586 | 100.00 |

# Chapter 5: Caregiving Trajectories and Metabolic Syndrome: a Longitudinal Study among Chinese Women

To be submitted for publication

**ABSTRACT**

**Background:** Caregiving stress may play a role in the pathogenesis of Metabolic Syndrome (MetS). However, few studies have investigated the consequences of caregiving on objectively measured health outcomes, such as MetS. This study used population based longitudinal data to examine the relationship between caregiving trajectory and MetS among Chinese women.

**Method**: This is a retrospective analysis of 1,636 women using three waves of data from the Ever-Married Women Survey component of the China Health and Nutrition Survey (2004, 2006, and 2009). Group-based trajectory analysis was used to examine the caregiving trajectories among women in China.

**Results**: Three caregiving trajectories were identified: 'rising to high-intense' caregivers (2.9%), 'stable low-intense' caregivers (14.2%), and non-caregivers (82.9%). In multivariable analyses, 'rising to high-intense' caregivers (Odds Ratio (OR) = 1.90; 95% Confidence Interval (CI): 0.90, 4.00) and 'stable low-intense' caregivers (OR = 1.56; 95% CI: 1.06, 2.29) were associated with higher odds of MetS compared with non-caregivers. Moreover, caregivers who provided 'stable low-intense' parental care were found to have marginally higher odds of pre-hypertension and high triglycerides than those who did not provide caregiving for their parents.

**Discussion**: Our results demonstrate that the caregiving trajectories were significantly associated with the risk of MetS. Findings from the study can be used to develop future stress management interventions to decrease MetS risk among women who provide care to their parents.

## 5.1 Introduction

Metabolic syndrome (MetS) is considered a worldwide epidemic, ranging in prevalence from 10% to 40% (233). MetS is characterized by a cluster of metabolic risk factors including hyperglycemia, obesity, elevated blood pressure and dyslipidemia (127). Prior evidence has suggested that MetS confers a 5-fold increase in the risk of type 2 diabetes mellitus and 2 times the risk of cardiovascular disease (234).

China is currently experiencing rapid economic, social and cultural changes. The economic transition in China has provoked remarkable changes in lifestyle involving overconsumption of dietary fat and reduction in physical activity, which may contribute to increased prevalence of MetS (128). According to the China Health and Nutrition Survey in 2009, the age-standardized prevalence of MetS was 21.3% based on the definition of revised National Cholesterol Education Program Adult Treatment Panel III (NCEP ATPIII) (128). Furthermore, the prevalence of MetS was higher in women (21.7%) than in men (20.9%) and of the five MetS components, high waist circumference was the most frequent component in women (128).

Existing research suggests that stress is a contributing factor to cardiovascular disease (75, 235, 236). Prior evidence has indicated that stress is associated with the components of MetS. Short-term (laboratory stress challenges) and long-term (job strain, divorce, and widowhood) stressors are associated with greater fasting glucose (237), blood pressure (238), lipids (239), and insulin levels (240). Research also shows workers in high stress occupations have a higher prevalence of MetS (241). Furthermore, the neuroendocrine and inflammatory markers of chronic stress have been associated with MetS (241-243). MetS was associated with raised 24-hour cortisol metabolite and normetanephrine output, which provides evidence of

alterations in function of both major neuroendocrine stress pathways in the MetS. However, few studies have examined the association between caregiving and risk of MetS (244, 245). The findings suggest that caregiving may have a bigger impact on triglycerides than on other lipids, and it is through this pathway that caregivers may be at increased cardiometabolic risk.

Several studies have examined the impact of caregiving on caregivers' health among the Chinese population, with most studies mainly focusing on the subjective health outcomes, such as self-rated health, quality of life and mental health problems (22, 180). Compared with non-caregivers, caregivers had significantly increased risk for reporting worse health, poorer QOL, more doctor visits, anxiety and depression, and weight loss (180) and overall, caregivers had consistently worse self-rated health status than non-caregivers (22). These results underscore the potential toll of parental caregiving on health and the need for services to reduce caregivers' stress and maintain their health status.

While early studies have provided information about the impact of caregiving on the subjective health outcomes, there is limited evidence assessing the association between caregiving and objective health outcomes among Chinese. To fill the gaps identified in the previous literature, this study firstly examined whether multiple caregiving trajectories existed in the three waves of data among Chinese women. Secondly, we aimed to assess the effects of caregiving trajectories on the risks of MetS and individual MetS component. We hypothesized that taking caregiving responsibility in early life is causative for MetS among Chinese women. Utilizing group-based trajectory analysis, this research is particularly useful in determining whether a cumulative increase in caregiving experience over time precipitates a greater risk of MetS.

## 5.2 Methods

Data source

This study used data from the China Health and Nutrition Survey (CHNS), which is a large-scale longitudinal survey conducted by the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention (199). The CHNS data involves nine large provinces across a wide geographic region with a range of economic and demographic variation. The analytic sample in this study used Ever-Married Women (EMW) Survey, which is a component of the CHNS and provides a unique opportunity to assess detailed information on the socioeconomic, behavioral, and familial contexts of women caregivers in China. The EMW was initiated in 1991 and now includes eight waves of data through 2011 with added respondents and replenished sample in follow-up years. Because the biomarker data were only collected in 2009 and data formats were different in early years, we used a sample of respondents who participated in the 2004 (I), 2006 (II), and 2009 (III) waves of the EMW in this study to better ensure comparability of responses. Individuals were excluded from analyses if they had missing data for the independent variable in any two waves of data, and dependent variable and covariates in wave III. The final analytic sample includes 1636 women. Compared to the excluded sample (N = 892), women remaining (N = 1636) in the analysis sample tended to be older, less educated, married, working, and less likely to drink alcohol (See table 5.4 in appendix). We addressed this potential selection bias in the discussion section.

Measures

*Dependent variable*

The outcome measures assessed in the study include: MetS, hypertension, pre-hypertension, fasting plasma glucose, C-reactive protein (CRP), Glycated hemoglobin (HbA1C), total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglycerides, and overweight.

The biomarker data were measured at wave III. Following an overnight fast, blood was collected by venipuncture and tested immediately for glucose. Plasma and serum samples were then frozen, and stored at -86°C for later laboratory analysis. All samples were analyzed in a national central lab in Beijing (medical laboratory accreditation certificate ISO 15189:2007) with strict quality control. Fasting glucose was measured with the GOD-PAP method [Randox Laboratories Ltd, UK]; HDL was measured using the polyethylene glycol (PEG)-modified enzyme method by determiner regents [Kyowa Medex Co., Ltd, Tokyo, Japan]; and triglycerides was measured using glycerol phosphate oxidase method and the PEG-modified enzyme method, respectively, by determiner regents [Kyowa Medex Co., Ltd, Tokyo, Japan]. Levels of biomarkers were categorized to represent risk using cut-off points recommended by the International Diabetes Federations (table 5.1).

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured at wave III by trained examiners using a mercury sphygmomanometer according to a standard protocol (226). Measures were collected in triplicate after a ten-minute seated rest. According to the American Heart Association's recommendations, at least two seated blood pressures should be properly taken (210). The mean of the latter two readings were used in the analysis. Hypertension was defined as SBP $\geq$ 140 mmHg or DBP $\geq$ 90 mmHg or taking antihypertensive drugs. Pre-hypertension was defined as SBP $\geq$ 130 mmHg or DBP $\geq$ 85 mmHg or taking antihypertensive drugs.

Height was measured without shoes to the nearest 0.1 cm using a portable SECA stadiometer (Seca North America East, Hanover, MD, USA); weight was measured without shoes and in light clothing to the nearest 0.1 kg on a calibrated beam balance. BMI was calculated as body weight (in kilograms) divided by the square of height (in meters). Overweight is defined as BMI $\geq$ 25 kg/m$^2$.

The MetS was defined based upon the updated NCEP-ATPIII for Asian (131) as presenting 3 or more of the following components: 1) waist circumference $\geq$ 90 cm for men $\geq$ 80 cm for women; 2) triglycerides $\geq$ 150 mg/dL; 3) HDL < 50 mg/dL; 4) blood pressure $\geq$ 130/85 mmHg or current use of antihypertensive medication; and 5) fasting glucose $\geq$ 100 mg/dL. MetS was coded as yes vs. no (reference) in the analysis.

*Independent variable*

The time spent on caregiving was measured at all three waves of data as a continuous variable. Time spent caring for parents and parents-in-law was summed to compute the overall time spent on elderly parental care. The respondents were asked: "During the past week, how many hours did you spend taking care of your mother?" Comparable questions were asked about respondents' care for their fathers, mothers-in-law, and fathers-in-law, respectively.

*Covariates*

The selection of covariates was guided by existing literature. This study included sociodemographic variables (age, education, employment status, and marital status), healthcare access variable (insurance), and health behavior factors (alcohol drinking and smoking status) measured in Wave III. Age was coded as a continuous variable (in years). Education attainment was categorized into 6 groups: none (reference), primary school graduate, lower middle school degree, upper middle school degree, technical or vocational degree, and college degree.

Employment status was grouped as working vs. not working (reference). Marital status was coded as married vs. never married/divorced/widowed (reference). Insurance was assessed as yes vs. no (reference). For the health behavior factors, alcohol drinking was coded as currently drinking (drink beer or any other alcoholic beverage during the current year) vs. currently not drinking (reference group). Smoking status was grouped as currently smoking vs. not currently smoking (reference group).

Statistical Analysis

Descriptive statistics were performed by determining means of continuous variables and proportions of categorical variables to describe the characteristics of the study population. Caregiving trajectories were compared by outcomes and covariates using the ANOVA for continuous variables and the Pearson chi-square test for categorical variables. The Fisher's exact test was used when one or more of the cells had an expected frequency of five or less.

**Stage 1: Identification of distinctive caregiving trajectories**

Group-based trajectory analysis was performed with the PROC TRAJ macro in SAS version 9.4 (246). The time spent on caregiving was used for the trajectory model. Data analysis was restricted to those study participants for whom caregiving data were available from at least 2 assessment waves. The PROC TRAJ macro assumes that missing data are missing completely at random, and the model is adjusted so that missing observations do not contribute to the sample size or analytical outcome (246).

The parameters for the trajectory model were determined on a maximum-likelihood basis (246). In the interest of parsimony, a three-group trajectory analysis model was defined (Figure 1). The caregiving intensity was grouped into three trajectories: non-caregiver, stable low-intense caregiver, and rising to high-intense caregiver. The objective of model selection in trajectory

analysis is not the maximization of statistic of model fit; rather, it is to summarize the distinctive features of the data in as parsimonious as possible (247). Plot data were generated by means of the macro "TRAJPLOT".

**Stage 2: Relation of caregiving trajectories to MetS risk at wave III**

Age adjusted logistic regression models were performed to assess the associations between caregiving trajectories and each outcome variable. We additionally adjusted models for factors known to influence cardiometabolic factors including education, working status, marital status, health insurance, smoking and alcohol drinking. Potential moderation by age and overweight status were examined by including the corresponding interaction term. The potential moderators were selected based on prior literature. The stratified analysis was conducted if the interaction term was significant. All the statistical analysis of the study was performed using SAS software, version 9.4. The statistical significance was based on the p value less than 0.05, and the marginal significant was defined as greater than 0.05 and less than 0.1.

## 5.3 Results

The caregiving trajectories were plotted in figure 5.1. Through the trajectory group assignment based on PROC TRAJ macro, 1355 participants (82.8%) were assigned to 'non-caregiver' group, 234 (14.3%) to 'stable low-intense caregiver' group, and 47 (2.9%) to 'rising to high-intense' group.

Descriptive findings for the baseline characteristics of participants by caregiving trajectories are presented in table 5.2. The average age of the study sample was 40 years. Almost 72% of participants reported having a job. Regarding the education attainment, 10.7% did not receive any education, 21.5% had primary school degree, 42.7% had lower middle school

degree, 12.2% had upper middle school degree, 12.9% had technical degree or only 4.6% college degree. Nearly all participants (98.0%) were married and reported to have health insurance (91.0%). For the health behaviors, 1.6% of women had a history of smoking, and 9.5% were current alcohol drinkers. Compared with non-caregivers, 'stable low-intense caregivers' and 'rising to high-intense caregivers' were older and more likely to have health insurance.

Approximately 12.5% of women had MetS. 'Rising to high-intense' caregivers had the highest prevalence of MetS (21.3%) compared with 'stable low-intense' caregivers (18.0%) and non-caregivers (11.2%) ($P < 0.01$). The significant differences among the three caregiving trajectories were also found for pre-hypertension, total cholesterol, and triglycerides. The overall prevalence of pre-hypertension, high total cholesterol and high triglycerides were 20.7%, 22.9% and 22.6%, respectively. The caregiving groups had much higher risk of pre-hypertension, high total cholesterol and high triglycerides compared with those who did not provide caregiving for their parents ($p < 0.05$). The risks of hypertension and high LDL were marginally different among the three caregiving groups. No significant differences among caregiving trajectories were observed for glucose, CRP, HbA1C, HDL and overweigh.

Table 5.3 shows age adjusted models for the associations between caregiving trajectories and each outcome measure. Caregiving trajectories were significantly associated with metabolic syndrome ($p = 0.03$). When comparing with non-caregivers, 'stable low-intense' caregivers were 52% more likely to have MetS (OR = 1.52; 95% CI: 1.03, 2.22); while 'rising to high-intense' caregivers were 94% more likely to develop MetS, with marginal significance (OR = 1.94; 95% CI: 0.93, 4.03). Marginally significant associations were observed when examining the relationship between caregiving trajectories and the risks of high triglycerides, pre-hypertension and high total cholesterol. With regard to high triglycerides, the odds was 1.37 times among

‘stable low-intense’ caregivers than non-caregivers (OR = 1.37; 95% CI: 1.00, 1.88); no statistically significant difference was found when comparing ‘rising to high-intense’ caregivers to non-caregivers. ‘Stable low-intense’ caregivers also had 34% higher odds in pre-hypertension and 32% higher risk in total cholesterol compared with non-caregivers, respectively (pre-hypertension: OR= 1.34, 95% CI: 0.96, 1.86; total cholesterol: OR= 1.32, 95% CI: 0.96, 1.81). Whereas no association was observed between ‘rising to high-intense’ caregivers and non-caregivers in terms of pre-hypertension and total cholesterol.

Associations between caregiving trajectories and cardiometabolic risk factors, accounting for age, education, working status, marital status, health insurance, smoking, and alcohol drinking, were also presented in table 5.3. The significant association was only observed in the relationship between caregiving trajectories and MetS after controlling for the covariates (p = 0.03). Results show that caregivers who provided ‘rising to high-intense’ care or ‘stable low-intense’ care had marginally significant or significant higher odds of MetS than those who did not provide caregiving for their parents (‘rising to high-intense’ caregivers: OR= 1.90, 95% CI: 0.90, 4.00; ‘stable low-intense’ caregivers: OR= 1.56, 95% CI: 1.06, 2.29). ‘Stable low-intense’ caregivers were marginally associated with higher risk of pre-hypertension and high triglycerides comparing with non-caregivers. The odds of pre-hypertension and high triglycerides was increased by 37% and 38% among ‘stable low-intense’ than non-caregivers after adjusting for potential confounders (pre-hypertension: OR= 1.37, 95% CI: 0.98, 1.91; triglycerides: OR= 1.38, 95% CI: 0.99, 1.88). No significant associations were observed with hypertension, high glucose, high CRP, high HbA1C, high total cholesterol, low HDL, high LDL, and overweight. Interactions between caregiving trajectories and age or overweight status were not statistically significant.

## 5.4 Discussion

To our knowledge, this is one of the first epidemiological studies to evaluate associations between measured MetS and other biomarkers in relation to caregiving trajectories among Chinese women. Using a group-based trajectory analysis, this study identified three different trajectories of caregiving in a national Chinese women sample from 2004 to 2009: non-caregivers, 'stable low-intense' caregivers, and 'rising to high-intense' caregivers. The two caregiving trajectories were significantly associated with higher risk of MetS compared with non-caregivers. Caregivers who provided 'stable low-intense' parental care were also found to be marginally associated with pre-hypertension and high triglycerides comparing with those who did not provide caregiving for their parents.

In our study, the prevalence of MeS was 12.5%, which was lower than the national data in 2009 among Chinese women (21.7%) (128). This is probably due to the different age composition in the samples: the mean age in our sample was 40.3 years, while it was 51.1 years in the national data (128). Prior evidence has shown the prevalence of MetS increases with increasing age (248). According to 2003-2012 NHANES data, the prevalence of MetS was 18.3% among those aged 20 to 39 years and increased to 46.7% among those aged 60 years or older (248). Consistent with prior findings, our result indicates that age was a positive predictor for MetS even after adjusting for other covariates (OR = 1.09; 95% CI: 1.06, 1.12). The prevalence of MetS may also vary due to the diverse populations of different regions, lifestyle, cultural behaviors, and the use of different diagnosis criteria (249).

Consistent with earlier findings (250, 251), our study found that a relatively small proportion of adult children (17.1%) were actually engaged in providing care to an elderly parent at a given time. According to an analysis of data from the National Survey of Families and

Household in China, only one in five elderly parents received assistance with household chores, transportation, or household repairs from an adult child within the previous month (250). In addition, caregiving may not be stable and unchanging, but develops over time. Nydegger proposes a life course of the relationship between adult child and parent in terms of filial role (252). In his theory, the adult child begins a process of filial distancing from the parent in late adolescence and young adulthood to establish his or her own identity as an adult. This is followed by a period of filial comprehension, where the adult child begins to understand the parent's world. Later, the child becomes increasingly aware of the parent's aging and gradually develops the ability to cope with parent's needs. This theory may explain the presence of the 'rising to high-intense' caregiving trajectory. Another possible explanation could be directly related to the parent's demand. The demand may increase due to the fact that the parent's functional abilities getting worse as aging.

Our results also demonstrated that the caregiving trajectories were significantly associated with the risk of MetS. Caregiving can be considered as a type of chronic stress due to the fact that caregivers consistently experience higher levels of self-reported stress and stress-related biomarkers than non-caregivers (138-140). Prolonged exposure to stress may affect the autonomic nervous system and neuroendocrine activity directly, which contribute to the development of MetS. A prospective cohort study showed a dose-response relation between exposure to work stressors over 14 years and risk of the MetS, independent of other relevant risk factors (253). Employees with chronic work stress (three or more exposures) were more likely to develop MetS than those without work stress (OR = 2.25, 95% CI: 1.31, 3.85). It remains unclear about the pathophysiological mechanisms that underlie the relationship between chronic stress and MetS. Prior research indicates that chronic psychological stress may reduce biological

resilience and thus disturb homoeostasis (254). And the altered adrenocortical function can influence hepatic lipoprotein metabolism and insulin sensitivity at target organs (255).

Additionally, we found that caregivers who provided 'stable low-intense' parental care showed marginally increased risk of pre-hypertension and high triglycerides compared with those who did not provide caregiving for their parents. There is growing empirical support for the hypothesis that exposure to chronic psychosocial stress contributes to the development of hypertension (256). Benjamin et al. assessed the risk of incident hypertension associated with spousal caregiving. They found that current caregiving significantly predicted hypertension incidence (RR = 1.36, 95% CI: 1.01, 1.83), and long-time caregivers had higher risk of hypertension onset compare with non-caregivers (RR = 2.29, 95% CI: 1.17, 4.49). The mechanisms by which chronic stress contributes to hypertension are complex and involve a variety of interrelated physiological, behavioral, and emotional pathways (218). Regarding triglycerides, it has been proposed that chronic stress exposure was associated to lipid dysregulation, thus altering lipid metabolism (257). Our study corroborates this investigation and showed that caregiving stress increased triglycerides level, which may be caused by decreased lipoprotein lipase activity (258).

There are several limitations that should be noted in this study. First, the main limitation of this study is that there is only one wave of biomarker data, precluding the analysis of incidence of MetS indicators. Second, we treated dependent variable as missing at random and remove records having missing values in any variables used in the analysis. It is possible that this assumption is not reasonable, and that relationships between the predictors and outcomes are different among respondents and non-respondents. Third, our ability to generalize results to a particular population may be limited. The EMW only includes ever married women aged 18 and

52 years, which precludes generalization of the findings to women of other ages or those who never married. In addition, the analysis is not weighted due to the fact that the complex design features are not available in the data. Fourth, the association between caregiving and health outcomes may also be confounded with selection effects. The healthy caregiver hypothesis suggests that individuals who are healthier and more capable of providing care are more likely to take on caregiving responsibilities. Finally, data limitations prohibited the inclusion of several potentially important variables. For example, there is a lack of information on what type of care that caregivers provided, and thus, we were unable to differentiate caregivers with distinct types/levels of caregiving tasks. This may potentially bias interpretation of the results.

Nevertheless, there are multiple strengths of this study. Firstly, objective measure of MetS and biomarkers were assessed in the study. In most previous studies, the assessment of caregivers' health has been largely subjective, rather than collecting objective data. There is ample evidence in previous literature of large disparities between the objective and subjective health measures in even very high quality surveys (190). Second, our study explored the health consequences of caregiving among Chinese in China. Little research exists that attempts to understand the impact of parental caregiving in this population. As a rapid demographic change to China's age structure, it is important to explore the health consequences of caregiving among Chinese. Lastly, we used group-based trajectory analysis to explore the caregiving trajectories. The trajectory groups are a useful statistical technique for capturing the essential features of the underlying complex reality of the longitudinal caregiving data, with added advantage of being simple to interpret.

In conclusion, by using the group-based trajectory analysis, we showed the existence of multiple caregiving trajectories among Chinese women. We also demonstrated the caregiving

trajectories were significantly associated with the risk of MetS. The implication of this study is directed towards expanding our understanding of the relationship between parental caregiving and MetS among Chinese women. Successful interventions to reduce stress over the life course among women providing care to their parents may prevent the risk of long-term cardiovascular health hazards.

## 5.5 Tables and Figures

Table 5.1. Cardiometabolic biomarkers and definitions

| Biomarker | Definition |
|---|---|
| Hypertension | SBP ≥ 140 mmHg or DBP ≥ 90 mmHg or taking antihypertensive drugs |
| Pre-hypertension | SBP ≥ 130 mmHg or DBP ≥ 85 mmHg or taking antihypertensive drugs |
| High glucose | Glucose ≥ 100 mg/dL |
| High HbA1C | HbA1C ≥ 6.5% |
| High total cholesterol | Total cholesterol ≥ 200 mg/dL |
| Low HDL | HDL < 50 mg/dL |
| High LDL | LDL > 130 mg/dL |
| High Triglycerides | Triglycerides ≥ 150 md/dL |
| High CRP | CRP ≥ 3 md/dL |
| Overweight | BMI ≥ 25 $kg/m^2$ |
| Metabolic syndrome | Presenting 3 or more of the following components: 1) waist circumference ≥ 90 cm for men ≥ 80 cm for women; 2) triglycerides ≥ 150 mg/dL; 3) HDL < 50 mg/dL; 4) blood pressure ≥ 130/85 mmHg or current use of antihypertensive medication; and 5) fasting glucose ≥ 100 mg/dL. |

Note: HbA1C, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; CRP, C-reactive protein.

Figure 5.1. The caregiving trajectories identified across the three waves of data

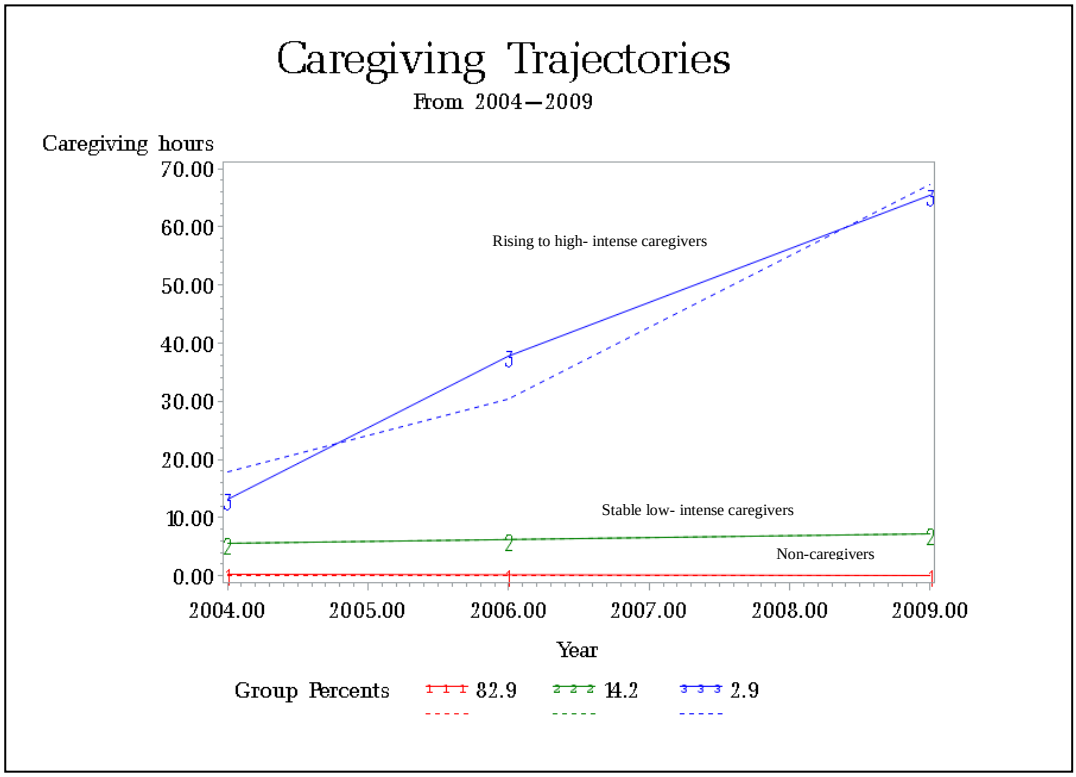


Table 5.2. Characteristics of the study population by caregiving trajectories (N=1636)

| | **Total** N (%)/Mean (SD) | **Caregiving trajectories** N (%)/Mean (SD) | | | **P-value** |
|---|---|---|---|---|---|
| | | Non-caregiver (N = 1356) | Stable low-intense | Rising to high-intense | |
| Age (years) | 40.34 (6.87) | 40.01 (6.88) | 42.00 (6.51) | 41.56 (6.96) | < 0.001 |
| Education | | | | | |
| None | 175 (10.7) | 146 (10.8) | 27 (11.5) | 2 (4.3) | 0.457 |
| Primary school graduate | 352 (21.5) | 297 (21.9) | 42 (18.0) | 13 (27.6) | |
| Lower middle school degree | 699 (42.7) | 584 (43.1) | 97 (41.4) | 18 (38.3) | |
| Upper middle school degree | 199 (12.2) | 156 (11.5) | 37 (15.8) | 6 (12.8) | |
| Technical or College degree | 211 (12.9) | 172 (12.7) | 31 (13.3) | 8 (17.0) | |
| Employment Status | | | | | |
| Employed | 1175 (71.8) | 347 (71.9) | 168 (71.8) | 33 (70.2 ) | 0.969 |
| Not employed | 461 (28.2) | 381 (28.1) | 66 (28.2) | 14 (29.8) | |
| Marital Status | | | | | |
| Married | 1603 (98.0) | 1329 (98.1) | 229 (97.9) | 45 (95.7) | 0.370 |
| Never married/divorced | 33 (2.0) | 26 (1.9) | 5 (2.1) | 2 (4.3) | |
| Health Insurance | | | | | |
| Yes | 1488 (91.0) | 1237 (91.3) | 205 (87.6) | 46 (97.9) | 0.049 |
| No | 148 (90.0) | 118 (8.7) | 29 (12.4) | 1 (2.1) | |
| Current Smoker | | | | | |
| Yes | 26 (1.6) | 25 (1.8) | 1 (0.4) | 0 (0) | 0.335 |
| No | 1610 (98.4) | 1330 (98.2) | 233 (99.6) | 47 (100) | |
| Current Drinking | | | | | |
| Yes | 156 (9.5) | 124 (9.1) | 29 (12.4) | 3 (6.4) | 0.259 |
| No | 1480 (90.5) | 1231 (90.9) | 205 (87.6) | 44 (93.6) | |
| Metabolic syndrome | | | | | |
| Yes | 204 (12.5) | 152 (11.2) | 42 (18.0) | 10 (21.3) | 0.003 |
| No | 1432 (87.5) | 1203 (88.8) | 192 (82.0) | 37 (78.7) | |
| Hypertension | | | | | |
| Yes | 206 (12.6) | 162 (12.0) | 40 (17.1) | 4 (8.5) | 0.076 |
| No | 1430 (87.4) | 1193 (88.0) | 194 (82.9) | 43 (91.5) | |
| Pre-hypertension | | | | | |
| Yes | 339 (20.7) | 262 (19.3) | 64 (27.4) | 13 (27.7) | 0.010 |
| No | 1297 (79.3) | 1093 (80.7) | 170 (72.6) | 34 (72.3) | |
| Glucose | | | | | |
| High | 286 (17.5) | 227 (16.8) | 49 (20.9) | 10 (21.3) | 0.2336 |
| Normal | 1350 (82.5) | 1128 (83.2) | 185 (79.1) | 37 (78.7) | |
| CRP | | | | | |
| High | 260 (15.9) | 215 (15.9) | 39 (16.7) | 6 (12.8) | 0.799 |
| Normal | 1376 (84.1) | 1140 (84.1) | 195 (83.3) | 41 (97.2) | |
| HbA1C | | | | | |
| High | 44 (2.7) | 37 (2.7) | 6 (2.6) | 1 (2.1) | 0.991 |
| Normal | 1592 (97.3) | 1318 (2.6) | 228 (97.4) | 46 (97.9) | |
| Total cholesterol | | | | | |
| High | 374 (22.9) | 293 (21.6) | 68 (29.1) | 13 (27.7) | 0.031 |
| Normal | 1262 (77.1) | 1062 (78.4) | 166 (70.9) | 34 (72.3) | |
| HDL | | | | | |
| Low | 537 (32.8) | 438 (32.3) | 84 (35.9) | 15 (31.9) | 0.556 |
| Normal | 1099 (67.2) | 8917 (67.7) | 150 (64.1) | 32 (68.1) | |
| LDL | | | | | |
| High | 349 (21.3) | 275 (20.3) | 60 (25.6) | 14 (29.8) | 0.065 |
| Normal | 1287 (78.7) | 1080 (79.7) | 174 (74.4) | 33 (70.2) | |
| Triglycerides | | | | | |
| High | 370 (22.6) | 291 (21.5) | 67 (28.6) | 12 (25.5) | 0.048 |
| Normal | 1266 (77.4) | 1064 (78.5) | 167 (71.4) | 35 (74.5) | |
| Overweight | | | | | |
| Yes | 448 (27.4) | 362 (26.7) | 69 (29.5) | 17 (36.2) | 0.266 |
| No | 1188 (72.6) | 993 (73.3) | 165 (70.5) | 30 (63.8) | |

Note: HbA1C, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; CRP, C-reactive protein

Table 5.3. Age adjusted and multiple logistic regression models of caregiving trajectories and cardiometabolic factors (N = 1636)

| | Caregiving trajectories | Age-adjusted model OR (95% CI) | Multivariable adjusted model[a] OR (95% CI) |
|---|---|---|---|
| Metabolic syndrome | Non-caregiver | ref | ref |
| | Stable low-intense | 1.52 (1.03, 2.22)** | 1.56 (1.04, 2.29)** |
| | Rising to high-intense | 1.94 (0.93, 4.03)* | 1.95 (0.92. 4.10)* |
| Hypertension | Non-caregiver | ref | ref |
| | Stable low-intense | 1.27 (0.86, 1.87) | 1.29 (0.87, 1.92) |
| | Rising to high-intense | 0.56 (0.20, 1.63) | 0.59 (0.20, 1.70) |
| Pre-hypertension | Non-caregiver | ref | ref |
| | Stable low-intense | 1.34 (0.96, 1.86)* | 1.37 (0.98, 1.91)* |
| | Rising to high-intense | 1.40 (0.71, 2.77) | 1.46 (0.74, 2.89) |
| High glucose | Non-caregiver | ref | ref |
| | Stable low-intense | 1.18 (0.83, 1.67) | 1.15 (0.81, 1.64) |
| | Rising to high-intense | 1.23 (0.60, 2.53) | 1.23 (0.60, 2.55) |
| High CRP | Non-caregiver | Ref | ref |
| | Stable low-intense | 1.04 (0.71, 1.51) | 1.00 (0.69, 1.47) |
| | Rising to high-intense | 0.76 (0.32, 1.82) | 0.78 (0.33, 1.87) |
| High HbA1C | Non-caregiver | ref | ref |
| | Stable low-intense | 0.76 (0.31, 1.83) | 0.76 (0.31, 1.84) |
| | Rising to high-intense | 0.64 (0.08, 4.79) | 0.63 (0.08, 4.80) |
| High Total cholesterol | Non-caregiver | ref | ref |
| | Stable low-intense | 1.32 (0.96, 1.81)* | 1.29 (0.94, 1.78) |
| | Rising to high-intense | 1.26 (0.65, 2.45) | 1.22 (0.63, 2.40) |
| Low HDL | Non-caregiver | ref | ref |
| | Stable low-intense | 1.16 (0.87, 1.55) | 1.16 (0.86, 1.55) |
| | Rising to high-intense | 0.97 (0.52, 1.82) | 0.94 (0.50, 1.77) |
| High LDL | Non-caregiver | ref | ref |
| | Stable low-intense | 1.17 (0.84, 1.63) | 1.15 (0.83, 1.61) |
| | Rising to high-intense | 1.50 (0.78, 2.90) | 1.47 (0.76, 2.86) |
| High Triglycerides | Non-caregiver | ref | ref |
| | Stable low-intense | 1.37 (1.00, 1.88)** | 1.38 (0.99, 1.88)* |
| | Rising to high-intense | 1.19 (0.61, 2.32) | 1.14 (0.58, 2.26) |
| Overweight | Non-caregiver | ref | ref |
| | Stable low-intense | 1.01 (0.74, 1.38) | 1.04 (0.76, 1.43) |
| | Rising to high-intense | 1.43 (0.77, 2.65) | 1.51 (0.80, 2.85) |

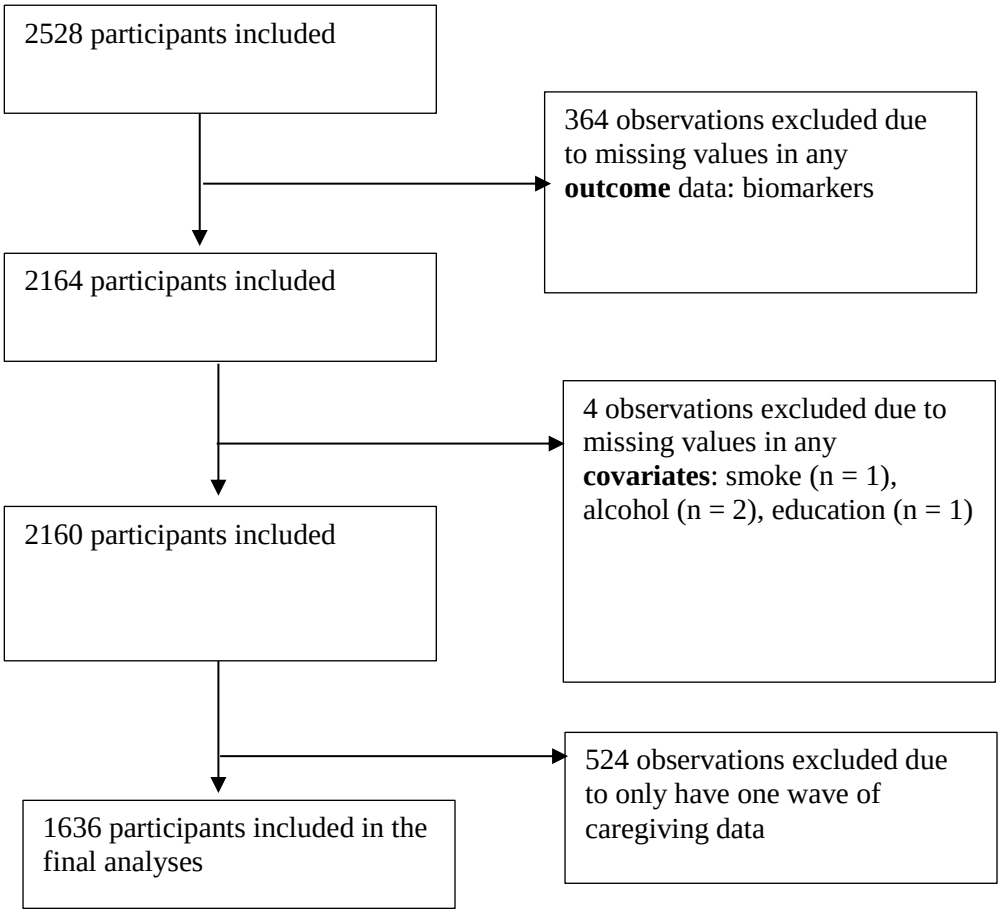
Note: HbA1C, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; CRP, C-reactive protein.

[a] models adjusted for age, education, working status, health insurance, and alcohol drinking

* $p \leq 0.1$ ** $p \leq 0.05$ *** $p \leq 0.01$

Appendix

Figure 5.2. Sample size flow chart.



**Sensitivity analysis**:

Table 5.4. Compare baseline characteristics between analysis sample and excluded sample with missing values

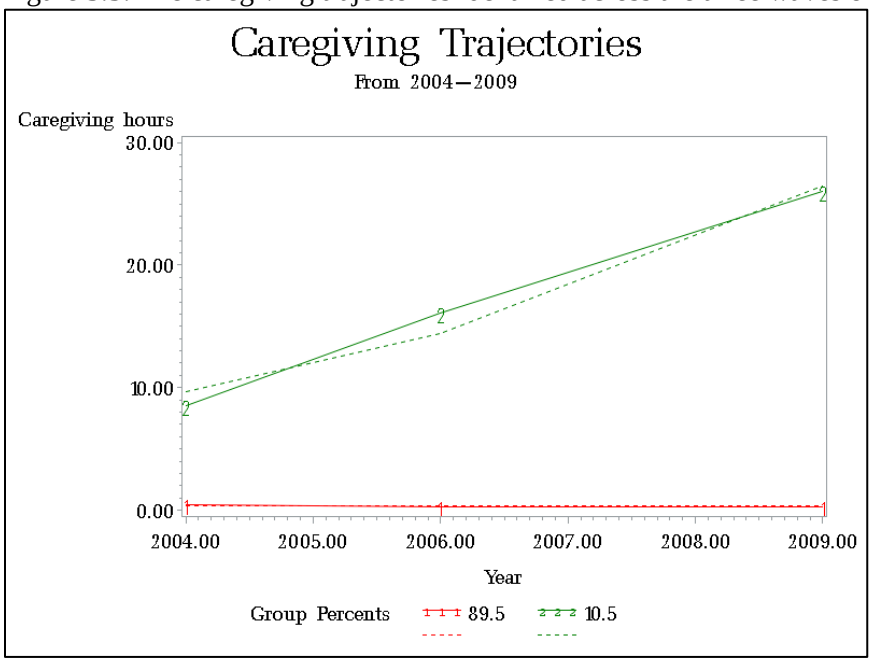
| | Analysis sample (n = 1636) | Excluded sample (n = 892) | P-Value |
|---|---|---|---|
| Age (years) | 40.3 (6.9) | 38.9 (9.3) | <0.001 |
| Education (n, %) | | | 0.02 |
| None | 175 (10.7) | 98 (11.0) | |
| Primary school graduate | 352 (21.5) | 156 (17.5) | |
| Lower middle school degree | 699 (42.7) | 371 (41.6) | |
| Upper middle school degree | 199 (12.2) | 135 (15.1) | |
| Technical or College degree | 211 (12.9) | 131 (14.7) | |
| Missing | 0 | 1 (0.1) | |
| Employment Status | | | <0.001 |
| Employed | 1175 (71.8) | 581 (65.1) | |
| Not employed | 461 (28.2) | 311 (34.9) | |
| Missing | 0 | 0 | |
| Marital Status | | | <0.001 |
| Married | 1603 (98.0) | 845 (94.7) | |
| Never married/divorced | 33 (2.0) | 47 (5.3) | |
| Missing | 0 | 0 | |
| Insurance | | | 0.22 |
| Yes | 1488 (90.9) | 798 (89.5) | |
| No | 148 (9.1) | 94 (10.5) | |
| Missing | 0 | 0 | |
| Smoking | | | 0.12 |
| Yes | 26 (1.6) | 18 (2.0) | |
| No | 1610 (98.4) | 872 (97.8) | |
| Missing | 0 | 2 (0.2) | |
| Current Drinking | | | 0.048 |
| Yes | 156 (9.5) | 93 (10.4) | |
| No | 1480 (90.5) | 796 (89.2) | |
| Missing | 0 | 3 (0.4) | |

Table 5.5. Trajectory Model Selection Criteria

| | BIC | AIC |
|---|---|---|
| 2 groups | -11979 | -11968 |
| 3 group | -9251 | -9232 |
| 4 groups | -8640 | -8612 |

Note: BIC, Bayesian Information Criterion; AIC, Alkaike Information Criterion

Figure 5.3. The caregiving trajectories identified across the three waves of data (2 groups)

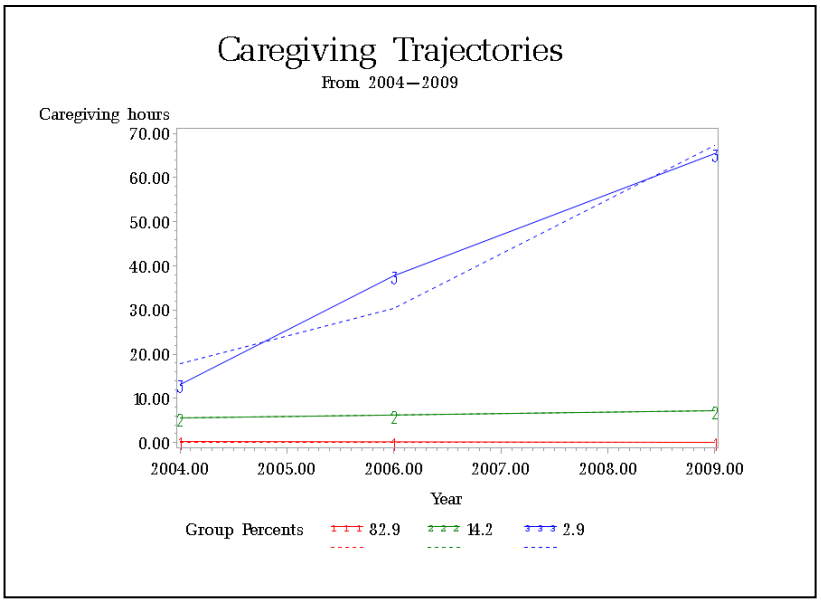



Maximum Likelihood Estimates
Model: Zero Inflated Poisson (ZIP)

| Group | Parameter | Estimate | Standard Error | T for H0: Parameter=0 | Prob > \|T\| |
|---|---|---|---|---|---|
| 1 | Intercept | -1.15832 | 0.04372 | -26.494 | 0.0000 |
| 2 | Intercept | -402.53664 | 12.11046 | -33.239 | 0.0000 |
| | Linear | 0.20200 | 0.00603 | 33.485 | 0.0000 |
| | Group membership | | | | |
| 1 | (%) | 89.50911 | 0.76982 | 116.273 | 0.0000 |
| 2 | (%) | 10.49089 | 0.76982 | 13.628 | 0.0000 |

BIC=-11980.64 (N=3770) BIC=-11979.01 (N=1665) AIC=-11968.17 L=-11964.17

Figure 5.4.The caregiving trajectories identified across the three waves of data (3 groups)

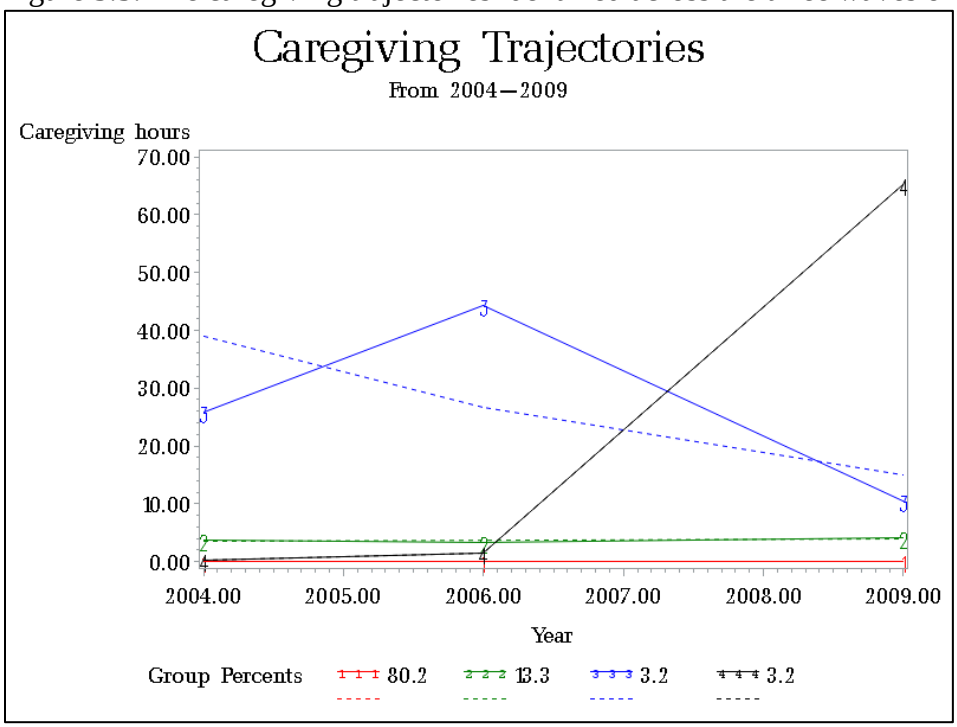



Maximum Likelihood Estimates
Model: Zero Inflated Poisson (ZIP)

| Group | Parameter | Estimate | Standard Error | T for H0: Parameter=0 | Prob > \|T\| |
|---|---|---|---|---|---|
| 1 | Intercept | -2.45255 | 0.07625 | -32.165 | 0.0000 |
| 2 | Intercept | -101.95671 | 18.37707 | -5.548 | 0.0000 |
| | Linear | 0.05173 | 0.00916 | 5.650 | 0.0000 |
| 3 | Intercept | -528.48271 | 6.47013 | -81.680 | 0.0000 |
| | Linear | 0.26515 | 0.00322 | 82.281 | 0.0000 |
| | Group membership | | | | |
| 1 | (%) | 82.92224 | 0.94251 | 87.981 | 0.0000 |
| 2 | (%) | 14.18670 | 0.87622 | 16.191 | 0.0000 |
| 3 | (%) | 2.89107 | 0.41203 | 7.017 | 0.0000 |

BIC= -9253.88 (N=3770)  BIC= -9251.02 (N=1665)  AIC= -9232.06  L= -9225.06

Figure 5.5. The caregiving trajectories identified across the three waves of data (4 groups)




Maximum Likelihood Estimates

Model: Zero Inflated Poisson (ZIP)

| Group | Parameter | Estimate | Standard Error | T for H0: Parameter=0 | Prob > \|T\| |
|---|---|---|---|---|---|
| 1 | Intercept | -3.20014 | 0.11771 | -27.187 | 0.0000 |
| 2 | Intercept | -50.36450 | 25.89903 | -1.945 | 0.0519 |
| | Linear | 0.02576 | 0.01291 | 1.995 | 0.0461 |
| 3 | Intercept | 385.70273 | 9.15005 | 42.153 | 0.0000 |
| | Linear | -0.19064 | 0.00456 | -41.796 | 0.0000 |
| 4 | Intercept | -2522.41455 | 14.75651 | -170.936 | 0.0000 |
| | Linear | 1.25764 | 0.00735 | 171.218 | 0.0000 |
| | Group membership | | | | |
| 1 | (%) | 80.24101 | 1.00906 | 79.521 | 0.0000 |
| 2 | (%) | 13.34825 | 0.87200 | 15.308 | 0.0000 |
| 3 | (%) | 3.24952 | 0.44211 | 7.350 | 0.0000 |
| 4 | (%) | 3.16122 | 0.43454 | 7.275 | 0.0000 |

BIC= -8643.94 (N=3770) BIC= -8639.85 (N=1665) AIC= -8612.76 L= -8602.76

# Chapter 6: Conclusion

Stress plays a significant role in the etiology and progression of cardiovascular disease. This dissertation work explored the associations between multiple dimensions of stress and the risk of hypertension. In paper 1, the study investigated the relationship between the risk of hypertension and perceived stress across various levels of social support and social isolation among Chinese, Korean and Vietnamese Americans in the U.S. In paper 2, the longitudinal study examined the long-term impact of parental caregiving on blood pressure trajectory among women in China. In paper 3, the study investigated the associations between parental caregiving trajectory and the risk of MetS.

## 6.1 Main findings

The findings in paper 1 clearly indicated that perceived stress was a strong predictor of hypertension among Asian Americans. Individuals with high perceived stress were 61% more likely to have hypertension compared to those with low levels of perceived stress. The results supported the main effect hypothesis that social support had a direct beneficial effect on hypertension, irrespective of whether persons were under stress. However, a stress-buffering effect of social support or social network was not demonstrated in this study. Our findings also suggested the relationship between perceived stress and hypertension was modified by gender. Among Asian American men, those with high level of perceived stress were significantly more likely to develop hypertension compared to those with low level of perceived stress. For women, no association between perceived stress and hypertension was found. In addition, the impact of perceived stress on hypertension may differ by Asian American subgroups as the significant

association between perceived stress and hypertension was only observed among Chinese Americans.

In paper 2, we observed that women who provide parental care exhibit higher systolic and diastolic blood pressure compared with non-caregivers across multiple waves. Caregivers and non-caregivers had similar levels of systolic blood pressure at baseline, but caregivers exhibited relatively higher growth rate over time. In addition, caregiving intensity plays a key role in the trajectory of blood pressure. Low-intensity but not high-intensity caregivers show higher growth rate compared with non-caregivers for both SBP and DBP.

In paper 3, the study identified three different trajectories of caregiving by using a group-based trajectory analysis: non-caregivers, 'stable low-intense' caregivers, and 'rising to high-intense' caregivers. 'Rising to high-intense' caregivers and 'stable low-intense' caregivers were associated with higher odds of MetS compared with non-caregivers. Moreover, caregivers who provided 'stable low-intense' parental care were found to have marginally higher odds of pre-hypertension and high triglycerides than those who did not provide caregiving for their parents.

In sum, this dissertation work provides evidence for the biological plausibility of psychosocial stress mechanisms linking stressors from everyday life with cardiovascular risk factors. The findings from the studies partly support the Transactional Model of Stress and Coping, although a stress-buffering effect of social support or social network was not demonstrated in this study.

## 6.2 Additional and Future Research

Overall, there is growing empirical support for the hypothesis that exposure to chronic psychosocial stress contributes to the development of hypertension. However, chronic stress is a

multidimensional construct. Additional studies are needed to investigate the health implications of chronic stress in different domains: occupational stress, social isolation and marital stress, low socioeconomic status (SES), and racial discrimination. In addition, the intensity and duration of stress exposure are assumed to be important determinants of health hazard. Future studies should consider collecting information on intensity and duration of the stress measures.

Evidence of sex and race/ethnicity differences highlights the importance of identifying the types of stressors that are most harmful for various groups. In our study, the impact of perceived stress on hypertension was only observed among male participants and Chinese Americans. Additional research is needed to investigate the underlying reasons. In addition, very few studies have included multi-ethnic populations in the examination of the association between chronic stress and health. It is important for future research in consideration of racial/ethnic differences in the relationships between stress and health consequences.

The samples used for paper 2 and 3 were limited to adult women aged 18 and 52 years. Therefore, the findings are not generalizable to older women or men. Future studies should use a national representative data including both men and women to capture the whole picture. It would be insightful to demonstrate the potential gender dynamics of caregiving in contemporary China.

## 6.3 Public Health Significance and Implication

This dissertation has several contributions to the existing research. Firstly, the dissertation adds to the current body of literature by exploring the relationship between stress and CVD risk factors through assessing two dimensions of stress: perceived stress and caregiving stress. Prior research mostly focuses on a single conceptualization of stress; however, stress is a

complex multidimensional construct that is challenging to operationalize. Thus, the comprehensive approach to conceptualize stress lends a more accurate depiction of the association between stress and CVD risk factors.

Second, the dissertation enriches the literature on the relationship between chronic stress and cardiovascular health among disaggregated Asian subgroups. Research has suggested that Asian Americans show high rates of CVD risk factors and have poor CVD risk factor control. Early studies investigating CVD risk factors among Asian Americans tended to focus on aggregated AAPIs. However, these populations are diverse with respect to country of birth, socioeconomic status, and time since immigration, language spoken, religion and other characteristics that may affect heath. Therefore, the chronic stress and hypertension among AAPIs as an aggregate can obscure heterogeneity in stress level and health status among Asian subgroups. In addition, little research exists that attempts to understand the impact of parental caregiving on blood pressure among Chinese. Nowadays, the demographic changes to China's age structure are astonishing. The increased life expectancy among older Chinese has also introduced new burdens on the family. Adult children shoulder greater responsibility in caring for their aging parents with chronic illness compared to the past. However, it is unclear how Chinese balance the competing demands and structural constraints of family and work while maintaining their physical health in the process of fulfilling their filial responsibilities. Therefore, it is important to explore the physiological consequences of caregiving among Chinese.

The larger implications of this work are directed towards expanding our understanding of the relationships between distinct types of stress and cardiovascular risk factors among Asian American subgroups and Chinese in China. It is important to recognize the diversity within this ethnic group as well as similarities with the general population. Thus, our study will highlight the

importance of identifying differences in health effects of stress among disaggregated AAPI subgroups in order to help health professionals prioritize which subgroups need the most urgent intervention in terms of stress management. Successful interventions to reduce the modifiable risk factors over the life course among individuals under stress may prevent the risk of long-term health hazards. In general, findings from the proposed study will be used to develop future stress management interventions, and incorporating culturally and linguistically appropriate strategies into community outreach and education to decrease cardiovascular disease risk within the Asian population.

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