PROLONGING HEALTHY WORKING LIVES: THE ASSOCIATION OF JOB CHARACTERISTICS AND WORKFORCE EXIT WITH MENTAL AND COGNITIVE HEALTH IN MID- AND LATE LIFE

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A dissertation submitted to Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy

Baltimore, Maryland
August, 2016

Abstract

Objectives: Because work and health interacts with each other over the life course, job characteristics and health factors associated with labor force participation deserve great research attention to reduce disease burden and protect human capital. This dissertation aimed to examine the association between psychosocial job characteristics and cognitive decline (Chapter 2 and 3) and the association between insomnia symptoms and job exit (Chapter 4) among middle-aged and older adults.

Methods: In Chapter 2, the association between cumulative work activities and cognitive changes was examined by multiple linear regression, using data from the Baltimore Epidemiologic Catchment Area (ECA) follow-up study and the Occupational Information Network. The interaction between workplace social interaction and physical demands was tested. In Chapter 3, the association between job strain at midlife and changes in cognitive function later in life was examined in a sample from the Baltimore ECA study using multiple linear regression models. In Chapter 4, the association between insomnia symptoms and subsequent job exit was examined in a nationally representative sample from the Health and Retirement Study using multinomial logistic regression models.

Results: In Chapter 2, higher cumulative mental demands or social interaction were significantly associated with less decrease in cognitive function as assessed by the Mini-Mental State Examination (MMSE) and the Immediate and Delayed Word Recall tasks. Higher cumulative physical demands were associated with greater decline in the MMSE, and the association was moderated by social interaction. In Chapter 3, participants with high strain jobs had significantly greater cognitive decline as assessed by the MMSE and Immediate Word Recall task, compared to those with low strain jobs. Analyses of Chapter 4 found that having more insomnia symptoms was associated with increased odds of health-related job exit. There was no association between insomnia and job exit due to non-health reasons.

Conclusions: The studies demonstrated potential intervention points in the workplace for promoting cognitive health later in life, and indicated the potential economic burden of insomnia that was attributable to reducing people's working lives. Future research should investigate the role of workplace social support in improving the psychosocial work environment and prolonging workforce participation.

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To my parents, grandparents and everyone who made me who I am today.

Acknowledgements

I would like to express my sincere gratitude to faculty, staff and students at the Johns Hopkins University. This dissertation would not have been possible without your support.

First of all, I sincerely think my advisor, Dr. Ramin Mojtabai, for your guidance and advice during this process. I've learned not only how to do scientific research, but also how to become a good researcher, which will help me along the road of my research career. I also wish to acknowledge the help and support of Dr. Joseph Gallo, who was my advisor for the first two years of my doctoral studies. I would like to thank Dr. Jacqueline Agnew who always made me feel encouraged, Dr. William Eaton who provided me with data for my dissertation, Dr. Darrell Gaskin who inspired my initial research ideas in cognitive health, and Dr. Lauren Nicholas who introduced me to the research area of aging and work. Many thanks to all my oral exam committee members for your time and help along the way: Drs. Jacqueline Agnew, Judith Bass, Kitty Chan, Marie Diener-West, William Eaton, Ramin Mojtabai, Lauren Nicholas, Adam Spira, Pamela Surkan and Antonio Trujillo (in alphabetical order). I greatly appreciate all your thoughtful feedback on my proposal and dissertation. My note of thanks also goes to all my friends, especially the SEALS--lovely ladies of my PhD cohort: Stacey Williams, Emma Stapp, Amanda Nguyen and Sarah Forrester.

Last but not least, I would like to extend my deepest gratitude to my parents. It is your unconditional love that encourages me to persist. Words cannot express my appreciation.

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Chapter 1. Introduction

1.1 Background

Population aging is a major demographic challenge faced by nations worldwide, as a result of increased life expectancy and decreased fertility rate over the past decades (United Nations, 2015; World Health Organization, 2011). The change in population's age structure shifts its workforce composition (Toossi, 2002). Despite of the relatively low labor-force participation rates among older adults in high-income countries (Staudinger, Finkelstein, Calvo, & Sivaramakrishnan, 2016), workers over age 55 will account for approximately one fourth of the labor force in the United States by 2020, which almost doubles the number in 2000 (Hayutin, Beals, & Borges, 2013). Although the timing for leaving the labor force is determined by a variety of factors such as financial incentives and labor-market flexibility, health problems and disabilities are still among the most common reasons for involuntary retirement, layoffs and failing to extend labor force participation in older adults (Nilsson, Hydbom, & Rylander, 2011; Staudinger et al., 2016). Because work and health interact with each other over the life course (Figure 1) (Clougherty, Souza, & Cullen, 2010), studying how work shapes individuals' health trajectories is of great importance for prolonging healthy working lives and maintaining human capital (Bloom et al., 2015; Staudinger et al., 2016).

The health effects of the physical and psychological work environment may accumulate and manifest in late life (Fletcher, Sindelar, & Yamaguchi, 2011; Kivimäki et al., 2012; Nexø, Meng, & Borg, 2016). This dissertation mainly focuses on the psychosocial environment, where job-related adverse health outcomes were commonly explained by the stress mechanisms (McEwen, 1998; Nieuwenhuijsen, Bruinvels, & Frings-Dresen, 2010; Stansfeld & Candy, 2006). The first leading job stress model is the job demand-control model developed by Karasek in the late 1970s, and has been widely used in occupational health research for decades (Häusser, Mojzisch, Niesel, & Schulz-Hardt, 2010; Karasek, 1979; Van der Doef & Maes, 1998, 1999). It defines job strain by "the interaction of job demands and job decision latitude" (or job control),

and proposes that mental strain occurs when job demands are high and job decision latitude is low (Karasek, 1979). Chronic exposure to job strain may increase the risk of a variety of medical conditions, such as cardiovascular disease (Nyberg et al., 2013), depression (Stansfeld, Shipley, Head, & Fuhrer, 2012) and dementia (Andel et al., 2012; Wang, Wahlberg, Karp, Winblad, & Fratiglioni, 2012). In the late 1980s, Johnson and Hall introduced a third dimension, social support, to the job demand-control model in a study about the relationship between psychosocial work environment and cardiovascular disease (Johnson & Hall, 1988). They dichotomized the workplace social support into "isolated or collective conditions", and found that low levels of work support "accentuate the impact of job strain" (Johnson & Hall, 1988).

Another job stress model, the job demands-resources model of burnout developed by Demerouti and colleagues in the early 2000s, has also gained popularity in recent years (Demerouti, Bakker, Nachreiner, & Schaufeli, 2001). It is similar to the job demand-control model, but broader in terms of concept definition and more flexible in application (Schaufeli & Taris, 2014). Job demands here include any job characteristics that can be a source of stress. Job resources refer to any job characteristics that may "be functional in achieving work goals", "stimulate personal growth and development" (Demerouti et al., 2001) and buffer the negative impacts of stressful job demands (Bakker & Demerouti, 2007), for example "feedback, job control and social support" (Schaufeli & Taris, 2014). This model emphasizes the main effects of two simultaneous processes, "the health impairment process" through high job demands and "the motivational process" through low job resources (Demerouti et al., 2001; Schaufeli & Bakker, 2004).

On the other hand, certain characteristics of the work environment may promote health, in particular cognitive health. Schooler (1984) proposed the environmental complexity theory based on the "causal relationships between occupational conditions and psychological functioning". The "complexity" in this context is defined by the diversity and quantity of stimuli in the environment (Schooler, 1984). The theory hypothesizes that stimulation from a complex

environment "rewards cognitive efforts" and motivates individuals to develop cognitive capacities (Schooler, 1984). Occupational self-direction, defined as "the use of initiative, thought, and independent judgement", is considered as the featured stimulus of a complex environment (Schooler, 1984). Schooler et al. (2004) further found that the influence of workplace self-directedness on cognitive functioning persisted into late life. This concept of self-direction overlaps to some extent with the job decision latitude of the job demand-control model (Karasek, 1979) and the organizational resources component of the job demands-resources model (Demerouti et al., 2001).

Occupation is also considered as a proxy for cognitive reserve, which refers to the individuals' capacity to resist brain pathology and optimize cognitive performance (Stern, 2002). The cognitive reserve theory hypothesizes that when having similar neuropathological damages, individuals with more cognitive reserve tend to have fewer clinical manifestations, compared to those with less cognitive reserve (Stern, 2002). The reserve evolves over the life course as lifetime experience accumulates (M Tucker & Stern, 2011). Mentally stimulating experience, such as high levels of occupational attainment, is associated with increased cognitive reserve (Stern, 2002). Epidemiologic and neurological literature also shows that low lifetime occupational attainment increases the risk of dementia (Stern et al., 1994; Valenzuela & Sachdev, 2006).

Individuals who exit the workforce lose the occupational source of environmental complexity and cognitive reserve, and may lack of mental stimulation to maintain high cognitive functioning levels. Economic literature demonstrates the negative causal effect of retirement on cognitive function (Bonsang, Adam, & Perelman, 2012; Mazzonna & Peracchi, 2012; Rohwedder & Willis, 2010). It was also found that time away from work due to unemployment predicted cognitive impairment in later life (Leist, Glymour, Mackenbach, van Lenthe, & Avendano, 2013). These findings support the "use it or lose it" hypothesis that engaging in a greater number of

mentally stimulating activities which exercise the brain protects individuals against cognitive decline at later stages of life (Salthouse, 2006; Swaab et al., 2002).

Many people who desire to have longer working lives are unable to do so due to health limitations (Nilsson et al., 2011). Existing research has examined the relationship of labor force exit with general health (Bound, Schoenbaum, Stinebrickner, & Waidmann, 1999) and specific medical conditions such as diabetes (Herquelot, Guéguen, Bonenfant, & Dray-Spira, 2011; Rumball-Smith, Barthold, Nandi, & Heymann, 2014), cardiovascular disease (Kouwenhoven-Pasmooij, Burdorf, Roos-Hesselink, Hunink, & Robroek, 2016) , obesity (Robroek et al., 2013), depression and anxiety (Rudolph & Eaton, 2015), and sleep disturbance (Haaramo, Rahkonen, Lahelma, & Lallukka, 2012; Lallukka, Haaramo, Lahelma, & Rahkonen, 2011). Limiting the impacts of such medical conditions on labor force participation may extend people's working lives, protect human capital and promote cognitive health in late life.

1.2 Statement of the Problem

A public health challenge of population aging is the burden of late-life cognitive impairment (World Health Organization & Alzheimer's Disease International, 2012). Decline in cognitive abilities is also a barrier to labor force participation. Identifying and modifying preventable midlife factors to slow the process of cognitive decline has become very important for reducing the disease and economic burden to the society (Baumgart et al., 2015). Because people usually spend about half of their waking time at work, risk and protective factors in the psychosocial work environment deserves research attention (Staudinger et al., 2016). Promoting cognitive health at the workplace may avoid early labor force exit and prolong working lives, which in return supports healthy aging (Staudinger et al., 2016). However, the evidence on how psychosocial work environment influences cognitive function later in life is not strong (Baumgart et al., 2015; Nexø et al., 2016; Plassman, Williams, Burke, Holsinger, & Benjamin, 2010). Existing research on the association between job characteristics and cognitive decline has been

mainly focused on mental demands, work complexity and work-related stress (Nexø et al., 2016; Then, Luck, Luppa, Thinschmidt, et al., 2014). Although studies on job strain tended to show that low job control is associated with poor cognitive function later in life, the findings on different cognitive domains are mixed. Moreover, findings about the association between workplace social interaction and cognitive decline are limited, and little is known about its potential interaction with physical demands.

Studies have examined health and workforce exit in several medical conditions. Sleep disturbance is among the most prevalent conditions (Ohayon, 2002), and often associated with role impairments and injuries at the workplace (Kessler et al., 2012; Kessler et al., 2011). However, prior work mainly focused on insomnia and disability (Eriksen, Natvig, & Bruusgaard, 2001; Haaramo et al., 2012; Lallukka et al., 2011; Salo et al., 2010; Sivertsen et al., 2006; Sivertsen et al., 2009), and little has been done to examine the association between insomnia symptoms and job exit other than disability retirement.

This dissertation will contribute to existing literature by investigating the association between psychosocial job characteristics and cognitive decline. It will also add evidence about labor force participation in mid- and late life by examining the association between insomnia symptoms and workforce exit.

1.3 Specific Research Aims and Hypotheses

This dissertation has three specific aims:

Specific Aim 1: To examine the cumulative effects of work activities on cognitive decline over an approximately twelve-year period in a population-based sample of middle-aged and older adults from the Baltimore Epidemiologic Catchment Area follow-up study, and to use job characteristics measures derived from the Occupational Information Network as job exposure matrices to study the cumulative job exposures.

Hypothesis 1.1: Participants with higher levels of cumulative mental demands experience less decline in cognitive function, compared to those with lower levels of cumulative exposures.

Hypothesis 1.2: Participants with higher levels of cumulative social interaction experience less decline in cognitive function, compared to those with lower levels of cumulative exposures.

Hypothesis 1.3: Participants with higher levels of cumulative physical demands experience greater decline in cognitive function, compared to those with lower levels of cumulative exposures.

Hypothesis 1.4: Social interaction and physical demands interact with each other on influencing cognitive function.

Specific Aim 2: To examine the association between job strain at midlife and cognitive decline later in life using longitudinal data of a population-based sample from the Baltimore Epidemiologic Catchment Area follow-up study.

Hypothesis 2.1: Participants with high-strain jobs (high job demands and low job control) at midlife experience greater cognitive decline later in life, compared to those with low-strain jobs (low job demands and high job control).

Hypothesis 2.2: Participants with passive jobs (low job demands and low job control) at midlife experience greater cognitive decline later in life, compared to those with low-strain jobs (low job demands and high job control).

Hypothesis 2.3: Participants with active jobs (high job demands and high job control) at midlife experience less decrease in cognitive function later in life, compared to those with high-strain jobs (high job demands and low job control) or passive jobs (low job demands and low job control).

Specific Aim 3: To examine the association between insomnia symptoms and subsequent job exit among a nationally representative sample of middle-aged and older adults, using longitudinal data from the Health and Retirement Study (HRS).

Hypothesis 3.1: Insomnia symptoms are associated with exiting from paid employment due to poor health in the subsequent two-year period.

Chapter 2. Cumulative Effects of Work Activities on Cognitive Decline: Linking Data from the Occupational Information Network to the Baltimore Epidemiologic Catchment Area Follow-up Study

2.1 Abstract

Background: Although the association of cognitive function with leisure-time activities has been well recognized, evidence of the association between work activities and cognitive function is limited. The objective of this study was to examine the cumulative effects of workplace mental, social and physical activities on cognitive decline over an approximately twelve-year period using data from the Baltimore Epidemiologic Catchment Area (ECA) follow-up study.

Methods: The study sample consisted of 376 to 389 participants (dependent on outcome measure) aged between 40 and 55 at the time of the Baltimore ECA Wave 3 assessment who reported ever working during the interval between the Wave 3 and Wave 4. Cognitive function was measured at the Wave 3 and Wave 4 using the Mini-Mental State Examination (MMSE), Immediate Word Recall task and Delayed Word Recall task. Job characteristics measures of mental demands, social interaction and physical demands were derived from the Work Activities section of the Occupational Information Network, and linked to the Baltimore ECA study using the US Census occupation codes and the Standard Occupational Classification codes. Multiple linear regression models were used to examine the associations between cumulative work activities and changes in cognitive function over the study period. The interaction between workplace social interaction and physical demands was also tested.

Results: Higher cumulative mental demands or social interaction were associated with less decline in cognitive function, after adjustment for age, sex, race, education, baseline self-rated health status, baseline score of cognitive measure, years of follow-up, total number of non-working years and total number of jobs held in the period. Significant effect modification by cumulative social interaction on the association between cumulative physical demands and

change in the MMSE was found. As the level of cumulative social interaction increased, increase in physical job demands was associated with less decline in the MMSE.

Conclusion: The findings support prior research on mental demands at work and cognitive decline, and provide evidence for a positive impact of workplace social interaction on cognitive function later in life among middle-aged adults.

2.2 Introduction

As the population ages, cognitive impairment has become a critical public health priority (World Health Organization & Alzheimer's Disease International, 2012). Decline in cognitive abilities is also a barrier to labor force participation. Because there has been no effective treatment for cognitive impairment, identifying and modifying preventable midlife risk factors is very important (Baumgart et al., 2015). Time spent on work is usually a major component of adult years. Work interacts with health over the life course and influences the aging process (Clougherty et al., 2010; Staudinger et al., 2016). Thus, potential risk and protective factors in the work environment deserve research attention.

Existing research on the association between psychosocial job characteristics and cognitive decline has been mainly focused on mental demands, work complexity and work-related stress (Nexø et al., 2016; Then, Luck, Luppa, Thinschmidt, et al., 2014). It was found that higher levels of mental demands were associated with slower rates of cognitive decline (Bosma, Van Boxtel, Ponds, Houx, & Jolles, 2003; Fisher et al., 2014; Marquie et al., 2010). The findings supported the "use it or lose it" hypothesis that engaging in more mental activities that exercise the brain protects individuals against cognitive decline at later stages of life (Salthouse, 2006). The negative causal effect of retirement on cognitive function further emphasizes the benefits of work activities to cognitive health (Bonsang et al., 2012; Dufouil et al., 2014; Mazzonna & Peracchi, 2012). Studies on work complexity and cognitive function were mainly conducted based on the environmental complexity theory (Schooler, 1984). The "complexity" refers to the

diversity and quantity of stimuli from the work environment that "reward cognitive effort" and motivate individuals to develop cognitive capacities and maintain high functioning levels (Schooler, 1984). Measures of work complexity with data, people and things from the Dictionary of Occupational Titles (DOT) were commonly used in such studies (Cain & Treiman, 1981). Results showed that higher levels of work complexity with people and data were associated with better late-life cognitive function (Andel, Kåreholt, Parker, Thorslund, & Gatz, 2007; Finkel, Andel, Gatz, & Pedersen, 2009; Ribeiro, Lopes, & Lourenço, 2013; Smart, Gow, & Deary, 2014) and lower risk of dementia (Andel et al., 2005; Karp et al., 2009; Kröger et al., 2008). Based on the job demand-control model (Karasek, 1979), studies on work-related stress tended to show that low job control was associated with poor cognitive function (Andel, Crowe, Kåreholt, Wastesson, & Parker, 2011; Sabbath, Andel, Zins, Goldberg, & Berr, 2016) and increased risk for dementia (Andel et al., 2012; Wang et al., 2012).

Research on work activities can be considered as a subset of the literature on the association of mental, social, or physical activities with cognitive aging in general (Jorm et al., 1998). The mental dimension was investigated in existing literature as described above, however, evidence on social and physical dimensions in relation to cognitive decline is limited, and little is known about the interaction between these work activities. The objective of the present study was to examine the cumulative effects of work activities on cognitive decline in a population-based sample of middle-aged and older adults from the Baltimore Epidemiologic Catchment Area (ECA) follow-up study. It was hypothesized:

Hypothesis 1: Participants with higher levels of cumulative mental demands experience less decline in cognitive function, compared to those with lower levels of cumulative exposures.

Hypothesis 2: Participants with higher levels of cumulative social interaction experience less decline in cognitive function, compared to those with lower levels of cumulative exposures.

Hypothesis 3: Participants with higher levels of cumulative physical demands experience greater decline in cognitive function, compared to those with lower levels of cumulative exposures.

Hypothesis 4: Social interaction and physical demands interact with each other on influencing cognitive function.

2.3 Methods

2.3.1 Study Participants

The Baltimore ECA follow-up study is a population-based study designed to study life course psychopathology (Eaton, Kalaydjian, Scharfstein, Mezuk, & Ding, 2007). A total of 3481 Baltimore residents were interviewed in 1981 (Wave 1). The follow-up interviews were conducted with 2768 participants in 1982 (Wave 2), 1920 participants in 1993-1996 (Wave 3) and 1071 participants in 2004-2005 (Wave 4). More details about the study are described elsewhere (Eaton et al., 2007).

In the present study, the Wave 3 and Wave 4 were used as the baseline and follow-up. Earlier waves were not used because cognitive measures in those waves were limited. Of the 1071 participants who participated in both baseline and follow-up waves, 505 participants in the age range of 40-55 at baseline were selected, in order to have a relatively homogeneous group. Participants older than age 55 at baseline were more likely to retire during the study period, which may contribute to additional cognitive decline (Bonsang et al., 2012; Mazzonna & Peracchi, 2012). Fifty-two out of the 505 participants reported having never worked between the Wave 3 and Wave 4. Among participants who ever worked during the study period, data for the Mini-Mental State Examination (MMSE), Immediate Word Recall and Delayed Word Recall tasks—the measures of cognitive functioning used in this study—were available for 389, 388, and 376 participants respectively.

2.3.2 Measures of Cognitive Functioning

The MMSE has been widely used in clinical and research settings to examine mental status and identify early changes in cognitive function (Folstein, Folstein, & McHugh, 1975). It tests five domains of cognition, including orientation, registration, attention and calculation, recall and language (Folstein et al., 1975). The score ranges from 0 to 30, with higher scores indicating better cognitive function. The Immediate and Delayed Word Recall tasks were used for assessing memory. Participants were read a list of 20 common words and asked to recall as many as they could immediately and 20 minutes later. Scores for each task range from 0 to 20, with higher scores indicating better memory. Cognitive decline was defined by absolute change in scores of the cognitive measures between the Wave 3 and Wave 4 (score at Wave 4 minus score at Wave 3).

2.3.3 Measures of Work Activities

At the Wave 4, participants were asked about their work history in each year, going back to the interview year of Wave 3. Labor force status in each year was ascertained by the question, "This is (year). What have you been doing most of the time this year, working, keeping house, going to school, or something else?" (Baltimore Health and Mental Health Study, 2004). "Something else" included being laid off, looking for jobs, retired, and disabled (Baltimore Health and Mental Health Study, 2004). If a participant was working, the participant was further asked whether he or she was working for the same company and in the same position, working for the same company but at a different position, or working for a different company. Information on "company", "type business", "position" and "activities" was collected for newly mentioned jobs (Baltimore Health and Mental Health Study, 2004). Occupations were coded with the three-digit 2000 Census occupation codes. The 2000 Census occupation codes were cross-walked to the six-digit 2010 Standard Occupational Classification (SOC) codes through the four-digit 2002 and 2010 Census occupation codes. The crosswalk file was obtained from the U.S. Census Bureau

(www.census.gov). For occupation codes in the ECA that did not have matches in the 2000 Census codes or the 2010 SOC codes, or had more than one detailed 2010 SOC codes, the 2010 SOC codes were assigned based on participants' description of their activities in the position.

Job characteristic measures were developed using data from the Occupational Information Network (O*NET) (www.onetonline.org). The O*NET, as the replacement to the DOT, is a source of occupational information developed by the United States Department of Labor (Peterson, Mumford, Borman, Jeanneret, & Fleishman, 1999). It is an online database based on the Standard Occupational Classification (SOC) system (U.S. Department of Labor, 2010). The SOC codes have four components, including major group, minor group, broad occupation and detailed occupation (U.S. Bureau of Labor Statistics, 2010). For example, the SOC code for the occupation chief executives is 11-1011. The O*NET-SOC includes the six-digit SOC, and has additional two digits for more detailed classification. Among the 974 data-level occupations, 704 are SOC-level occupations with the additional two digits being 00, and the rest occupations are more detailed (U.S. Department of Labor, 2010). For example, the O*NET SOC for chief executives is 11-1011.00, and another more detailed code with the same SOC code is 11-1011.03 (chief sustainability officers).

The O*NET provides worker-oriented and job-oriented data (O*NET Resource Center). The worker-oriented data include worker characteristics, work requirements, experience requirements. The job-oriented data include occupational requirements, workforce characteristics and occupation-specific information. The measures on work activities used in the present study were obtained from the O*NET work activities section in the domain of occupational requirements.

The O*NET database was initially developed based on data collected from occupation analysts, and then updated by ongoing surveys conducted among each occupation's worker population informants (O*NET Resource Center). Data are collected using a two-stage design (O*NET Resource Center). In the first stage, a random sample of businesses employing workers

in the occupations of interest is selected. In the second stage, a random sample of workers in the occupations of the businesses is selected. Selected respondents are interviewed using standardized questionnaires. Data about importance of a certain activity to a job were ascertained by the question, "How important is the activity to your current job? Not important, somewhat important, important, very important, or extremely important" (O*NET Resource Center). The present study used the transformed scores on a 0-100 scale obtained from the O*NET website.

The measures of work activities included ten items on mental processes (Cronbach's alpha=0.92), three items on social interactions (Cronbach's alpha=0.79), and two items on physical demands (Cronbach's alpha=0.94). The Cronbach's alpha coefficients for internal consistency were calculated in the O*NET occupation sample (n=856 jobs in the O*NET). Details of the items are listed in the Appendix Table S2.1. Composite scores of the three activity domains were generated in the following steps. First, original O*NET data were aggregated at the six-digit SOC level. Second, for SOC codes of broad occupations that did not have exact matches in the O*NET, job characteristics were calculated by averaging the O*NET descriptors of corresponding detailed occupations (Appendix Table S2.2). Third, a composite score was generated by dividing the summative score by the number of items over which the sum was calculated.

The ECA occupation data were then linked to the composite O*NET measures through the Census occupation codes and SOC codes described above. The cumulative exposure to a certain type of work activity over the time interval between the Baltimore ECA Wave 3 and Wave 4 interviews was calculated by summing the composite scores of each working year during the study period. The cumulative scores were then standardized across the study sample to a normal distribution with a mean of zero and a standard deviation of one (Fletcher et al., 2011).

2.3.4 Covariates

Covariates used in the analysis included age, sex, race/ethnicity (non-Hispanic white, others), education (below high school, high school, above high school), baseline self-rated health status (excellent, good, fair or poor), baseline score of cognitive measure (MMSE, Immediate Word Recall and Delayed Word Recall tasks), years of follow-up (11-13 years), the number of non-working years during the follow-up period (range: 0-12 years), and the total number of jobs held during this period (one, two, more than two jobs).

2.3.5 Statistical Analysis

Exploratory analyses were conducted to examine sample characteristics and correlations between cumulative work activities during the study period. Changes in cognitive scores from the Wave 3 to Wave 4 were examined using paired t-tests. Participants who worked throughout the period were also compared with those who had non-working years.

Multiple linear regression models were used to examine the association between cumulative job exposures and cognitive decline over an approximate twelve-year period. Regression diagnostics were performed, and robust variance estimates were used to account for minor issues in normality, heteroscedasticity and outliers. The dependent variables were continuous measures of cognitive changes between the Wave 3 and Wave 4 (score at Wave 4 minus score at Wave 3) assessed by the MMSE, Immediate Word Recall and Delayed Word Recall respectively. The primary independent variables were standardized measures of cumulative mental demands, social interaction and physical demands. Three sets of models were tested for the MMSE, Immediate Word Recall and Delayed Word Recall tasks respectively. In each set, a model was tested for each job characteristics (Models 1-3), adjusted for age, sex, race, education, baseline self-rated health status, baseline score of the cognitive measure, years of follow-up, total number of non-working years and the number of jobs held during the follow-up period. The interaction between workplace social interaction and physical demands was then

tested. The interaction between mental demands and physical demands was not reported because of the strong correlation between mental demands and social interaction (Appendix Table S2.3).

In a sensitivity analysis, we examined the association between cumulative job exposures and cognitive decline in the subsample of participants who worked throughout the study period.

The analyses were conducted using STATA version 12 (Stata Corporation, College Station, TX). All significance tests were evaluated by two-sided tests at the level of $p<0.05$.

2.4 Results

2.4.1 Sample Characteristics

At baseline, the mean age of the study sample was 45.7 years (standard deviation [SD]: 4.2); 63.8% were female, 41.4% were non-white, 19.0% had education level below high school, and 17.0% rated health as fair or poor (Table 2.1). The years of follow-up ranged from 11 to 13 years, and was 11.9 years on average (SD: 0.7). The MMSE scores ranged from 23 to 30 at baseline with three participants (<1%) scoring below 24, which is generally considered as an indicator of cognitive deficits, and ranged from 19 to 30 at the follow-up wave with seven participants (<2%) scoring below 24.

On average, the study sample worked for 89% of the time during the follow-up period. The mean working-year was 10.5 years (SD: 2.5) (Table 2.1). Approximately 58% of the sample had only one job, and two thirds of the sample worked throughout the period. The longest-held job during the study period for each participant were identified. Among the 161 unique occupations, the three most frequent occupations were “secretary and administrative assistant”, “elementary or middle school teacher” and “bookkeeping, accounting, or auditing clerk” (Table 2.2).

2.4.2 Association between Cumulative Work Activities and Cognitive Changes

As shown in Table 2.3, the average scores of three cognitive measures declined significantly over the period between the Wave 3 and Wave 4. Table 2.4 presents the association between cumulative job exposures and cognitive changes. It was found that a one standard deviation increase in cumulative mental demands during the study period was associated with 0.31 units less decrease in the MMSE (adjusted b=0.31; 95% CI: 0.04 to 0.57; p=0.023), adjusted for baseline age, sex, race, education, baseline self-rated health status, baseline MMSE, years of follow-up, total number of non-working years and total number of jobs held during the follow-up period (Model 1). With adjustment for the same set of covariates, a one standard deviation increase in cumulative social interaction was associated with 0.29 units less decrease in MMSE (adjusted b=0.29; 95% CI: 0.01 to 0.57; p=0.041) (Model 2). However, a one standard deviation increase in cumulative physical demands was associated with 0.14 units greater decrease in the MMSE (adjusted b=-0.14; 95% CI: -0.29 to 0.004; p=0.057) (Model 3).

The association between cumulative physical demands and change in the MMSE was found to be moderated by cumulative social interaction (Model 4). Figure 1 presents the slopes of change in the MMSE on cumulative physical demands when the cumulative social interaction was held constant at different values from low (-1.1), median (0) to high (1.1). As the level of workplace social interaction increased from low to high, increase in physical job demands was associated with less decrease in cognitive scores.

The effects of work activities on the Immediate and Delayed Word Recall tasks were in the same direction as those for the MMSE. Social interaction was shown to have strong positive effects on memory (Immediate Word Recall task: adjusted b=0.56; 95% CI: 0.10 to 1.02; p=0.018; Delayed Word Recall task: adjusted b=0.70; 95% CI: 0.28 to 1.13; p=0.001). The cumulative effects of physical demands on memory and the effect modifications were not significant, however (Table 2.4). Detailed results are presented in the Appendix Table S2.4-S2.7.

2.4.3 Sensitivity Analysis

Participants who reported working throughout the study period were identified as a subsample for sensitivity analyses. The sample sizes of the subsample were thus limited to 253 for the analyses of the MMSE, 253 for the Immediate Word Recall task, and 245 for the Delayed Word Recall task. Compared to participants who worked throughout the study period, those who had non-working years were more likely to have lower cumulative mental demands (adjusted b=-0.24; 95% CI: -0.39 to -0.08; p=0.003) and cumulative social interaction (adjusted b=-0.16; 95% CI: -0.30 to -0.02; p=0.023), but higher cumulative physical demands (adjusted b=0.34; 95% CI: 0.11 to 0.57; p=0.004), after adjusting for baseline age, sex, race, education level, baseline self-rated health status and MMSE, years of follow-up, and total number of jobs held during the follow-up period (Table S2.8).

The results of the analyses in the subsample of participants who worked throughout the study period were consistent with the main analyses, but the statistical significance was reduced for analyses of change in the MMSE scores. The positive effect of social interaction remained statistically significant for the Immediate Word Recall and Delayed Word Recall tasks (Appendix Table S2.9-S2.12).

2.5 Discussion

To extend existing work on job characteristics and cognitive function later in life, this study examined the association between cumulative work activities and cognitive changes over an approximately twelve-year period in a population-based sample from the Baltimore ECA follow-up study. Work activities were measured along three dimensions (mental, social and physical) based on the O*NET categorization. Baseline cognitive function was controlled to isolate the attributable cognitive changes due to the cumulative job exposure in the study period. It was found that higher cumulative mental demands and social interaction at the workplace were associated with less cognitive decline after adjusting for potential confounders. The data also

revealed effect modification of social interaction on the association between physical demands and cognitive function as measured by the MMSE.

The observed finding on cumulative mental demands was consistent with existing literature (Nexø et al., 2016), and supported the "use it or lose it" hypothesis that engaging in a greater number of mental activities protects individuals against cognitive decline (Salthouse, 2006). Pre-existing cognitive abilities for conducting certain mental activities during the subsequent period (Salthouse, 2006) and the phenomenon of regression to the mean were controlled by the adjustment for baseline cognitive function. However, potential reverse causality which leads to non-causal associations may still exist. Participants who experienced cognitive decline during the study period might have transitioned to jobs requiring lower cognitive abilities or have exited the labor force, thus had less cumulative exposure to mentally stimulating work activities. On average, the percentages of the follow-up period not in working status were approximately 10% in the study sample, and 32.4% among participants who did not work throughout the study period. And approximately 42% of the study participants had at least one job change. The number of job changes and the number of non-working years were included as covariates to account for the potential reverse causation, but it may not be fully adjusted due to the limitations of the study design.

Strong associations between cumulative social interaction at the workplace and cognitive decline were found in all three cognitive measures. The associations remained significant for the Immediate Word Recall and Delayed Word Recall tasks among participants who worked throughout the study period. The measure of social interaction was developed based on three O*NET work-activity items, including internal communication, external communication and interpersonal relationship (Appendix Table S2.1). Existing studies on the association between the social dimension of job characteristics and cognitive decline were primarily focused on work complexity with people, based on Schooler's environmental complexity theory (Schooler, 1984; Schooler, Mulatu, & Oates, 1999). Items on work complexity with people included "mentoring,

negotiating, instructing, supervising, diverting, persuading, speaking-signaling, serving and taking instructions-helping" (Miller, 1980). Whereas, the social interaction measure used in the present study focused on communication and interpersonal relationships, which is broader and may include feedback, social support and other interpersonal interaction at the workplace. The buffering effect of workplace social support, as proposed in the job demand-control-support model and the job demands-resources model, may protect cognitive health by attenuating the negative impacts of work-related stress and reducing the risk of medical conditions such as cardiovascular disease and depression that may impair cognitive function (Demerouti et al., 2001; Johnson & Hall, 1988).

In this analysis, no statistically significant relationships between cumulative physical demands and cognitive changes were observed. However, we found a trend level significant association between physical demands and decline in the MMSE (p=0.057), and the association was moderated by social interaction. Jobs with high physical demands are more likely to be less skilled and associated with lower socioeconomic status (Warren, Hoonakker, Carayon, & Brand, 2004). Higher cumulative physical demands were found to be associated with greater cognitive decline, which supported existing literature on physical exertion or manual labor demands (Jorm et al., 1998; Potter, Plassman, Helms, Foster, & Edwards, 2006). However, as the level of cumulative social interaction increased, the negative impacts decreased. When the social interaction level was high, increase in cumulative physical demands was associated with less decrease in cognitive function, which was in accordance with findings on the protective effects of physical activities on cognitive health (Sofi et al., 2011).

When exploring the correlation between the three work-activity domains, we found that the correlation between cumulative physical demands and mental demands/social interaction in participants who worked throughout the study period differed from that in participants who had non-working years (Appendix Table S2.3). Among participants who worked throughout the study period, physical demands were negatively correlated with mental demands/social

interaction, which was consistent with the notion that physically-demanding jobs are usually less-skilled and involve less mental demands or social interaction. However, among participants who had non-working years, physical demands were positively correlated with mental demands/social interaction. Having jobs with high demands in all domains may indicate risk of high job strain, which could be a potential reason for workforce exit, work absenteeism or job changes.

Several limitations of this study should be noted. First, participants reported their work status of each year, but data on their work intensity were not available, for example, full-time or part-time work, hours worked per week and weeks worked in that year. Thus, cumulative exposures used in the analyses were rough estimations. We also did not have data for participants' experience besides the reported job, such as leisure-time activities and secondary jobs. Second, although the O*NET provided comprehensive descriptors for hundreds of job titles, it did not account for individual-level variations (Cifuentes, Boyer, Lombardi, & Punnett, 2010). We did not use multilevel analysis as recommended in existing literature (Cifuentes et al., 2010), because the numbers of participants with same job titles were small. In addition, we used the recent O*NET version in order to have information for more job titles. The characteristics of some jobs in recent years may be different from those in the early 2000s when the Wave 4 of the Baltimore ECA was fielded. Third, reverse causality and selection are two potential non-causal links between job characteristics and cognitive health (Clougherty et al., 2010). Although detailed job history between Wave 3 and Wave 4 was available, cognitive function was only measured at two time points. Thus temporal order of job transitions and cognitive decline cannot be established. Because people were self-selected into occupations, selection bias may also account for some of the associations. Selection of a different occupation may reflect a change in cognitive function. Although we adjusted for baseline characteristics including cognitive function and self-rated health status, there may still be omitted variables that affect both job exposure and cognitive decline. Fourth, the sample sizes were limited, which may have affected the power associated with the statistical analyses. In addition, the study participants were

sampled from Baltimore residents in 1981, and differential attrition occurred during the follow-up. Approximately 42% of the initial sample had died by Wave 4, 53% of the survivors completed the Wave 4 interview, and cognitive impairment in 1981 was strongly associated with mortality and loss of contact (Eaton et al., 2007). Bias due to differential attrition may have attenuated the association of interest. Moreover, the facts that the initial sample was drawn from a single geographic location more than three decades ago and the proportion of females in the study sample was relatively high (63.8%) limited the geographic and population generalizability of the results. Fifth, the standardized cumulative exposures were used in the analysis, which could be difficult to translate into interventions, and quantify for clinical applications. Sixth, although the MMSE and Word Recall tasks are widely used in research, they are not enough to measure comprehensive domains of cognitive function, and there may also be ceiling and floor effects of the MMSE in the study sample (Franco-Marina et al., 2010).

The study also has a number of strengths. Detailed job history allowed us to examine how cumulative job exposures contributed to cognitive changes over the study period. Occupations coded with the US Census Occupation codes made it possible to link the population-level data with the O*NET, and make use of the comprehensive job characteristics database. The study also contributes to existing literature by examining the association between cumulative work activities and cognitive decline, workplace social interaction in relation to cognitive function, and the effect modification of workplace social interaction on the association between physical demands and cognitive function.

Workplace built environment can be a potential intervention point to promote protective work activities. Built environment is defined as "the human-made space in which people live, work, and recreate on a day-to-day basis" (Roof, 2008), such as neighborhoods and buildings. It has significant impacts on population health (Perdue, Stone, & Gostin, 2003), and is found to influence people's physical activity (Adlakha et al., 2015; Handy, Boarnet, Ewing, & Killingsworth, 2002; Hoehner et al., 2013) and mental health (Evans, 2003). The built

environment can promote social interaction by increasing proximity, “creating focal points”, having “activity generators” and arranging furniture (Evans, 2003). Having natural elements in the work environment may also help to reduce stress, promote restoration and maintain cognitive performance (Evans, 2003).

In conclusion, the findings of the study suggest that higher levels of mental demands and social interaction at the workplace may protect people against cognitive decline. Workplace social support deserves greater research attention. It is important to further examine its long-term effects on cognitive function. In particular, future research should be done to investigate the characteristics of workplace social support, potential mechanisms through which it influences cognitive function, and the feasibility and effectiveness of possible interventions.

Chapter 3. Job Strain at Midlife and Cognitive Decline Later in Life: Evidence from the Baltimore Epidemiologic Catchment Area Follow-up Study

3.1. Abstract

Background: Although the job demand-control model has been widely used to study the association of work-related stress with mental and physical health for decades, it is applied to cognitive health only in recent years, and the findings are mixed. The objective of this study was to examine the association between job strain at midlife and cognitive changes over an approximately eleven-year period in a population-based sample from the Baltimore Epidemiologic Catchment Area (ECA) follow-up study.

Methods: The study sample consisted of 428 to 445 participants, dependent on outcome, aged between 35 and 55 at the Baltimore ECA Wave 3 who reported the psychosocial job characteristics of the full-time job they held in the year of the Wave 3 interview. Cognitive function was assessed at both Wave 3 and Wave 4 using the Mini-Mental State Examination (MMSE), Immediate Word Recall and Delayed Word Recall tasks. Measures of job strain were generated using scales of job dimensions, including psychological job demands, physical job demands and decision authority. Multiple linear regression models were used to examine the association between job strain at midlife and changes in cognitive function in the subsequent eleven-year period.

Results: Compared to participants with low strain jobs, those with high strain jobs had significantly greater cognitive decline as assessed by the MMSE (adjusted b=-0.46; 95% CI:-0.77 to -0.14; p=0.005) and the Immediate Word Recall task (adjusted b=-1.09; 95% CI: -1.69 to -0.49; p<0.001), after adjustment for age, sex, race, education, baseline self-rated health status, and baseline score of the cognitive measure. Participants with passive jobs and active jobs also had greater decline in the performance of the Immediate Word Recall task than those with low strain jobs (Passive jobs: adjusted b=-1.15; 95% CI: -1.89 to -0.41; p=0.002. Active jobs: adjusted b=-0.84; 95% CI: -1.33 to -0.35; p=0.001).

Conclusion: The findings support the view that high job strain, defined by high psychological or physical demands and low decision authority, is associated with a greater decline in global cognition and memory later in life. Future research should examine the potential moderation effects of workplace social support, and develop interventions to reduce worked-related stress and promote cognitive health.

3.2 Introduction

With the growth in the burden of dementia (Prince et al., 2013; Wimo et al., 2013), efforts have been made to identify modifiable determinants at midlife to prevent late-life cognitive decline (Baumgart et al., 2015). Work, as a major component of adult life, not only determines one's socioeconomic status, but also shapes the health trajectories and the aging process (Clougherty et al., 2010; Staudinger et al., 2016).

The job demand-control model developed by Karasek in the late 1970s is one of the main theoretical frameworks of research on the psychosocial work environment and health. It proposes that job demands and job decision latitude (or job control) are two essential worker-level elements of the psychosocial work environment (Karasek, 1979). Job demands are the work load placed on workers (Karasek, 1979). Job decision latitude is defined as "the discretion permitted the worker in deciding how to meet the demands", and consists of decision authority and skill discretion (Karasek, 1979). Decision authority refers to individuals' degree of control over their jobs and the possibility of having influence on their teams (Karasek, 1979). Skill discretion describes the extent to which a job provides opportunities for workers to develop high-level skills, "learn new things" and use creativity (Karasek, 1979). Stressors resulting from high job demands can be managed by job control, but can also manifest as mental strain when such control is low (Karasek, 1979). Therefore, job strain is a composite measure of job demands and control. Jobs with high demands and low control are considered as "high strain", and those with low demands and high control are considered as "low strain" (Karasek, 1979). Jobs with both high

demands and high control are considered as “active”, and may promote “development of new behavior patterns both on and off the job” (Karasek, 1979). Jobs with both low demands and low control are considered as “passive”, and may suppress “overall activity” and “general problem-solving activity” (Karasek, 1979; Suomi & Harlow, 1972).

The job demand-control model has been widely used to study the impacts of job characteristics on physical health (Schnall, Landsbergis, & Baker, 1994; Van der Doef & Maes, 1998) and mental health (Häusser et al., 2010; Van der Doef & Maes, 1999). Two main hypotheses that have been proposed and reported in existing literature are the strain hypothesis and the buffer hypothesis. The strain hypothesis focused on the association between high job strain and adverse health outcomes, and posited that the effect of job demands and control could be either additive or multiplicative (Häusser et al., 2010; Van der Doef & Maes, 1999). The buffer hypothesis emphasized the moderating effect of job control on the impact of job demands on health outcomes, and posited that the effect of job demands and control was exclusively multiplicative (Häusser et al., 2010; Van der Doef & Maes, 1999). The two hypotheses are not mutually exclusive, and the latter is often considered as a special case of the former (Van der Doef & Maes, 1999).

Work-related stress may cause functional and structural deficits in the brain directly through physiological mechanisms such as increasing allostatic load (Ganster & Rosen, 2013; McEwen, 1998; McEwen & Sapolsky, 1995; Sapolsky, 1996), or affect cognitive function indirectly through adverse consequences of a variety of medical conditions, thus leads to cognitive decline and increases the risk of dementia in late life (Andel et al., 2012; Crowe, Andel, Pedersen, & Gatz, 2007; Seidler et al., 2004; Wang et al., 2012). However, evidence on job strain as a midlife risk factor of late-life cognitive decline is limited (Agbenyikey et al., 2015; Andel et al., 2011; Andel et al., 2015; Elovainio et al., 2009; Sabbath et al., 2016; Stenfors, Hanson, Oxenstierna, Theorell, & Nilsson, 2013). Although studies tended to show that low job control was associated with poor cognitive function later in life, the findings on different cognitive

domains were mixed. Sabbath et al. (2016) examined the association between pre-retirement job strain and post-retirement cognitive function measured by eight cognitive tests. It was found that passive and high-strain jobs were related to poor phonemic and semantic fluency after retirement, but no associations were found with the MMSE and verbal memory (Sabbath et al., 2016). In addition, because baseline measures on cognitive function were not available in the study (Sabbath et al., 2016), reverse causality was a threat to the validity. Andel et al. (2015) also examined cognitive change in relation to retirement using growth curve modeling. They found that low job control and high job strain were associated with greater decline in episodic memory during the post-retirement period, but not in the pre-retirement period (Andel et al., 2015). Elovainio et al. (2009) found that longer exposure to high job strain was associated with poorer memory and other cognitive domains in the base model, but the associations were attenuated after adjusting for employment grade.

The objective of the present study was to examine the association between job strain at midlife and changes in global cognition and memory over an approximately eleven-year period among a population-based sample from the Baltimore Epidemiologic Catchment Area (ECA) follow-up study. The study tested the following hypotheses:

Hypothesis 1: Participants with high-strain jobs (high job demands and low job control) at midlife experience greater cognitive decline later in life, compared to those with low-strain jobs (low job demands and high job control).

Hypothesis 2: Participants with passive jobs (low job demands and low job control) at midlife experience greater cognitive decline later in life, compared to those with low-strain jobs (low job demands and high job control).

Hypothesis 3: Participants with active jobs (high job demands and high job control) at midlife experience less decrease in cognitive function later in life, compared to those with high-strain jobs (high job demands and low job control) or passive jobs (low job demands and low job control).

3.3 Methods

3.3.1 Study Participants

The Baltimore ECA follow-up study is a community-based, prospective cohort study designed to investigate life course psychopathology (Eaton et al., 2007). The initial interview of the Baltimore ECA (Wave 1) was conducted in 1981 among 3481 Baltimore residents. The participants were followed up in 1982 (Wave 2, n=2768), 1993-1996 (Wave 3, n=1920) and 2004-2005 (Wave 4, n=1071). More details about the follow-up study are described elsewhere (Eaton et al., 2007).

The Wave 3 of the Baltimore ECA comprised the baseline of the present study and Wave 4 the follow-up. Of the 1920 participants in the Wave 3, 1252 reported job characteristics of the most recent full-time job. The 825 participants who either were still working at the reported full-time job by the time of the Wave 3 interview (n=816), or stopped the job in the same year as the Wave 3 interview (n=19) were selected. The sample was further restricted to the 490 participants who were aged between 35 and 55, had normal cognitive function (Mini-Mental State Examination (MMSE) ≥24) at Wave 3 and participated in the Wave 4. Of these, data were available at Wave 4 on the MMSE for 445 participants, on the Immediate Word Recall task for 441 participants, and on the Delayed Word Recall task for 428 participants. Thus, these totals represented the final sample sizes for each outcome.

3.3.2 Measures of Cognitive Decline

The MMSE has been widely used in clinical and research settings to test mental status and early changes in cognitive function (Folstein et al., 1975). This test covers five domains of cognition, including orientation, registration, attention and calculation, recall and language (Folstein et al., 1975). The total MMSE scores range from 0 to 30, with higher scores indicating better cognitive function. The Immediate and Delayed Word Recall tasks measure verbal episodic memory in

particular. A list of 20 common words were read to participants one at a time, and participants were asked to recall as many as they could immediately and then 20 minutes later. The score of each task ranges from 0 to 20, with higher scores indicating better memory.

In the present study, cognitive change was defined as change in cognitive scores between the Wave 3 and Wave 4 (i.e. score at Wave 4 minus score at Wave 3). The change scores were approximately normally distributed in the study sample (Appendix Figure S3.1).

3.3.3 Measures of Job Strain

The job characteristics items in the Baltimore ECA study were adopted from the Quality of Employment Surveys (Quinn, Mangione, & Seashore, 1975), which were originally used for developing the job demand-control model (Karasek, 1979; Mausner-Dorsch & Eaton, 2000). Mausner-Dorsch and Eaton (2000) conducted a factor analysis using the Baltimore ECA job characteristics items, and identified job dimensions that confirmed the job demand-control model. Accordingly, the present study formed job scales of physical job demands (7 items), psychological job demands (3 items), decision authority (3 items) and skill discretion (5 items) using the same sets of items (Appendix Table S3.1) (Mausner-Dorsch & Eaton, 2000). The questions were answered on a four-point rating scale from "strongly disagree" to "strongly agree". Items were reverse-coded when necessary so that higher score indicated higher job demands, decision authority or skill discretion (Appendix Table S3.1). Continuous variables of the four job scales were generated by adding the response values of each dimension (Mausner-Dorsch & Eaton, 2000). The summative measures were approximately normally distributed in the study sample (Appendix Figure S3.2). Dichotomized variables for high demands and low control were created based on the median split (Mausner-Dorsch & Eaton, 2000). Although skill discretion is a component of job control in the job demand-control model (Karasek, 1979), it was found to be unassociated with cognitive change in this analysis (Appendix Table S3.2). Thus, the composite measure of job strain was generated using the dichotomized psychological demands,

physical demands and decision authority (Figure 3), consistent with the measures used by Mausner-Dorsch and Eaton (2000) . In the present analysis, high job strain was composed of high psychological or physical demands and low decision authority. Low job strain was composed of low psychological and physical demands and high decision authority. Passive jobs were those with low psychological and physical demands and low decision authority. Active jobs were considered as having high psychological or physical demands and high decision authority.

3.3.4 Covariates

Covariates used in the analysis included age, sex, race/ethnicity (non-Hispanic white, others), education (below high school, high school, above high school), baseline self-rated health status (excellent, good, fair or poor) and baseline cognitive function (MMSE, Immediate Word Recall and Delayed Word Recall tasks).

3.3.5 Statistical Analysis

Multiple linear regression models were used to examine the association between job strain at baseline and cognitive change over the eleven-year period. Regression diagnostics were performed, and robust variance estimates were used to account for minor issues in normality, heteroscedasticity and outliers. The dependent variables were continuous measures of changes in cognitive function between the Baltimore ECA Wave 3 and Wave 4 assessed by the MMSE, Immediate Word Recall and Delayed Word Recall tasks. The primary independent variable was a four-category variable for job strain. Two adjusted models were tested. The base model only adjusted for baseline score of the cognitive measure, and the full model adjusted for age, sex, race, education, baseline self-rated health status and baseline score of the cognitive measure.

In separate analyses, the summated scores for decision authority and skill discretion dimensions were used to represent job control. Physical demands were separated from psychological demands, and job strain was examined respectively (Appendix Figure S3.3).

3.4 Results

3.4.1 Sample Characteristics

At baseline, the mean age of the study sample was 43.3 years (standard deviation [SD]: 5.4) with two fifths between age 45 and 55; 59.1% were female; 39.8% were non-white; 14.6% had an education below high school; and 14.4% rated their health as fair or poor (Table 3.1). The mean follow-up period between the Wave 3 and Wave 4 was 10.8 years (SD: 0.6; range: 9.3-12.1).

The median psychological demands score was 7 (range: 3-12), median physical demands score was 17 (range: 10-28), median decision authority score was 9 (range: 3-12), and median skill discretion score was 15 (range: 7-20) (Table 3.1). Decision authority was negatively correlated with physical demands, but had strong positive correlation with skill discretion (Table 3.2). Physical demands were positively correlated with psychological demands. Approximately 24.9% of the study sample had low-strain jobs, 11.7% had passive jobs, 41.1% had active jobs and 22.3% had high-strain jobs (Table 3.1).

When comparing the baseline characteristics of 184 participants who were excluded due to loss to follow-up at Wave 4 (n=139) or missing cognitive measures (n=45) with those included in the study sample, we found that the excluded participants did not significantly differ from the study sample in age, sex, race, baseline self-rated health, baseline memory and job dimensions. However, excluded individuals were more likely to have lower baseline MMSE (p=0.017) and a lower education levels (p=0.030).

3.4.2 Association Between Job Strain and Cognitive Changes Later in Life

Overall, there was decline in all cognitive measures in all job groups, as evidenced by the uniformly negative mean change scores (Table 3.3). Table 3.4 presents the results of the multiple linear regression models of the association between classifications of job strain and changes in cognitive function between the Wave 3 and Wave 4 (full results of the models are presented in Appendix Table S3.3-S3.5). Compared to low job strain, high job strain was associated with

significantly greater cognitive decline in the base model, as assessed by the MMSE, Immediate Word Recall and Delayed Word Recall tasks. The association remained statistically significant for the MMSE (adjusted b=-0.46; 95% CI: -0.77 to -0.14; p=0.005) and Immediate Word Recall task (adjusted b=-1.09; 95% CI: -1.69 to -0.49; p<0.0001) in the full model.

Compared to participants with low strain jobs, people in all other job groups experienced a steeper decline in cognitive functioning, as evidenced by the uniformly negative regression coefficients (Table 3.4). The strongest association was observed in the Immediate Word Recall task. Comparing to low job strain, passive jobs were associated with the greatest decline in memory (adjusted b=-1.15; 95% CI: -1.89 to -0.41; p=0.002), followed by high-strain jobs (adjusted b=-1.09; 95% CI: -1.69 to -0.49; p<0.0001) and active jobs (adjusted b=-0.84; 95% CI: -1.33 to -0.35; p=0.001).

The findings of the sensitivity analyses were generally in accordance with the main analyses. Results are presented in the Appendices (Appendix Table S3.6-S3.8).

3.5 Discussion

This study examined the association between job strain at midlife and cognitive change later in life using a population-based sample from the Baltimore ECA study. It was found that high job strain at midlife was associated with significantly greater decline in performance of the MMSE and Immediate Word Recall task over an approximately eleven-year period, compared to low job strain. The results were robust to adjustment for age, sex, race, education and baseline self-rated health status. Passive and active jobs were also found to have negative impacts on memory as assessed by the Immediate Word Recall task.

This study provided new evidence for the association of high job strain (high demands and low control) with global cognition and verbal episodic memory later in life. It is consistent with existing research on work-related stress and poor health outcomes (Ganster & Rosen, 2013),

and supported the strain hypothesis that high job strain was related to adverse health outcomes (Häusser et al., 2010).

Work-related stress is appraised when job demands exceed workers' coping abilities (Karasek, 1979). It may influence cognitive health through physiological and psychological pathways. Normally, stress activates the hypothalamus-pituitary-adrenal axis, raises the level of glucocorticoids produced by the adrenals, and helps individuals to deal with urgent situations (Lupien, McEwen, Gunnar, & Heim, 2009). However, when stress exposure becomes chronic, the persistent activation of stress response negatively affects the functioning and structure of the brain (Lupien et al., 2009), and dysregulates the human body systems. The term "allostatic load" was developed to describe physiological consequences of chronic stress exposure (McEwen, 1998). Increased allostatic load may lead to disease development such as cardiovascular and cerebrovascular disease that indirectly affect cognitive health (McEwen, 1998). Cardiovascular disease is the most studied outcome in research on job demand-control. Kivimaki et al. (2012) indicated in a meta-analysis that preventing workplace stress might reduce the risk for coronary heart disease. Moreover, stress, including job strain (Bonde, 2008), has been well studied in relation to depression (Hammen, 2005; Monroe & Simons, 1991), which may confer increased risks of cognitive impairment in late life (Byers & Yaffe, 2011; Crowe et al., 2007; Ownby, Crocco, Acevedo, John, & Loewenstein, 2006; Wang et al., 2012).

The job demand-control model recognizes job control as an important component of the psychosocial work environment (Karasek, 1979). Control beliefs have been known as determinants of health behaviors that promote cognitive performance (Agrigoroaei & Lachman, 2011). Past research has found that a sense of low control is associated with high psychological stress and suppressed mental activities (Kirschbaum et al., 1995; Lachman & Andreoletti, 2006; West & Yassuda, 2004). Thus, when facing high job demands, people lacking autonomy at the workplace bear higher risk for poor cognitive performance.

In this study, passive jobs (low demands and low control) were found to be significantly associated with poorer memory later in life. Sabbath et al. (2016) found that passive work was related with lower verbal fluency, but a relationship with memory was not found. Passive jobs such as janitor and deliveryman, are considered to suppress cognitive and problem-solving activities (Karasek, 1979; Karasek et al., 1998). According to the "use it or lose it" hypothesis and the cognitive reserve theory, engaging in less mentally stimulating activities may lead to greater cognitive decline at a later stage of life.

The finding of the association between active jobs and decline in the Immediate Word Recall task did not support the hypothesis that active jobs promote "development of new behavior patterns" (Karasek, 1979), and are associated with less cognitive decline. Existing findings on active jobs and cognitive function are also mixed. Andel et al. (2011) found that active jobs were associated with "better cognitive performance and lower likelihood of impairment" in a sample of 827 participants from the 1968 Swedish Level of Living Survey. Elovaino et al. (2009) found that having less exposure to active jobs was associated with poor cognitive performance using data from the Whitehall II study. Agbenyikey et al. (2015) found that active jobs were associated with better abstract reasoning skills but poorer verbal learning and memory among participants from the Framingham Offspring cohort.

This study's finding that individuals with active jobs had greater decline in memory compared to those with low-strain jobs may be explained by the difference in occupational prestige as measured by the Nam-Powers-Terrie Occupational Status Scores (NAM). The NAM scores were positively correlated with psychological job demands, decision authority and skill discretion respectively, but negatively correlated with physical demands (Table 3.2). The distribution of the NAM scores varied significantly across the four groups (Appendix Figure S3.4). Participants with low-strain jobs had significantly higher occupational prestige than the other groups (Appendix Table S3.9). High-strain jobs did not differ from passive jobs in mean NAM score, but had significantly lower mean score than low-strain jobs or active jobs (Appendix

Table S3.9). The average NAM score of the active-job group was significantly lower than that of the low-strain group by approximately eight points (Appendix Table S3.9). Social and behavioral factors associated with low occupational prestige may mediate the association between job characteristics and cognitive decline. The finding that active jobs did not differ from passive and high-strain jobs on memory needs to be further investigated using larger samples.

The study has limitations. First, there is potential selection bias. Although we controlled for education, early-life factors that affect both job characteristics and late-life cognitive decline may still exist, such as childhood cognitive abilities (Cheng & Furnham, 2012). Second, we also did not know about the participants' experiences outside of the workplace. Although work is a major contributor to daily-life activities, leisure-time activities also impact cognitive function (Rovio et al., 2005; Wilson et al., 2002), but were not available in the analysis. Third, reverse causality may exit. On the one hand, job characteristics shape the trajectory of cognitive decline; on the other hand, cognitive abilities can influence occupation choices and transitions. The notion of preserved differentiation purports that a certain level of mental ability is a predetermined factor for conducting certain mental activities (Salthouse, 2006). Individuals with higher cognitive capacities are more likely to obtain higher levels of educational and occupational attainment which provide opportunities for continued mental activities in high quantity and quality (Deary, 2012). Individuals with cognitive decline that impairs their work performance may have to switch to jobs with lower requirements for cognitive abilities.

Acknowledging these limitations, this study's results support the view that high job strain, defined by high psychological or physical demands and low decision authority, is associated with a greater decline in global cognition and memory later in life. The deleterious effects of high-strain jobs on health and cognition may be modified by reducing job demands or increasing job control. For example, the speeds of moving production lines were directly related to the workload placed on line workers. Data from the United Food and Commercial Workers showed that line speeds in the red meat industry rose by approximately 20% from 1988 to 2008,

which not only increased workplace injuries but also affected food safety (United Food and Commercial Workers). Workload can be managed by adjusting the line speeds directly, or by increasing employees' control over their work. The Ford Motor Company shifts the traditional assembly lines to team-based operations by letting workers use initiatives to achieve work goals, rather than simply following instructions (American Psychological Association, 2003). By increasing job control, it raises workers' job satisfaction, mental demands and interpersonal interaction, which are beneficial to mental and cognitive health.

Workplace social support, as a protective factor, has been recognized in more recent job stress models such as the job demand-control-support model (Johnson & Hall, 1988) and the job demands-resources model (Demerouti et al., 2001). Future research should examine the moderation effects of workplace social support on the association between job strain and cognitive decline, and investigate possible mechanisms. Enhancing social support could be a potential intervention point to improve the psychosocial work environment and promote cognitive health in the long run.

Chapter 4. Insomnia as a Predictor of Job Exit among Middle-Aged and Older Adults: Results from the Health and Retirement Study

4.1 Abstract

Background: The influence of poor health on exiting the workforce has been recognized, but little is known about the role of insomnia. We examined the association between insomnia symptoms and subsequent job exit among middle-aged and older adults using data from the Health and Retirement Study (HRS).

Methods: The study sample consisted of 5746 respondents aged between 50 and 70 who were working for pay when interviewed in the HRS 2004 and followed up in the HRS 2006. Multinomial logistic regression models were used to determine the association between number of insomnia symptoms (0, 1-2, 3-4) and job exit (no exit, health-related exit, or exit due to other reasons).

Results: In models adjusting for demographic characteristics, baseline health status and baseline job characteristics, a level of 3-4 insomnia symptoms was associated with increased odds of leaving the workforce due to poor health (adjusted Relative Risk Ratio=1.9, 95% Confidence Interval, 1.04-3.58; p=0.036). There was no association between insomnia symptoms and job exit due to non-health reasons.

Conclusions: The experience of a greater number of insomnia symptoms was independently associated with leaving paid employment. Screening for and treating insomnia symptoms in the workplace may improve work productivity, prolong labor force participation, and maintain quality of life.

4.2 Introduction

Insomnia, characterized by deficits in sleep quantity and/or quality, is a prevalent condition in middle-aged and older adults (Ohayon, 2002). The prevalence of insomnia increases from age 45 and reaches approximately 50% in adults aged 65 and over (Ohayon, 2002). It may cause mood dysregulation, decrease quality of life, and increase interpersonal conflicts (LeBlanc et al., 2007). It is also commonly comorbid with physical and mental health problems, and can be either a risk factor or consequence of medical conditions such as depression (Baglioni et al., 2011; Ford & Kamerow, 1989), anxiety (Ford & Kamerow, 1989), and cardiovascular disease (Sofi et al., 2014). Because comorbidities, which are prevalent among middle-aged and older adults, complicate its course, insomnia tends to be persistent in these populations (Green, Espie, Hunt, & Benzeval, 2012).

Insomnia is often associated with role impairments in the workplace. Results from the America Insomnia Survey showed that insomnia was significantly associated with low performance (Kessler et al., 2011), costly workplace accidents and errors (Shahly et al., 2012), and injuries (Kessler et al., 2012). The annualized economic burden of insomnia in the total US workforce was estimated to be $63.2 billion for lost work performance (Kessler et al., 2011), and $31.1 billion for workplace accidents and errors (Shahly et al., 2012).

Decrements in work performance or workplace injuries due to insomnia and poor health may lead to workforce exit (van Rijn, Robroek, Brouwer, & Burdorf, 2014), which increases financial burdens on the society. Studies have demonstrated that insomnia increased the risk of disability retirement through medical conditions, risky health behaviors and social dysfunction (Eriksen et al., 2001; Haaramo et al., 2012; Lallukka et al., 2011; Salo et al., 2010; Sivertsen et al., 2006; Sivertsen et al., 2009). However, little has been done to examine the association between insomnia and job exit more generally. Thus, the objective of this study was to examine the association between insomnia and subsequent job exit, using longitudinal data of a nationally representative sample from the Health and Retirement Study (HRS).

4.3 Methods

4.3.1 Study Sample

The data were obtained from the Health and Retirement Study, which is a longitudinal survey with a nationally representative sample of older adults aged 50 and over and their spouses (Juster & Suzman, 1995). Respondents have been interviewed on a biannual basis since 1992. The HRS 2004 and HRS 2006 surveys were used as our baseline and follow-up waves. Sample eligibility was further limited to respondents who: (1) were working for pay at baseline , (2) were aged between 50 and 70 at baseline, which was the 10-90 percentile age range of the working population from the HRS 2004 core interview; (3) had baseline information on insomnia symptoms, age, sex, race, education, household income, self-rated health status, and history of psychiatric problems, diabetes and heart disease; (4) had non-zero weights for the HRS 2004, and (5) completed the HRS 2006 core interview (Figure 4).

Of the 6361 who met the baseline inclusion criteria, 5746 (90.3%) were included in analyses. Among 523 respondents who did not complete the 2006 core interview, 4 (0.8%) dropped out of the study, 71 (13.6%) died and 448 (85.7%) had remained in the study, though the interviews were not obtained.

4.3.2 Measures

Dependent Variable

The dependent variable was a categorical variable incorporating information on work transitions in the two-year post-baseline period and, for those not employed, reasons for leaving the previous employer or business. The three categories were no job exit, job exit due to poor health, and job exit due to other reasons. Job exit was defined as transitioning from working for pay (working full-time, working part-time, or partially retired) to not working (retired, unemployed, disabled or other). The non-working status could be either temporary or permanent. Work status was

ascertained by the questions, “Are you doing any work for pay at the present time?” and “Are you working now, temporarily laid off, unemployed and looking for work, disabled and unable to work, retired, a homemaker, or what?” (Health and Retirement Study). If respondents experienced changes in work status or employers, questions on reasons for leaving the previous job were asked, for example, “Why did you leave that employer? Did the business close, were you laid off or let go, did you leave to take care of family members, or what?” (Appendix Table S4.1) (Health and Retirement Study). Those who responded that they were not working were classified according to whether they stated the reason as “poor health” or whether they cited another reason.

Primary Independent Variable

The primary independent variable was a categorical variable according to the number of insomnia symptoms reported at baseline. Data were ascertained from four questions: “How often do you have trouble falling asleep?”, “How often do you have trouble with waking up during the night?”, “How often do you have trouble with waking up too early and not being able to fall asleep again?”, and “How often do you feel really rested when you wake up in the morning?” (Health and Retirement Study). The possible responses included “most of the time”, “sometimes”, and “rarely or never” (Health and Retirement Study). A binary indicator was generated for each insomnia symptom, with “most of the time” being coded as 1 for the first three questions, and “rarely or never” being coded as 1 for the fourth question. The scores on the four questions were summed (range=0-4). A three-category variable was then created based on this summary score, with 0 being no symptom, 1 being 1-2 symptoms, and 2 being 3-4 symptoms.

Covariates

Covariates of interest were respondents’ baseline characteristics, including demographic variables, health-related variables and job characteristics. Demographic variables included age

(50-61, 62-70), sex (male, female), race (white, black, other), highest degree of education (below high school, high school, above high school), and household income. The original variables for age, sex, race and education were taken from the HRS 2012 Cross-Wave Track File which includes information for all HRS respondents across the years. Age 62 was chosen as the cutoff to create the binary variable for age, because it is the earliest age when people can start to receive retirement benefits in the United States. The original variable for total household income was taken directly from the RAND data file available on HRS data website (Chien et al., 2015) and developed based on the RAND Wealth and Income Imputations (Hurd, Meijer, Moldoff, & Rohwedder, 2015). We identified the quartiles of household income from the full sample of the HRS 2004 core interview, and grouped respondents by quartiles (below median, between median and the third quartile, above the third quartile).

Working status at baseline (full-time, part-time, partly retired) was classified by working hours and participant report of retirement status. Working more than 35 hours per week and more than 36 weeks per year was considered as working full-time as opposed to working part-time (Chien et al., 2015). Partial retirement was identified by the question on labor force status described above and the question "At this time do you consider yourself partly retired, completely retired, or not retired at all?" (Health and Retirement Study). Respondents also provided data on job characteristics by responding to questions about whether their jobs involved "a lot of stress" based on a five-level Likert scale ranging from strongly agree to strongly disagree, and the frequency with which it required "lots of physical effort" on a four-level scale ranging from all the time to none (Health and Retirement Study).

Self-rated health status, depressive symptoms, and histories of medical conditions were also assessed. Health status was originally rated on a five-point scale ranging from excellent to poor, and we generated a three-category variable for above good, good and below good. Depressive symptoms in the past week were assessed using a brief eight-item version of the Center for Epidemiologic Studies-Depression (CESD) scale (Andresen, Malmgren, Carter, &

Patrick, 1994). We excluded the CESD item on sleep from this analysis, reverse coded the two items on happiness and enjoying life, and then generated a categorical variable for the number of depressive symptoms (no depressive symptoms, 1-2 symptoms, 3+ symptoms). We also created three binary indicators for relevant histories of medical conditions, including diabetes, psychiatric problems and heart disease. The responses were ascertained by questions asking whether a respondent had ever had or whether a doctor had ever told them that they had certain conditions (Appendix Table S4.1).

4.3.3 Statistical Analysis

Exploratory analyses were conducted to examine the characteristics of independent variables. Baseline characteristics were compared between respondents with job exit and those who continued working, using chi-square tests.

We explored reasons for sample attrition, and compared baseline characteristics between respondents lost to follow-up and eligible/available respondents. For covariates with less than or equal to five missing values, missing observations were dropped. For covariates with more missing values, we employed multiple imputation by chained equations (five replicates) to impute missing values using age, sex, education, baseline household income, baseline labor force status, baseline self-rated health status, baseline insomnia symptoms, and histories of diabetes, psychiatric problems and heart disease (Raghunathan, Lepkowski, Van Hoewyk, & Solenberger, 2001). The percentage imputed was 7.0% for depressive symptoms, 4.4% for job involving much stress and 4.7% for job requiring much physical effort.

Multinomial logistic regression models were used to examine the association between insomnia symptoms and subsequent job exit, including a model adjusted for demographic characteristics only (Base Model), and a fully adjusted model accounting for demographic characteristics, health status and job characteristics (Full Model). The significance of the linear trends for the categories of insomnia symptoms was also tested.

Two sensitivity analyses were conducted. In the first sensitivity analysis, we used a broader definition of insomnia by classifying responses of "sometimes" as indicating an insomnia symptom. In the second, we focused on respondents who worked full-time at baseline by excluding part-time and partly retired workers, and examined the association of insomnia with their transitions out of full-time jobs.

All statistical analyses were conducted using statistical software Stata version 12 (Stata Corporation, College Station, TX), taking account of the HRS strata, clusters and sampling weights. All significance tests were evaluated at the level of $p<.05$.

4.4 Results

4.4.1 Sample Characteristics at Baseline

Among the 5746 respondents included the present analysis, 80.1% were between age 50 and 61 at baseline, 48.0% were females, 86.1% were white, 39.9% had education above high-school, 20.8% had household income below the median of the full sample of HRS 2004, and 74.8% were working full-time (Table 4.1). In terms of health conditions, 35.8% reported at least one insomnia symptom, 14.6% rated health status as fair or poor, and 33.4% had at least one depressive symptom in the past week; 12.0% had a history of psychiatric problems; 11.6% had a history of diabetes; and 11.5% had a history of heart disease. When asked about job characteristics at baseline, 57.8% agreed or strongly agreed that their jobs involved much stress, 30.8% reported that their jobs required lots of physical effort all the time, almost all the time or most of the time.

Of the 956 respondents who experienced job exit during the two-year follow-up period, 203 exited due to poor health, and 753 exited not due to health-related reasons (Table 4.1). Respondents who exited due to health reasons were more likely to be black and less educated, and tended to have lower income, a greater number of insomnia symptoms, more depressive symptoms, poorer self-rated health status, and a positive history of psychiatric problems, diabetes

or heart disease. These respondents were also more likely to have jobs with high levels of physical demands.

The 5838 respondents who completed the HRS 2006 interview did not differ from the 523 who were not in the HRS 2006 with regard to the number of insomnia symptoms, age and histories of medical conditions. However, those who were not in the HRS 2006 interview were more likely to be non-white, to have less education, to have low incomes, to report poor self-rated health status and to have more depressive symptoms.

4.4.2 Association of Insomnia with Subsequent Job Exit

In the base model, compared to respondents with no symptoms of insomnia, the odds of leaving a job due to poor health was 3.8 times greater for those with three or four insomnia symptoms (95% Confidence Interval (CI), 2.09 to 6.76; $p<0.001$), and 1.8 times greater for those with one or two insomnia symptoms (95% CI, 1.25 to 2.46; $p<0.01$). The linear trend across the levels of insomnia symptoms was statistically significant ($p<0.001$). However, there was no significant association between insomnia and job exit not due to health-related reasons (Table 4.2).

After additionally adjusting for health-related variables and job characteristics, the increase in odds for the most severe insomnia group (3-4 symptoms) remained significant, although the magnitude of the association between insomnia and job exit due to poor health was reduced (Table 4.2). The odds of leaving a job due to poor health was 1.9 times greater for those with three or four insomnia symptoms (95% CI, 1.04 to 3.58; $p=0.036$). The association between insomnia symptoms and job exit due to non-health reasons remained non-significant.

4.4.3 Sensitivity Analysis

In the sensitivity analysis using a broader definition of insomnia to include milder cases and that focused on exiting full-time employment, the findings were all in accordance with those in the main analysis, but the associations between insomnia symptoms and subsequent job exit due to

poor health were weaker. The significant results remained in the base models, but became statistically non-significant in the full models (Appendix Table S4.2-S4.3).

4.5 Discussion

This study used data from a nationally representative sample of middle-aged and older adults to examine the effect of insomnia on subsequent exit from paid employment during a two-year period. We found that having three or four insomnia symptoms was independently associated with an approximately twofold increase in odds of health-related job exit, compared to having no insomnia symptoms.

To our knowledge, this is the first study examining the association of insomnia with workforce exit in the US population. Our findings support prior studies on insomnia and work-related disability or disability retirement in European countries (Eriksen et al., 2001; Haaramo et al., 2012; Lallukka et al., 2011; Salo et al., 2010; Sivertsen et al., 2006; Sivertsen et al., 2009), and contribute to existing literature by including other types of health-related job exit besides disability. Of the 203 respondents in our study who exited their jobs due to poor health, more than two thirds were retired but not disabled. As the population ages, workers are expected to prolong their labor force participation. Addressing factors that stop people from remaining in the labor force and identifying markers indicating a need for early intervention are important from a societal perspective. A meta-analytic review by Van Rijn et al. (2014), identified perceived poor health, mental health problems and chronic disease as risk factors for exiting from paid employment. These factors are closely associated with insomnia and may be confounders of the relationship between insomnia and job exit. Our findings were consistent with this, showing mental health and diabetes to be associated with leaving the labor force for either health or non-health reasons. However, even after adjustment for these factors, our results suggest a profound negative impact of insomnia on labor force participation.

In past research, insomnia was shown to significantly reduce work performance and increase workplace accidents and injuries (Kessler et al., 2012; Kessler et al., 2011; Shahly et al., 2012), which may lead to involuntary job exit or disability. Severe insomnia may also precede post-baseline physical and psychological morbidities that impair work capabilities (Baglioni et al., 2011; Sofi et al., 2014). Moreover, it may be an indicator of maladaptive behaviors such as alcohol and substance use, smoking and physical inactivity that influence subsequent health outcomes and functioning (Brower, 2015; Head, Stansfeld, & Siegrist, 2004; Lallukka et al., 2011). Alternatively, insomnia may be related to health problems at baseline that progress to eventually necessitate labor force exit.

The association of insomnia with job exit was limited to exits due to health reasons. No such association was observed for exits due to non-health reasons. The specificity of the association lends support to a causal relationship, in which insomnia promotes poor health and subsequent job exit.

The findings regarding histories of medical conditions (Table 4.2) are consistent with recent research on the association of labor force exit with diabetes (Herquelot et al., 2011; Kouwenhoven-Pasmooij et al., 2016; Rumball-Smith et al., 2014) and psychiatric problems (Rudolph & Eaton, 2015). Because sleep disturbance is closely associated with these conditions (Gottlieb et al., 2005; Grandner, Jackson, Pak, & Gehrman, 2012), and they all influence work performance significantly (Kessler et al., 2011; Tunceli et al., 2005), future research should also examine how they interact with each other on affecting labor force participation.

Our study has limitations. First, the number of respondents with job exit due to poor health (n=203) was relatively small, which did not allow stratification by status upon leaving employment (retired, unemployed, or disabled). Second, we assumed that respondents who did not complete the follow-up interview had an equal chance of experiencing job exit as those who remained in the study. This assumption cannot be tested. Third, job stress could be a potential confounder, because it has been shown to be positively associated with sleep disturbances

(Knudsen, Ducharme, & Roman, 2007), and could also be a reason for workforce exit. Although we adjusted it in the analyses, the assessment of job stress and physical demands were based on single questions with unknown reliability and validity. However, dose-response relationships between the job characteristics and job exit due to poor health were observed, which was consistent with the notion that high psychological or physical job demands might increase the likelihood of exiting from paid employment. Fourth, we did not have information on how often the insomnia symptoms occurred, and whether the insomnia symptoms reported were acute or chronic due to lack of time frame in the survey questions. However, it was found in recent study that the trajectories of insomnia severity scores varied in a small range over an eight-year period (Kaufmann et al., 2016), which supported that the reported insomnia symptoms could be considered as relatively stable traits rather than temporary states.

The study also has several strengths. First, prior studies investigating similar research questions were conducted in European counties, and many studies have focused on job exit due to disability. We used data from a nationally representative sample of US older adults, and examined job exit for different reasons. Second, respondents were asked about reasons for leaving their previous jobs, which allowed us to focus on health-related workforce exit and provides evidence for potential interventions. Third, the HRS provides comprehensive measures for individuals' demographic, health and labor force status, which allowed us to control for a wide range of potential confounders.

The findings indicated the potential economic burden of insomnia that was attributable to reducing people's working lives. The costs of insomnia from healthcare services, absenteeism, productivity loss, workplace accidents and errors have been well recognized (Daley, Morin, LeBlanc, Gregoire, & Savard, 2009; Shahly et al., 2012). However, its costs from labor force loss and increasing pension burden have not been previously investigated.

Future research could extend the current study by looking at pathways to permanent labor force exit after experiencing a job exit due to poor health, and identifying pre-exit factors that

were associated with permanent exit. Such factors could be more meaningful intervention points to reduce labor force loss. Second, the job characteristics of workers who left paid employment due to insomnia could be studied, to see if insomnia is a mediator of the association between job characteristics and early job exit. If such causal pathway held, interventions could be focused on reducing health threats in the work environment. In health care settings, when treating insomnia patients, doctors may ask about their job characteristics and give advice accordingly. Third, the non-health reasons for job exit could be examined individually to see if there is any significant association similar to that of poor health.

In conclusion, this study provided evidence for an association of insomnia with job exit among middle-aged and older adults. We found that having three or four insomnia symptoms was associated with exiting from paid employment in the subsequent two years. Screening for insomnia symptoms and treating insomnia may improve people's work productivity and prolong their labor force participation. If corroborated by future research, the findings from this study lend support to wider use of evidence-based management strategies for insomnia symptoms in middle-aged and older adults.

Chapter 5. Discussion

5.1 Summary of Main Findings

The overall focus of this dissertation was to examine risk and protective factors that may affect cognitive health and labor force participation among middle-aged and older adults. The three studies investigated (1) the cumulative effects of work activities on cognitive decline (Chapter 2); (2) the association between job strain at midlife and cognitive decline later in life (Chapter 3); (3) the association between insomnia symptoms and subsequent job exit (Chapter 4).

In Chapter 2, job-exposure matrices of work activities were generated using the Occupational Information Network and linked to the study sample from the Baltimore ECA follow-up study through the US Census occupation codes and the Standard Occupational Classification codes. Higher cumulative mental demands and social interaction at the workplace were associated with less cognitive decline over an approximate twelve-year period after adjusting for potential confounders. The data also revealed that social interaction moderated the negative impacts of cumulative physical demands on cognitive function as measured by the MMSE.

In Chapter 3, individual-level data on psychosocial job characteristics from the Baltimore ECA follow-up study were used to generate a composite measure of job strain based on the job demand-control model (Karasek, 1979). High job strain at midlife was associated with significantly greater decline in performance of the MMSE and Immediate Word Recall task over an approximately eleven-year period, compared to low job strain. Passive jobs and active jobs were also found to have negative impacts on memory as assessed by the Immediate Word Recall task.

In Chapter 4, data were drawn from a nationally representative sample of middle-aged and older adults in the Health and Retirement Study. Having more insomnia symptoms was independently associated with an approximately twofold increase in odds of health-related job

exit during a two-year period, compared to having no insomnia symptom. No association was found between insomnia symptoms and job exit not due to health-related reasons.

5.2 Limitations

Selection bias was a potential threat to validity of studies in Chapter 2 and Chapter 3. Individuals with better health and socioeconomic status during their childhood and early adulthood were more likely to have better health trajectory and job opportunities (Clougherty et al., 2010). This is especially a challenge in research related to cognitive health. Childhood intelligence has been found to be heritable and strongly predict educational attainment, occupational attainment and health over the life course (Benyamin et al., 2014; Deary, 2012). The preserved differentiation hypothesis also proposes that mental ability level is a predetermined factor for conducting certain mental activities (Salthouse, 2006). Individuals with higher cognitive abilities in early life are more likely to have skilled jobs with higher socioeconomic positions rather than blue-collar or low-grade jobs (Deary, 2012). However, data on early-life cognitive abilities are usually not available in aging studies and experimental designs are not feasible.

Another aspect of selection is related to the phenomenon of healthy worker survival. Workers with health problems are more likely to leave jobs earlier and would not be included in the analyses. In the present analyses, participants who had never worked during the follow-up period (Chapter 2) or were not working in the year of the Wave 3 interview (Chapter 3) were excluded, which may attenuate the true association between job characteristics and health outcomes. For example, participants with heart disease caused by job strain may have died before or during the study period, or have switched to jobs with lower exposures by the time of the Wave 3 interview. Because psychosocial job characteristics were only reported for the most recent job, previous history of job strain was not available in the analysis. Additionally, participants might also fail to find a job due to poor cognitive function and thus never entered the study.

Cognitive measures used in Chapter 2 and Chapter 3 included MMSE and Immediate and Delayed Word Recall tasks. These measures are commonly used in research settings, but are not sufficiently detailed to account for different domains of cognitive function. Cognitive abilities consist of crystallized intelligence and fluid intelligence (Cattell, 1963). Crystallized intelligence refers to the knowledge capacity, which is based on knowledge from life experience (Baltes, 1987). Fluid intelligence refers to the ability in processing information and solving new problems independently of existing knowledge (Baltes, 1987). Although higher level of fluid intelligence may enhance the capacity of crystallized intelligence (Ackerman, 1996), the two intelligence dimensions evolve differentially over the lifespan (Baltes, 1987). Fluid intelligence increases during childhood and adolescence, peaks in early adulthood and then starts to decline, while crystallized intelligence increases along with fluid intelligence in early life and continues accumulating throughout the life course (Baltes, 1987). Different cognitive abilities are based on different combinations of the two types of intelligence (Engle, Tuholski, Laughlin, & Conway, 1999). A wide range of cognitive domains need to be investigated in studies of the relationship between the psychosocial work environment and cognitive decline.

5.3 Strengths

Both the Baltimore Epidemiologic Catchment Area follow-up study and the Health and Retirement Study collected longitudinal data on participants' job histories, labor force status and work transitions. This allowed us to study job characteristics and job exit in relation to mental and cognitive health over time.

The job titles reported in the Baltimore ECA study were coded using the three-digit US Census occupation codes, and linkable to the Occupational Information Network database through the Standard Occupational Classification codes. Since the O*NET was first developed in 1998 (Peterson et al., 1999; Peterson et al., 2001), it has been used to investigate occupational exposures in relation to a variety of health outcomes (Cifuentes et al., 2010). Despite the

increasing trend of applying the O*NET to research, it has only been used in a few studies on late-life cognitive decline (Andel et al., 2015; Fisher et al., 2014; Grzywacz, Segel-Karpas, & Lachman, 2016; Pool et al., 2016; Then, Luck, Luppa, Arélin, et al., 2014; Then et al., 2015), and the derived measures varied across studies. Chapter 2 provided additional evidence for the use of the O*NET as a job-exposure matrix in studying work and cognitive health. Meanwhile, the self-reported measures of the psychosocial work environment from the Baltimore ECA study allowed analysis of job characteristics at the individual level (Chapter 3), which compensated for the limitations of job-exposure matrices.

The study reported in Chapter 4 was among the first to examine the association between insomnia symptoms and workforce exit in the US middle-aged and older adult population. We explored reasons for job exit and separated health-related exits from exits due to other reasons, which lends support to a causal pathway from insomnia symptoms, poor health to exiting from paid employment.

5.4 Public Health Implications

There are two general implications of the studies. First, the findings demonstrated potential intervention points for promoting cognitive health later in life (Chapter 2 and Chapter 3). While job strain was associated with greater cognitive decline, mental demands and social interaction may protect against the decline. Social interaction characterized by workplace communication and interpersonal relationship can be modified through improving organizational climate. An interactive and supportive environment is an intangible resource that helps workers to cope with work-related stress (Bakker & Demerouti, 2014), improves work engagement (Bakker, Hakanen, Demerouti, & Xanthopoulou, 2007), thus reduces threats to cognitive health in the long run. Furthermore, the findings indicated the potential economic burden of insomnia that was attributable to reducing people's working lives (Chapter 4). The costs of insomnia from healthcare services, absenteeism, productivity loss, workplace accidents and errors have been

well recognized (Daley et al., 2009; Shahly et al., 2012). However, its costs from labor force loss and increased pension burden have not been previously investigated. Policy makers and employers should implement interventions at the workplace to prevent the onset of insomnia symptoms. Programs should also be developed to screen for insomnia and its related comorbidities and help workers to manage the conditions appropriately.

5.5 Future Directions

Future research needs to investigate how to modify risk factors at the workplace to promote cognitive health in late life and thus prolong workforce participation. Workplace social support is an important aspect of the psychosocial work environment. Both the job demand-control-support model (Johnson & Hall, 1988; Karasek, Triantis, & Chaudhry, 1982) and the job demands-resources model (Demerouti et al., 2001) suggest the buffering effect of social support on work-related stress. However, very few studies have examined such job characteristics in relation to late-life cognitive function (Andel et al., 2012). Researchers may explore the quality, quantity and types of workplace social support, as well as potential mechanisms through which it influences cognitive health, for example, buffering work-related stress, reducing psychological distress from work-family conflicts (Kossek, Pichler, Bodner, & Hammer, 2011), or increasing social network size and off-work social engagement (Cacioppo & Hawkley, 2009). In addition, the external social resources proposed in the job demands-resources model include not only support at the workplace, but also support from family and peers (Demerouti et al., 2001). If the buffering effect of off-work social support on job strain existed, family and community environments could also be potential intervention points to protect cognitive health against work hazards.

Existing studies on work-related stress and late-life cognitive function were mainly based on the job demand-control model, and no study has used the more flexible job demands-resources model. Lack of resources to meet the job demands leads to disengagement, which may suppress

mental activities and affect cognitive performance. The cross-sectional relationship between job burnout and cognitive deficits has been explored (Deligkaris, Panagopoulou, Montgomery, & Masoura, 2014). Future research should examine the longitudinal association based on the job demands-resources model.

Additionally, individuals without adequate resources to cope with the stress resulting from environmental demands can become disengaged and withdraw from their jobs as a way of self-protection (Demerouti et al., 2001), or lose work abilities early due to poor health. Research has investigated the association of job strain with early retirement (Elovainio et al., 2005) and disability pension (Laine et al., 2009; Mäntyniemi et al., 2012). Job strain was also found to be related to sleep disturbances (Åkerstedt et al., 2002). Future research needs to explore if insomnia is a mediator of the association between job strain and early labor force exit. If such relationship existed, interventions to prolong working lives could focus on ways to manage job strain and prevent medical conditions such as insomnia.

In conclusion, the interactive relationship between work and health deserves greater research attention in the context of global aging. Future research needs to further examine how benefits and hazards from the psychosocial work environment shape the aging trajectories and influence labor force participation in mid- and late life.

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Tables

Chapter 2 Tables

Table 2.1. Characteristics of the study sample with complete MMSE measures at the Baltimore ECA Wave 3 and Wave 4 (n=389).

Sample Characteristics	Participants with complete MMSE measures (n=389)
Age, mean (SD)	45.7 (4.2)
Female, N (%)	248 (63.8)
Non-white race, N (%)	161 (41.4)
Education, N (%)	
Below high school	74 (19.0)
High school	136 (35.0)
Above high school	179 (46.0)
Baseline self-rated health status, N (%)	
Excellent	105 (27.0)
Good	218 (56.0)
Fair	64 (16.5)
Poor	2 (0.5)
Years of follow-up, mean (SD)	11.9 (0.7)
Years of workforce status during the follow-up period, mean (SD)	
Working	10.5 (2.5)
Not working	1.3 (2.5)
Unemployed	0.1 (0.6)
Retired	0.3 (1.3)
Disabled	0.3 (1.3)
House-keeping	0.5 (1.6)
School	0.02 (0.2)
Other	0.1 (0.6)
% of the follow-up period in working status, mean (SD)	89 (21)
Number of jobs held during the follow-up period, N (%)	
One	224 (57.6)
Two	103 (26.5)
More than two	62 (15.9)

Abbreviations: ECA, Epidemiologic Catchment Area study; MMSE, mini-mental state examination; SD, standard deviation.

Table 2.2. O*NET job characteristics of the three most frequent longest-held occupations between the Baltimore ECA Wave 3 and Wave 4 in the study sample.

Occupation	SOC codes	N (%)	Job characteristics, level (summative score)		
			Mental demands	Social interaction	Physical demands
Secretaries and Administrative assistants	43-6010	18 (4.6)	Median (56.8)	Median (76.3)	Low (24.9)
Elementary and middle school teachers	25-2020	12 (3.1)	Median (69.5)	Median (70.1)	Median (36.3)
Bookkeeping, accounting, and auditing clerks	43-3031	10 (2.6)	Median (53.6)	Median (60)	Low (13.5)

Notes: The levels of job characteristics: summative scores of job characteristics were standardized across job titles to a normal distribution with a mean of zero and a standard deviation of one. The job characteristics level of an occupation was categorized as high if the standardized score was above one, as low if below negative one, and otherwise as median.

Abbreviations: ECA, Epidemiologic Catchment Area study; O*NET, Occupational Information Network; SOC, standard occupational classification.

Table 2.3. Summary statistics of baseline and follow-up cognitive function and cognitive changes, mean (SD).

	N	Baseline cognitive function (Wave 3)	Follow-up cognitive function (Wave 4)	Cognitive change (Wave 4 minus Wave 3)	*p* value
Study sample					
MMSE	389	28.88 (1.40)	28.65 (1.67)	-0.22 (1.67)	0.0087
Immediate Word Recall	388	8.22 (2.46)	7.53 (2.56)	-0.69 (2.81)	<0.0001
Delayed Word Recall	376	6.54 (2.53)	6.03 (2.50)	-0.51 (2.73)	0.0004
Subsample of participants who worked throughout the study period					
MMSE	253	28.92 (1.32)	28.90 (1.29)	-0.02 (1.40)	0.8230
Immediate Word Recall	253	8.38 (2.50)	7.81 (2.45)	-0.57 (2.70)	0.0009
Delayed Word Recall	245	6.72 (2.57)	6.31 (2.51)	-0.41 (2.69)	0.0182

Abbreviations: MMSE, mini-mental state examination; SD, standard deviation.
p values were calculated by paired t-tests.

Table 2.4. The effects of cumulative work activities on cognitive changes from the Baltimore ECA Wave 3 to Wave 4 (Wave 4 minus Wave 3) in the study sample.

	MMSE (n=389) b (95% CI)	Immediate Word Recall (n=388) b (95% CI)	Delayed Word Recall (n=376) b (95% CI)
Model 1. Mental dimension			
Mental demands	0.31* (0.04, 0.57)	0.46^{+} (-0.01, 0.93)	0.39^{+} (-0.07, 0.84)
Model 2. Social dimension			
Social interaction	0.29* (0.01, 0.57)	0.56* (0.10, 1.02)	0.70** (0.28, 1.13)
Model 3. Physical dimension			
Physical demands	-0.14^{+} (-0.29, 0.004)	-0.16 (-0.42, 0.09)	-0.17 (-0.43, 0.08)
Model 4. Effect modification			
Social interaction	0.14 (-0.15, 0.43)	0.49^{+} (-0.06, 1.04)	0.70** (0.19, 1.22)
Physical demands	-0.15^{+} (-0.32, 0.01)	-0.07 (-0.38, 0.24)	0.001 (-0.31, 0.32)
Social interaction X Physical demands	0.25** (0.06, 0.44)	0.15 (-0.15, 0.45)	0.003 (-0.29, 0.30)

Notes: Models were adjusted for baseline age, sex, race, education, baseline self-rated health status, baseline score of cognitive measure, years of follow-up, total number of non-working years, and total number of jobs held. Detailed results were in the Appendix Table S2.3-S2.6.
Abbreviations: 95% CI, 95% confidence interval; ECA, Epidemiologic Catchment Area study; MMSE, mini-mental state examination.
$^{+}$ $p<0.1$, * $p<0.05$, ** $p<0.01$.

Chapter 3 Tables

Table 3.1. Characteristics of the study sample with complete MMSE measures at the Baltimore ECA Wave 3 and Wave 4 (n=445).

	Participants with complete MMSE measures (n=445)
Age (continuous), mean (SD)	43.3 (5.35)
Age (category), N (%)	
35-44	268 (60.22)
45-55	177 (39.78)
Female sex, N (%)	263 (59.10)
Non-white race, N (%)	177 (39.78)
Education, N (%)	
Below high school	65 (14.61)
High school	159 (35.73)
Above high school	221 (49.66)
Occupational prestige (NAM score), mean (SD)	59.1 (23.04)
Self-rated health, N (%)	
Excellent	124 (27.87)
Good	257 (57.75)
Fair or poor	64 (14.38)
Job dimensions (continuous), mean (SD)	
Psychological demands (range: 3 to 12; median: 7)	7.4 (1.51)
Physical demands (range: 10 to 28; median: 17)	17.3 (3.17)
Decision authority (range: 3 to 12; median: 9)	9.0 (1.69)
Skill discretion (range: 7 to 20; median: 15)	15.3 (2.44)
Job demand-control (dichotomized), N (%)	
High physical demands	189 (42.47)
High psychological demands	188 (42.25)
Low decision authority	151 (33.93)
Low skill discretion	156 (35.06)
Job strain (quadrants), N (%)	
Low strain	111 (24.94)
Passive	52 (11.69)
Active	183 (41.12)
High strain	99 (22.25)

Notes: Low strain: low psychological and physical demands and high decision authority;
Passive: low psychological and physical demands and low decision authority;
Active: high psychological or physical demands and high decision authority;
High strain: high psychological or physical demands and low decision authority.

Abbreviations: ECA, Epidemiologic Catchment Area study; MMSE, mini-mental state examination; NAM, the Nam-Powers-Terrie Occupational Status Scores; SD, standard deviation.

Table 3.2. Correlation between dimensions of job characteristics in the study sample (n=445).

	Physical demands	Psychological demands	Decision authority	Skill discretion	Occupational prestige
Physical demands	1.00				
Psychological demands	0.12**	1.00			
Decision authority	-0.11*	-0.03	1.00		
Skill discretion	0.01	0.05	0.60***	1.00	
Occupational prestige	-0.28***	0.14**	0.27***	0.39***	1.00

Note: occupational prestige was measured by the Nam-Powers-Terrie Occupational Status Scores.
* $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Table 3.3. Summary statistics of baseline and follow-up cognitive function and cognitive change (Wave 4 minus Wave 3), mean (SD).

	N	Baseline cognitive function (Wave 3)	Follow-up cognitive function (Wave 4)	Cognitive change (Wave 4 minus Wave 3)	*p* value
Full sample					
MMSE	445	29.02 (1.26)	28.91 (1.36)	-0.11 (1.50)	0.114
Immediate Word Recall	441	8.31 (2.55)	7.74 (2.43)	-0.57 (2.66)	<0.001
Delayed Word Recall	428	6.69 (2.55)	6.24 (2.51)	-0.45 (2.74)	<0.001
Low strain jobs					
MMSE	111	29.33 (0.94)	29.30 (0.92)	-0.04 (1.06)	0.721
Immediate Word Recall	111	8.85 (2.47)	8.64 (2.20)	-0.21 (2.70)	0.421
Delayed Word Recall	107	7.07 (2.43)	6.80 (2.23)	-0.27 (2.60)	0.283
Passive jobs					
MMSE	52	28.94 (1.41)	28.79 (1.29)	-0.15 (1.46)	0.451
Immediate Word Recall	50	8.34 (2.18)	7.30 (2.34)	-1.04 (2.56)	0.006
Delayed Word Recall	49	6.67 (2.35)	6.10 (2.37)	-0.57 (2.88)	0.171
Active jobs					
MMSE	183	28.98 (1.32)	28.86 (1.47)	-0.11 (1.73)	0.370
Immediate Word Recall	182	8.13 (2.57)	7.57 (2.40)	-0.56 (2.61)	0.004
Delayed Word Recall	176	6.61 (2.66)	6.13 (2.56)	-0.48 (2.80)	0.023
High strain jobs					
MMSE	99	28.81 (1.32)	28.64 (1.53)	-0.17 (1.48)	0.253
Immediate Word Recall	98	8.03 (2.72)	7.26 (2.55)	-0.78 (2.73)	0.006
Delayed Word Recall	96	6.42 (2.63)	5.89 (2.70)	-0.53 (2.76)	0.062

Abbreviation: MMSE, mini-mental state examination; SD, standard deviation.
p values were calculated by paired t-tests.

Table 3.4. Multiple linear regression models of the association between job strain at the Baltimore ECA Wave 3 and cognitive changes from the Wave 3 to Wave 4 (Wave 4 minus Wave 3).

	MMSE (n=445)		Immediate Word Recall (n=441)		Delayed Word Recall (n=428)	
	b (95% CI)	*p* value	b (95% CI)	*p* value	b (95% CI)	*p* value
Base Model						
Low strain	ref	-	ref	-	ref	-
Passive	-0.37 (-0.73, -0.01)	0.045	-1.14 (-1.86, -0.42)	0.002	-0.54 (-1.30, 0.22)	0.161
Active	-0.31 (-0.57, -0.04)	0.025	-0.79 (-1.29, -0.28)	0.002	-0.49 (-1.01, 0.03)	0.066
High strain	-0.47 (-0.78, -0.16)	0.003	-1.06 (-1.66, -0.46)	0.001	-0.66 (-1.29, -0.03)	0.041
Full Model						
Low strain	ref	-	ref	-	ref	-
Passive	-0.34 (-0.69, 0.02)	0.062	-1.15 (-1.89, -0.41)	0.002	-0.42 (-1.21, 0.38)	0.301
Active	-0.31 (-0.58, -0.03)	0.027	-0.84 (-1.33, -0.35)	0.001	-0.47 (-0.96, 0.02)	0.061
High strain	-0.46 (-0.77, -0.14)	0.005	-1.09 (-1.69, -0.49)	0.000	-0.58 (-1.20, 0.04)	0.067

Notes: Low strain: low psychological and physical demands and high decision authority;
Passive: low psychological and physical demands and low decision authority;
Active: high psychological or physical demands and high decision authority;
High strain: high psychological or physical demands and low decision authority.

Base model adjusted for baseline score of the cognitive measure.

Full model adjusted for age, sex, race, education, baseline self-rated health status and baseline score of the cognitive measure.

Full results are presented in Appendix Table S4.6-4.8.

Abbreviations: 95% CI, 95% confidence interval; ECA, Epidemiologic Catchment Area study; MMSE, mini-mental state examination; ref, reference.

Chapter 4 Tables

Table 4.1. Baseline sample characteristics by type of job exit at the HRS 2006 (n=5746).

Baseline Characteristics N (weighted %)	Total (n=5746)	Job Exit due to Poor Health (n=203)	Job Exit due to Other Reasons (n=753)	No Job Exit (n=4790)	*p* value
Insomnia symptoms					<0.001
None	3725 (64.2)	100 (46.0)	465 (63.1)	3160 (65.0)	
1-2	1706 (30.1)	76 (37.4)	246 (31.3)	1384 (29.7)	
3-4	315 (5.7)	27 (16.6)	42 (5.6)	246 (5.3)	
Age					<0.001
50-61	3737 (80.1)	125 (79.0)	338 (62.4)	3274 (82.3)	
62-70	2009 (19.9)	78 (21.0)	415 (37.6)	1516 (17.7)	
Female	2991 (48.0)	109 (52.6)	430 (53.5)	2452 (47.2)	0.021
Race					<0.001
White	4606 (86.1)	136 (76.7)	608 (86.9)	3862 (86.4)	
Black	799 (8.6)	53 (17.1)	112 (9.2)	634 (8.2)	
Other	341 (5.3)	14 (6.1)	33 (3.9)	294 (5.5)	
Education					<0.001
Below high school	712 (9.1)	57 (22.7)	116 (12.5)	539 (8.2)	
High school	2992 (51.0)	106 (55.6)	427 (55.0)	2459 (50.3)	
Above high school	2042 (39.9)	40 (21.8)	210 (32.5)	1792 (41.5)	
Household income					<0.001
Below Q2	1397 (20.8)	102 (44.7)	210 (24.8)	1085 (19.4)	
Between Q2 and Q3	1728 (29.1)	48 (25.8)	229 (28.3)	1451 (29.4)	
Above Q3	2621 (50.1)	53 (29.5)	314 (46.9)	2254 (51.2)	
Self-rated health					<0.001
Above good	3052 (55.4)	46 (24.7)	346 (49.4)	2660 (57.3)	
Good	1807 (30.0)	65 (28.6)	281 (34.0)	1461 (29.5)	
Below good	887 (14.6)	92 (46.7)	126 (16.6)	669 (13.2)	
Depressive symptoms					<0.001
None	3401 (59.6)	76 (37.0)	433 (56.9)	2892 (60.7)	
1-2	1346 (22.9)	61 (29.0)	199 (25.7)	1086 (22.4)	
3-4	595 (10.5)	51 (27.0)	73 (10.6)	471 (9.8)	

Missing	404 (7.1)	15 (7.0)	48 (6.9)	341 (7.1)	
History of medical conditions					
Psychiatric problems	674 (12.0)	49 (28.8)	104 (15.7)	521 (11.0)	<0.001
Diabetes	728 (11.6)	55 (28.9)	113 (14.6)	560 (10.6)	<0.001
Heart disease	723 (11.5)	37 (16.1)	117 (14.3)	569 (10.9)	0.019
Work status					<0.001
Full-time	4009 (74.8)	104 (56.3)	414 (58.8)	3491 (77.4)	
Part-time	796 (13.7)	41 (20.8)	122 (18.5)	633 (12.9)	
Partly retired	941 (11.5)	58 (23.0)	217 (22.7)	666 (9.7)	
Job requiring much physical effort					0.002
All or almost all the time	1098 (18.3)	60 (29.6)	142 (17.8)	896 (17.9)	
Most of the time	743 (12.5)	32 (17.9)	103 (13.4)	608 (12.2)	
Some of the time	1670 (30.0)	55 (26.1)	207 (29.1)	1408 (30.2)	
None or almost none	1968 (34.2)	39 (18.5)	268 (35.0)	1661 (34.7)	
Missing	267 (5.1)	17 (7.9)	33 (4.8)	217 (49.7)	
Job involving much stress					0.058
Strongly agree	1096 (20.9)	37 (22.5)	131 (19.1)	928 (21.1)	
Agree	1999 (36.9)	69 (33.7)	220 (32.1)	1710 (37.6)	
Disagree	2104 (33.3)	73 (33.8)	313 (38.2)	1718 (32.7)	
Strongly disagree	294 (4.2)	9 (3.0)	58 (6.1)	227 (4.0)	
Missing	253 (4.8)	15 (7.0)	31 (4.5)	207 (4.7)	

Abbreviations: HRS, Health and Retirement Study; Q2, the second quartile; Q3, the third quartile.

Table 4.2. Multinomial logistic regression models of the association between insomnia symptoms and subsequent job exit (n=5746). No job exit is the reference group.

	Base Model		Full Model	
	Job Exit due to Poor Health RRR (95% CI)	Job Exit due to Other Reasons RRR (95% CI)	Job Exit due to Poor Health RRR (95% CI)	Job Exit due to Other Reasons RRR (95% CI)
Insomnia symptoms				
None	ref	ref	ref	ref
1-2	1.75** (1.25, 2.46)	1.06 (0.83, 1.35)	1.23 (0.85,1.77)	0.97 (0.76,1.23)
3-4	3.76*** (2.09, 6.76)	1.11 (0.74, 1.67)	1.93* (1.04,3.58)	0.96 (0.61,1.51)
Test of linear trend	p<0.001	p=0.613	p=0.036	p=0.841
Age				
50-61	ref	ref	ref	ref
62-70	1.14 (0.85, 1.53)	2.72*** (2.23, 3.32)	1.03 (0.73,1.47)	2.24** (1.76,2.86)
Female	1.01 (0.75, 1.36)	1.30* (1.04, 1.61)	1.00 (0.74,1.36)	1.20 (0.95,1.51)
Race				
White	ref	ref	ref	ref
Black	1.91** (1.32, 2.76)	1.05 (0.78, 1.41)	1.81** (1.21,2.71)	1.07 (0.80,1.43)
Other	1.03 (0.47, 2.26)	0.73 (0.47, 1.13)	0.93 (0.43,1.99)	0.74 (0.47,1.17)
Education				
Below high school	2.86*** (1.72, 4.76)	1.68** (1.23, 2.30)	1.87* (1.02, 3.42)	1.68** (1.22, 2.31)
High school	1.54* (1.08, 2.19)	1.30* (1.01, 1.68)	1.31 (0.91, 1.89)	1.31* (1.02, 1.70)
Above high school	ref	ref	ref	ref
Household income				
Below Q2	2.47*** (1.59, 3.85)	1.05 (0.83, 1.32)	1.42 (0.89,2.27)	0.90 (0.70,1.15)
Between Q2 and Q3	1.21 (0.79, 1.84)	0.90 (0.67, 1.19)	0.91 (0.59,1.41)	0.84 (0.63,1.13)
Above Q3	ref	ref	ref	ref
Self-rated health status				
Above good			ref	ref
Good			1.50 (0.90,2.50)	1.20 (0.95,1.50)
Below good			3.16** (1.76,5.69)	1.20 (0.84,1.71)
Depressive symptoms				
None			ref	ref

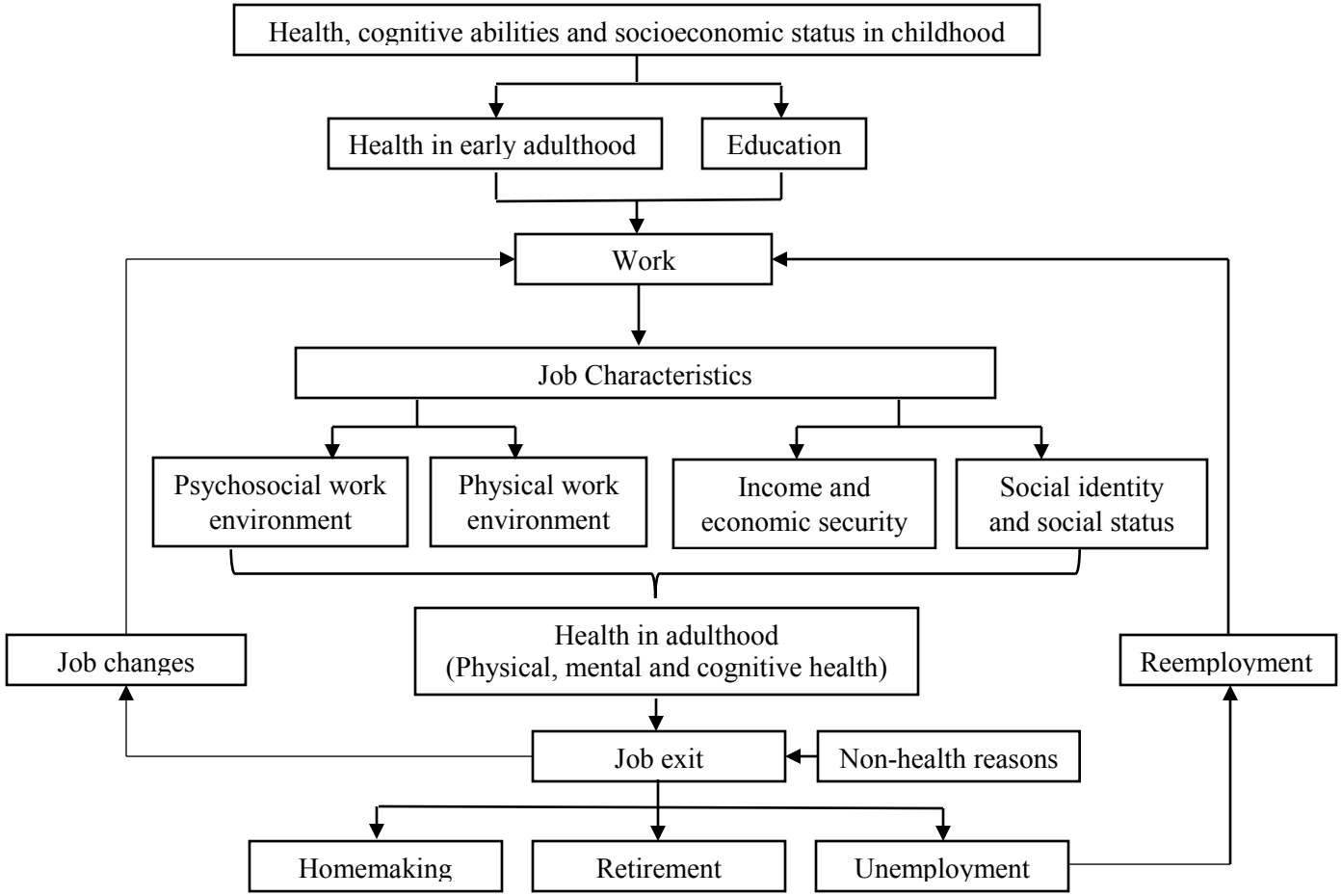
1-2	1.26 (0.77,2.06)	1.14 (0.88,1.48)
3-4	1.37 (0.84,2.21)	1.06 (0.70,1.59)
History of medical conditions		
Psychiatric problems	2.01** (1.32,3.07)	1.42* (1.04,1.95)
Diabetes	2.03** (1.33,3.09)	1.25 (0.95,1.65)
Heart disease	1.00 (0.61,1.64)	1.08 (0.80,1.46)
Baseline work status		
Full-time	ref	ref
Part-time	1.76** (1.16,2.68)	1.66*** (1.26,2.18)
Partly retired	2.96*** (1.79,4.89)	2.06*** (1.56,2.72)
Job requiring much physical effort		
All or almost of the time	1.74 (0.94,3.25)	0.92 (0.67,1.25)
Most of the time	1.58 (0.75,3.35)	0.97 (0.71,1.33)
Some of the time	1.24 (0.66,2.35)	0.93 (0.72,1.20)
None or almost none	ref	ref
Job involving much stress		
Strongly agree	2.04 (0.85,4.89)	1.01 (0.67,1.52)
Agree	1.70 (0.72,4.02)	0.86 (0.59,1.26)
Disagree	1.69 (0.71,4.03)	0.93 (0.65,1.31)
Strongly disagree	ref	ref

Abbreviations: 95% CI, 95% confidence interval; Q2, the second quartile; Q3, the third quartile; ref, reference; RRR, relative risk ratio.
*p<0.05, **p<0.01, ***p<0.001.

Figures

Introduction Figure

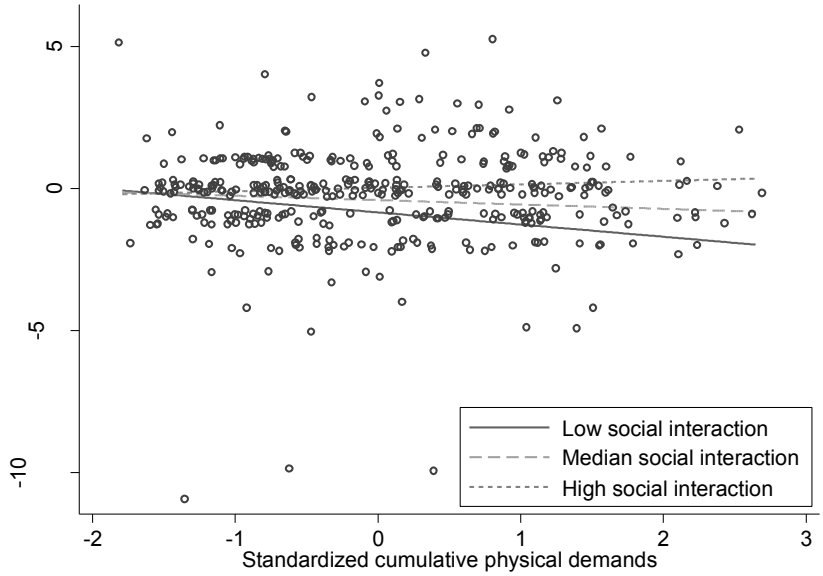
Figure 1. Conceptual framework of work and health over the life course.



Note: The conceptual framework was developed based on the framework by Clougherty et al. (2010).

Chapter 2 Figure

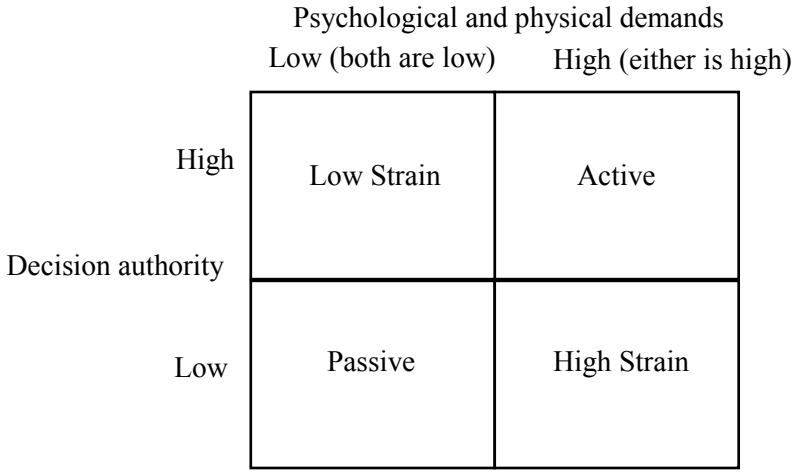
Figure 2. Effect modification by cumulative social interaction on the association between cumulative physical demands and change in the MMSE.



Abbreviation: MMSE, mini-mental state examination.

Chapter 3 Figure

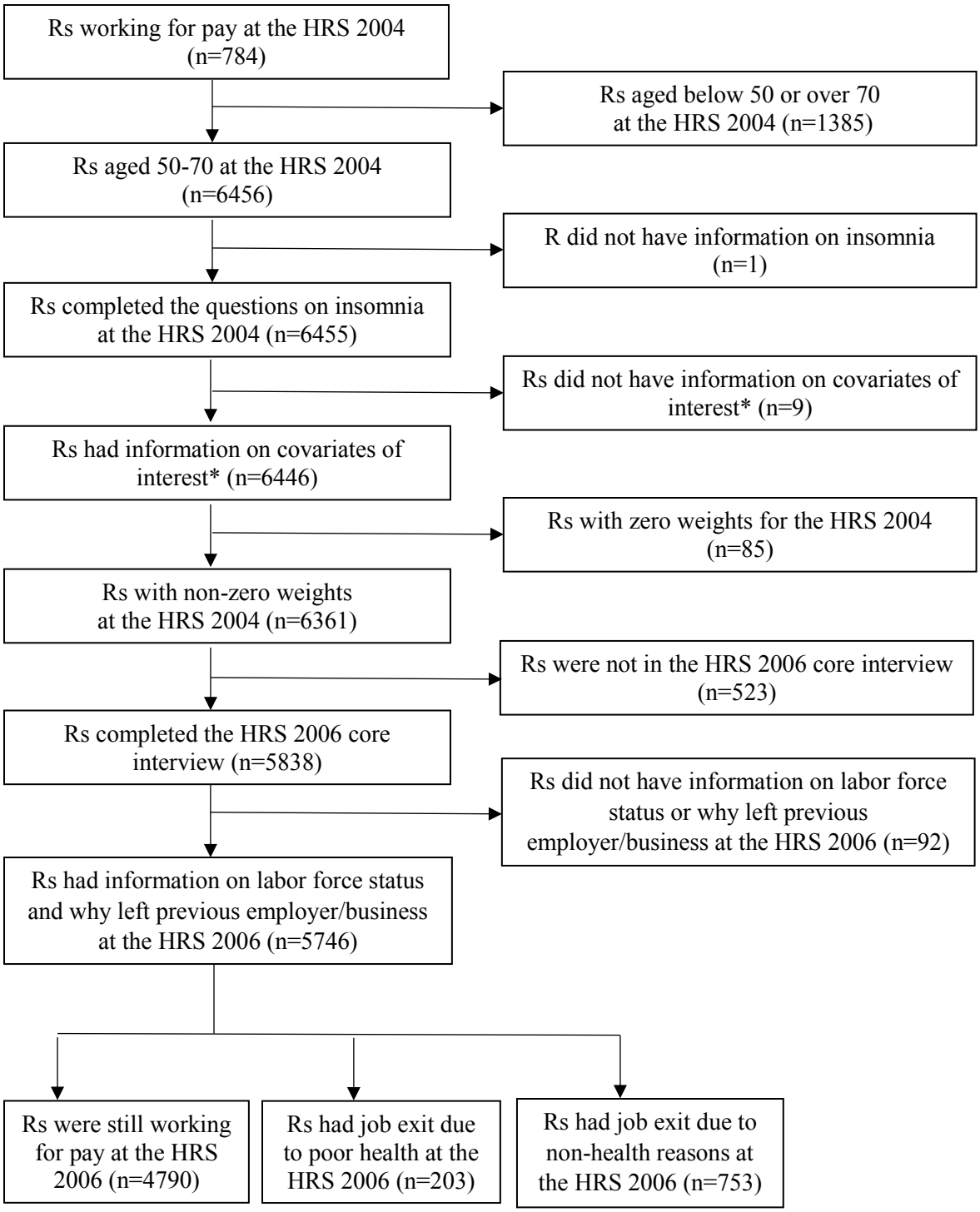
Figure 3. Job-strain measures based on job demands and job control.



Note: The figure was developed based on the job demand-control model (Karasek, 1979).

Chapter 4 Figure

Figure 4. Sample construction process.



Note: *Variables included age, sex, race, education, self-rated health status, household income and history of medical conditions.
Abbreviations: HRS, Health and Retirement Study; R, respondent.

Appendices

Chapter 2 Appendix Tables

Table S2.1. Measures of work activities from the Occupational Information Network (O*NET).

Domains	O*NET Work Activities	Description
Mental Processes (Mental demands)		
	Judging the Qualities of Things, Services, or People	Assessing the value, importance, or quality of things or people.
	Processing Information	Compiling, coding, categorizing, calculating, tabulating, auditing, or verifying information or data.
	Evaluating Information to Determine Compliance with Standards	Using relevant information and individual judgment to determine whether events or processes comply with laws, regulations, or standards.
	Analyzing Data or Information	Identifying the underlying principles, reasons, or facts of information by breaking down information or data into separate parts.
	Making Decisions and Solving Problems	Analyzing information and evaluating results to choose the best solution and solve problems.
	Thinking Creatively	Developing, designing, or creating new applications, ideas, relationships, systems, or products, including artistic contributions.
	Updating and Using Relevant Knowledge	Keeping up-to-date technically and applying new knowledge to your job.
	Developing Objectives and Strategies	Establishing long-range objectives and specifying the strategies and actions to achieve them.
	Scheduling Work and Activities	Scheduling events, programs, and activities, as well as the work of others.
	Organizing, Planning, and Prioritizing Work	Developing specific goals and plans to prioritize, organize, and accomplish your work.
Interacting with Others (Social interaction)		
	Communicating with Supervisors, Peers, or Subordinates	Providing information to supervisors, co-workers, and subordinates by telephone, in written form, e-mail, or in person.
	Communicating with Persons Outside Organization	Communicating with people outside the organization, representing the organization to customers, the public, government, and other external sources. This information can be exchanged in person, in writing, or by telephone or e-mail.
	Establishing and Maintaining Interpersonal Relationships	Developing constructive and cooperative working relationships with others, and maintaining them over time.
Physical activities (Physical demands)		
	Performing General Physical Activities	Performing physical activities that require considerable use of your arms and legs and moving your whole body, such as climbing,

	lifting, balancing, walking, stooping, and handling of materials.
Handling and Moving Objects	Using hands and arms in handling, installing, positioning, and moving materials, and manipulating things.

Table S2.2. List of broad occupations and the corresponding detailed O*NET-SOC codes used.

SOC of broad occupations	O*NET-SOC codes of detailed occupation				
11-2020	11-2021.00	11-2022.00			
11-9030	11-9031.00	11-9032.00	11-9033.00	11-9039.01	11-9039.02
13-1030	13-1031.00	13-1031.01	13-1031.02	13-1032.00	
13-1070	13-1071.00	13-1074.00	13-1075.00		
13-2070	13-2071.00	13-2071.01	13-2072.00		
15-1150	15-1151.00	15-1152.00			
17-2070	17-2071.00	17-2072.00	17-2072.01		
17-2110	17-2111.01	17-2111.02	17-2111.03	17-2112.00	17-2112.01
17-3010	17-3011.01	17-3011.02	17-3012.01	17-3012.02	17-3013.00
17-3020	17-3021.00	17-3022.00	17-3023.01	17-3023.03	17-3024.00
	17-3024.01	17-3025.00	17-3026.00	17-3027.00	17-3027.01
	17-3029.01	17-3029.02	17-3029.03	17-3029.04	17-3029.05
	17-3029.06	17-3029.07	17-3029.08	17-3029.09	17-3029.10
	17-3029.11	17-3029.12			
19-2030	19-2031.00	19-2032.00			
19-4090	19-4091.00	19-4092.00	19-4093.00	19-4099.01	19-4099.02
	19-4099.03				
21-1010	21-1011.00	21-1012.00	21-1013.00	21-1014.00	21-1015.00
21-1020	21-1021.00	21-1022.00	21-1023.00		
21-1099	21-1091.00	21-1092.00	21-1093.00	21-1094.00	
23-2090	23-2091.00	23-2093.00			
25-1000	25-1011.00	25-1021.00	25-1022.00	25-1031.00	25-1032.00
	25-1041.00	25-1042.00	25-1043.00	25-1051.00	25-1052.00
	25-1053.00	25-1054.00			
25-2010	25-2011.00	25-2012.00			
25-2020	25-2021.00	25-2022.00	25-2023.00		
25-2030	25-2031.00	25-2032.00			
25-2050	25-2051.00	25-2052.00	25-2053.00	25-2054.00	25-2059.01
25-3000	25-3011.00	25-3021.00	25-3099.02		
25-4010	25-4011.00	25-4012.00	25-4013.00		
25-9090	25-9011.00	25-9021.00	25-9031.00	25-9041.00	
27-1010	27-1011.00	27-1012.00	27-1013.00	27-1014.00	
27-1020	27-1021.00	27-1022.00	27-1023.00	27-1024.00	27-1025.00
	27-1026.00	27-1027.00			
27-2030	27-2031.00	27-2032.00			
27-2040	27-2041.01	27-2041.04	27-2042.01	27-2042.02	
27-3020	27-3021.00	27-3022.00			
27-3090	27-3091.00				
27-4010	27-4011.00	27-4012.00	27-4013.00	27-4014.00	
27-4030	27-4031.00	27-4032.00			
29-1060	29-1061.00	29-1062.00	29-1063.00	29-1064.00	29-1065.00
	29-1066.00	29-1067.00	29-1069.01	29-1069.02	29-1069.03
	29-1069.04	29-1069.05	29-1069.06	29-1069.07	29-1069.08
	29-1069.09	29-1069.10	29-1069.11	29-1069.12	
29-2010	29-2011.00	29-2011.01	29-2011.02	29-2011.03	29-2012.00
29-2030	29-2031.00	29-2032.00	29-2033.00	29-2034.00	29-2035.00

29-2050	29-2051.00	29-2052.00	29-2053.00	29-2054.00	29-2055.00
	29-2056.00	29-2057.00			
29-2090	29-2091.00	29-2092.00	29-2099.01	29-2099.05	29-2099.06
	29-2099.07				
29-9000	29-9011.00	29-9012.00	29-9091.00	29-9092.00	29-9099.01
31-1010	31-1011.00	31-1013.00	31-1014.00	31-1015.00	
33-1099	33-1011.00	33-1012.00	33-1021.01	33-1021.02	
33-3010	33-3011.00	33-3012.00			
33-9030	33-9031.00	33-9032.00			
35-2010	35-2011.00	35-2012.00	35-2013.00	35-2014.00	35-2015.00
37-2019	37-2011.00	37-2012.00			
37-3010	37-3011.00	37-3012.00	37-3013.00		
39-3010	39-3011.00	39-3012.00			
39-3090	39-3091.00	39-3092.00	39-3093.00		
39-9030	39-9031.00	39-9032.00			
39-9099	39-9011.00	39-9011.01	39-9021.00	39-9031.00	39-9032.00
	39-9041.00				
41-2010	41-2011.00	41-2012.00			
41-4010	41-4011.00	41-4011.07	41-4012.00		
41-9020	41-9021.00	41-9022.00			
41-9099	41-9091.00	41-9011.00	41-9012.00	41-9021.00	41-9022.00
	41-9031.00	41-9041.00			
43-4199	43-4011.00	43-4021.00	43-4031.00	43-4041.00	43-4051.00
	43-4061.00	43-4071.00	43-4081.00	43-4111.00	43-4121.00
	43-4131.00	43-4141.00	43-4151.00	43-4161.00	43-4171.00
	43-4181.00				
43-5030	43-5031.00	43-5032.00			
43-6010	43-6011.00	43-6012.00	43-6013.00	43-6014.00	
43-9199	43-9011.00	43-9021.00	43-9022.00	43-9031.00	43-9041.00
	43-9051.00	43-9061.00	43-9071.00	43-9081.00	
45-2090	45-2091.00	45-2092.01	45-2092.02	45-2093.00	
45-4020	45-4021.00	45-4022.00	45-4023.00		
47-2020	47-2021.00	47-2022.00			
47-2040	47-2041.00	47-2042.00	47-2043.00	47-2044.00	
47-2080	47-2081.00	47-2082.00			
47-2150	47-2151.00	47-2152.01	47-2152.02		
47-3010	47-3011.00	47-3012.00	47-3013.00	47-3014.00	47-3015.00
	47-3016.00				
47-5099	47-5011.00	47-5012.00	47-5013.00	47-5021.00	47-5031.00
	47-5041.00	47-5042.00	47-5049.00	47-5051.00	47-5061.00
	47-5071.00	47-5081.00			
49-2020	49-2021.00	49-2021.01	49-2022.00		
49-3040	49-3041.00	49-3042.00	49-3043.00		
49-3090	49-3091.00	49-3092.00	49-3093.00		
51-2020	51-2021.00	51-2022.00	51-2023.00		
51-2090	51-2091.00	51-2092.00	51-2093.00		
51-3020	51-3021.00	51-3022.00	51-3023.00		
51-4050	51-4051.00	51-4052.00			
51-4120	51-4121.06	51-4121.07	51-4122.00		

51-4199	51-4011.00	51-4012.00	51-4021.00	51-4022.00	51-4023.00
	51-4031.00	51-4032.00	51-4033.00	51-4034.00	51-4035.00
	51-4041.00	51-4051.00	51-4052.00	51-4061.00	51-4062.00
	51-4071.00	51-4072.00	51-4081.00	51-4111.00	51-4121.06
	51-4121.07	51-4122.00	51-4191.00	51-4192.00	51-4193.00
	51-4194.00				
51-6050	51-6051.00	51-6052.00			
51-9010	51-9011.00	51-9012.00			
51-9020	51-9021.00	51-9022.00	51-9023.00		
51-9030	51-9031.00	51-9032.00			
51-9080	51-9081.00	51-9082.00	51-9083.00		
53-1000	53-1011.00	53-1021.00	53-1021.01	53-1031.00	
53-3020	53-3021.00	53-3022.00			
53-3030	53-3031.00	53-3032.00	53-3033.00		
53-4010	53-4011.00	53-4012.00	53-4013.00		
53-7199	53-7111.00	53-7121.00			

Table S2.3. Correlation between cumulative work activities during the time interval between the Baltimore ECA Wave 3 and Wave 4.

	Mental demands	Social interaction	Physical demands
Study sample (n=389)			
Mental demands	1.00		
Social interaction	0.91***	1.00	
Physical demands	0.02	0.03	1.00
Participants worked throughout the period (n=253)			
Mental demands	1.00		
Social interaction	0.72***	1.00	
Physical demands	-0.41***	-0.44***	1.00
Participants with non-working years (n=136)			
Mental demands	1.00		
Social interaction	0.94***	1.00	
Physical demands	0.30***	0.30***	1.00

Abbreviation: ECA, Epidemiologic Catchment Area study.
* $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Table S2.4. The effects of cumulative work activities on change in the MMSE from the Baltimore ECA Wave 3 to Wave 4 (Wave 4 minus Wave 3) in the study sample (n=389).

	Model 1 Mental demands		Model 2 Social interaction		Model 3 Physical demands	
	b	t	b	t	b	t
Cumulative job exposure (standardized)	0.31*	(2.28)	0.29*	(2.05)	-0.14^{+}	(-1.91)
MMSE at baseline	-0.55**	(-7.84)	-0.55**	(-7.77)	-0.56**	(-7.80)
Age at baseline	-0.01	(-0.68)	-0.01	(-0.70)	-0.01	(-0.64)
Female sex	-0.08	(-0.50)	-0.13	(-0.82)	-0.16	(-0.95)
Race, non-white	-0.11	(-0.71)	-0.12	(-0.80)	-0.13	(-0.88)
Education						
Below high school	ref	-	ref	-	ref	-
High school	0.57*	(2.31)	0.58*	(2.29)	0.60*	(-2.41)
Above high school	0.43^{+}	(1.73)	0.49^{+}	(1.90)	0.52*	(-2.08)
Self-rated health at baseline						
Excellent	ref	-	ref	-	ref	-
Good	0.08	(0.48)	0.09	(0.54)	0.11	(-0.63)
Fair or poor	0.13	(0.54)	0.10	(0.40)	0.14	(-0.55)
Years of follow-up	0.13	(1.18)	0.11	(1.02)	0.21^{+}	(-1.87)
Total number of non-working years	0.03	(0.67)	0.04	(0.64)	-0.08*	(-2.18)
Total number of jobs held						
One	ref	-	ref	-	ref	-
Two	0.14	(0.77)	0.14	(0.79)	0.13	(-0.73)
More than two	0.12	(0.62)	0.09	(0.44)	0.13	(-0.67)
N	389		389		389	
R-squared	0.230		0.228		0.227	

Abbreviations: ECA, Epidemiologic Catchment Area study; MMSE, mini–mental state examination; ref, reference.
$^{+}$ $p<0.1$, * $p<0.05$, ** $p<0.01$.

Table S2.5. The effects of cumulative work activities on change in the Immediate Word Recall task from the Baltimore ECA Wave 3 to Wave 4 (Wave 4 minus Wave 3) in the study sample (n=388).

	Model 1 Mental demands		Model 2 Social interaction		Model 3 Physical demands	
	b	t	b	t	b	t
Cumulative job exposure (standardized)	0.46^{+}	(1.91)	0.56*	(2.38)	-0.16	(-1.26)
Immediate Word Recall at baseline	-0.68**	(-13.20)	-0.69**	(-13.34)	-0.67**	(-13.14)
Age at baseline	-0.07*	(-2.34)	-0.07*	(-2.39)	-0.07*	(-2.29)
Female sex	0.39	(1.57)	0.29	(1.11)	0.31	(-1.14)
Race, non-white	-0.51*	(-2.00)	-0.51*	(-1.99)	-0.56*	(-2.24)
Education						
Below high school	ref	-	ref	-	ref	-
High school	0.20	(0.58)	0.18	(0.52)	0.26	(-0.77)
Above high school	0.58	(1.54)	0.62^{+}	(1.73)	0.75*	(-2.12)
Self-rated health at baseline						
Excellent	ref	-	ref	-	ref	-
Good	0.37	(1.33)	0.39	(1.41)	0.4	(-1.44)
Fair or poor	-0.03	(-0.07)	-0.09	(-0.22)	-0.02	(-0.04)
Years of follow-up	-0.46**	(-2.66)	-0.52**	(-2.90)	-0.35*	(-2.12)
Total number of non-working years	0.09	(1.05)	0.14	(1.49)	-0.07	(-1.40)
Total number of jobs held						
One	ref	-	ref	-	ref	-
Two	-0.68*	(-2.44)	-0.67*	(-2.38)	-0.68*	(-2.44)
More than two	-0.37	(-1.12)	-0.44	(-1.33)	-0.36	(-1.08)
N	388		388		388	
R-squared	0.360		0.361		0.355	

Abbreviations: ECA, Epidemiologic Catchment Area study; ref, reference.
$^{+}$ $p<0.1$, * $p<0.05$, ** $p<0.01$.

Table S2.6. The effects of cumulative work activities on change in the Delayed Word Recall task from the Baltimore ECA Wave 3 to Wave 4 (Wave 4 minus Wave 3) in the study sample (n=376).

	Model 1 Mental demands		Model 2 Social interaction		Model 3 Physical demands	
	b	t	b	t	b	t
Cumulative job exposure (standardized)	0.39^{+}	(1.67)	0.70**	(3.25)	-0.17	(-1.33)
Delayed Word Recall at baseline	-0.70**	(-14.34)	-0.69**	(-14.46)	-0.69**	(-14.32)
Age at baseline	-0.08**	(-3.03)	-0.09**	(-3.10)	-0.08**	(-2.97)
Female sex	0.56*	(2.31)	0.42^{+}	(1.68)	0.47^{+}	(-1.80)
Race, non-white	-0.89**	(-3.33)	-0.83**	(-3.09)	-0.93**	(-3.49)
Education						
Below high school	ref	-	ref	-	ref	-
High school	0.16	(0.51)	0.08	(0.24)	0.19	(-0.62)
Above high school	0.84*	(2.53)	0.76*	(2.37)	0.95**	(-2.91)
Self-rated health at baseline						
Excellent	ref	-	ref	-	ref	-
Good	0.06	(0.22)	0.08	(0.28)	0.09	(-0.32)
Fair or poor	-0.12	(-0.32)	-0.20	(-0.52)	-0.11	(-0.30)
Years of follow-up	-0.27^{+}	(-1.74)	-0.38*	(-2.37)	-0.17	(-1.10)
Total number of non-working years	0.10	(1.22)	0.21**	(2.60)	-0.05	(-0.93)
Total number of jobs held						
One	ref	-	ref	-	ref	-
Two	-0.37	(-1.39)	-0.36	(-1.35)	-0.38	(-1.41)
More than two	-0.17	(-0.54)	-0.26	(-0.85)	-0.15	(-0.50)
N	376		376		376	
R-squared	0.393		0.403		0.391	

Abbreviations: ECA, Epidemiologic Catchment Area study; ref, reference.
$^{+}$ $p<0.1$, * $p<0.05$, ** $p<0.01$.

Table S2.7. Effect modification by cumulative social interaction on the association between cumulative physical demands and cognitive changes from the Baltimore ECA Wave 3 to Wave 4 (Wave 4 minus Wave 3) in the study sample.

	MMSE		Immediate Word Recall		Delayed Word Recall	
	b	t	b	t	b	t
Physical demands	-0.15^{+}	(-1.84)	-0.07	(-0.44)	0.001	(0.01)
Social interaction	0.14	(0.97)	0.49^{+}	(1.77)	0.70**	(2.67)
Social interaction X Physical demands	0.25**	(2.65)	0.15	(0.97)	0.003	(0.02)
Cognitive function at baseline	-0.55**	(-7.94)	-0.69**	(-13.32)	-0.69**	(-14.44)
Age at baseline	-0.01	(-0.53)	-0.07*	(-2.31)	-0.09**	(-3.06)
Female sex	-0.24	(-1.39)	0.24	(0.91)	0.42	(1.64)
Race, non-white	-0.08	(-0.50)	-0.49^{+}	(-1.96)	-0.83**	(-3.09)
Education						
Below high school	ref	-	ref	-	ref	-
High school	0.49^{+}	(1.91)	0.14	(0.39)	0.08	(0.24)
Above high school	0.39	(1.50)	0.57	(1.57)	0.76*	(2.33)
Self-rated health at baseline						
Excellent	ref	-	ref	-	ref	-
Good	0.08	(0.45)	0.37	(1.37)	0.08	(0.28)
Fair or poor	0.07	(0.27)	-0.10	(-0.25)	-0.20	(-0.52)
Years of follow-up	0.16	(1.44)	-0.49**	(-2.72)	-0.38*	(-2.25)
Total number of non-working years	-0.11	(-1.55)	0.06	(0.41)	0.21	(1.60)
Total number of jobs held						
One	ref	-	ref	-	ref	-
Two	0.16	(0.89)	-0.65*	(-2.33)	-0.36	(-1.34)
More than two	0.15	(0.75)	-0.40	(-1.21)	-0.26	(-0.84)
N	389		388		376	
R-squared	0.240		0.363		0.403	

Abbreviations: ECA, Epidemiologic Catchment Area study; MMSE, mini–mental state examination; ref, reference.
$^{+}$ $p<0.1$, * $p<0.05$, ** $p<0.01$.

Table S2.8. Multiple linear regression models of the association between having non-working years and cumulative job exposures during the time interval between the Baltimore ECA Wave 3 and Wave 4 (n=389).

	Model 1 Mental demands		Model 2 Social interaction		Model 3 Physical demands	
	b	robust se	b	robust se	b	robust se
Having non-working years (Yes/No)	-0.24**	(0.08)	-0.16*	(0.07)	0.34**	(0.12)
MMSE at baseline	0.01	(0.02)	0.01	(0.02)	-0.08**	(0.03)
Age at baseline	0.004	(0.01)	0.004	(0.01)	-0.004	(0.01)
Female sex	0.02	(0.06)	0.21***	(0.05)	-0.62***	(0.09)
Race, non-white	-0.22***	(0.05)	-0.20***	(0.05)	0.32***	(0.09)
Education						
Below high school	ref	-	ref	-	ref	-
High school	0.27***	(0.07)	0.26***	(0.07)	-0.41***	(0.12)
Above high school	0.60***	(0.08)	0.43***	(0.07)	-0.69***	(0.11)
Self-rated health at baseline						
Excellent	ref	-	ref	-	ref	-
Good	0.01	(0.06)	-0.03	(0.06)	0.19	(0.10)
Fair or poor	-0.04	(0.08)	0.08	(0.08)	0.10	(0.12)
Years of follow-up	-0.06	(0.04)	-0.04	(0.04)	-0.11	(0.06)
Total number of working years	0.27***	(0.01)	0.30***	(0.01)	0.22***	(0.02)
Total number of jobs held						
One	ref	-	ref	-	ref	-
Two	0.02	(0.06)	0.005	(0.06)	-0.08	(0.10)
More than two	0.08	(0.07)	0.19**	(0.07)	-0.06	(0.11)
N	389		389		389	
R-squared	0.748		0.781		0.316	

Note: among the 389 participants, 136 had non-working years and 253 did not have non-working years.
Abbreviations: ECA, Epidemiologic Catchment Area study; MMSE, mini–mental state examination; ref, reference.
* $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Table S2.9. The effects of cumulative work activities on change in the MMSE from the Baltimore ECA Wave 3 to Wave 4 (Wave 4 minus Wave 3) among participants who worked throughout the study period (n=253).

	Model 1 Mental demands		Model 2 Social interaction		Model 3 Physical demands	
	b	t	b	t	b	t
Cumulative job exposure (standardized)	0.17	(1.39)	0.19	(-1.38)	-0.06	(-0.78)
MMSE at baseline	-0.63**	(-9.13)	-0.64**	(-9.07)	-0.64**	(-8.90)
Age at baseline	0.003	(0.18)	0.004	(-0.23)	0.005	(-0.26)
Female sex	-0.05	(-0.36)	-0.09	(-0.62)	-0.09	(-0.59)
Race, non-white	-0.28^{+}	(-1.80)	-0.29^{+}	(-1.86)	-0.31*	(-1.98)
Education						
Below high school	ref	-	ref	-	ref	-
High school	0.47^{+}	(1.70)	0.47^{+}	(-1.73)	0.50^{+}	(-1.79)
Above high school	0.46^{+}	(1.76)	0.50^{+}	(-1.95)	0.54*	(-2.06)
Self-rated health at baseline						
Excellent	ref	-	ref	-	ref	-
Good	-0.05	(-0.35)	-0.05	(-0.29)	-0.04	(-0.24)
Fair or poor	-0.02	(-0.06)	-0.05	(-0.18)	-0.04	(-0.12)
Years of follow-up	0.01	(0.08)	-0.01	(-0.04)	0.05	(-0.39)
Total number of jobs held						
One	ref	-	ref	-	ref	-
Two	0.16	(0.99)	0.17	(-1.07)	0.17	(-1.01)
More than two	0.08	(0.38)	0.05	(-0.25)	0.09	(-0.43)
N	253		253		253	
R-squared	0.345		0.345		0.342	

Abbreviations: ECA, Epidemiologic Catchment Area study; MMSE, mini–mental state examination; ref, reference.
$^{+}$ $p<0.1$, * $p<0.05$, ** $p<0.01$.

Table S2.10. The effects of cumulative work activities on change in the Immediate Word Recall task from the Baltimore ECA Wave 3 to Wave 4 (Wave 4 minus Wave 3) among participants who worked throughout the study period (n=253).

	Model 1 Mental demands		Model 2 Social interaction		Model 3 Physical demands	
	b	t	b	t	b	t
Cumulative job exposure (standardized)	0.45	(1.60)	0.54*	(-2.04)	-0.11	(-0.81)
Immediate Word Recall at baseline	-0.68**	(-11.73)	-0.69**	(-11.86)	-0.67**	(-11.62)
Age at baseline	-0.05	(-1.27)	-0.05	(-1.23)	-0.04	(-1.14)
Female sex	0.46	(1.54)	0.36	(-1.13)	0.40	(-1.21)
Race, non-white	-0.62^{+}	(-1.93)	-0.63^{+}	(-1.92)	-0.69*	(-2.18)
Education						
Below high school	ref	-	ref	-	ref	-
High school	0.20	(0.44)	0.18	(-0.41)	0.30	(-0.71)
Above high school	0.42	(0.83)	0.47	(-1.00)	0.66	(-1.47)
Self-rated health at baseline						
Excellent	ref	-	ref	-	ref	-
Good	0.47	(1.53)	0.49	(-1.63)	0.49	(-1.61)
Fair or poor	-0.31	(-0.56)	-0.40	(-0.69)	-0.36	(-0.63)
Years of follow-up	-0.84**	(-4.03)	-0.89**	(-4.20)	-0.74**	(-3.69)
Total number of jobs held						
One	ref	-	ref	-	ref	-
Two	-0.54	(-1.59)	-0.51	(-1.50)	-0.52	(-1.52)
More than two	0.13	(0.35)	0.06	(-0.17)	0.16	(-0.44)
N	253		253		253	
R-squared	0.402		0.404		0.395	

Abbreviations: ECA, Epidemiologic Catchment Area study; ref, reference.
$^{+}$ $p<0.1$, * $p<0.05$, ** $p<0.01$.

Table S2.11. The effects of cumulative work activities on change in the Delayed Word Recall task from the Baltimore ECA Wave 3 to Wave 4 (Wave 4 minus Wave 3) among participants who worked throughout the study period (n=245).

	Model 1 Mental demands		Model 2 Social interaction		Model 3 Physical demands	
	b	t	b	t	b	t
Cumulative job exposure (standardized)	0.25	(0.98)	0.70**	(-3.04)	-0.08	(-0.57)
Delayed Word Recall at baseline	-0.66**	(-10.88)	-0.66**	(-11.14)	-0.66**	(-10.86)
Age at baseline	-0.08*	(-2.10)	-0.08*	(-2.08)	-0.08*	(-1.99)
Female sex	0.56^{+}	(1.81)	0.41	(-1.27)	0.51	(-1.49)
Race, non-white	-0.91**	(-2.62)	-0.80*	(-2.32)	-0.94**	(-2.68)
Education						
Below high school	ref	-	ref	-	ref	-
High school	0.72^{+}	(1.74)	0.56	(-1.39)	0.75^{+}	(-1.92)
Above high school	1.17**	(2.70)	0.98*	(-2.36)	1.28**	(-3.12)
Self-rated health at baseline						
Excellent	ref	-	ref	-	ref	-
Good	0.21	(0.66)	0.24	(-0.77)	0.23	(-0.72)
Fair or poor	-0.49	(-1.00)	-0.56	(-1.10)	-0.52	(-1.04)
Years of follow-up	-0.48*	(-2.55)	-0.60**	(-3.16)	-0.42*	(-2.23)
Total number of jobs held						
One	ref	-	ref	-	ref	-
Two	-0.19	(-0.55)	-0.18	(-0.53)	-0.18	(-0.52)
More than two	0.39	(1.24)	0.27	(-0.88)	0.41	(-1.29)
N	245		245		245	
R-squared	0.395		0.41		0.393	

Abbreviations: ECA, Epidemiologic Catchment Area study; ref, reference.
$^{+}$ $p<0.1$, * $p<0.05$, ** $p<0.01$.

Table S2.12. Effect modification by cumulative social interaction on the association between cumulative physical demands and cognitive changes from the Baltimore ECA Wave 3 to Wave 4 (Wave 4 minus Wave 3) among participants who worked throughout the study period.

	MMSE		Immediate Word Recall		Delayed Word Recall	
	b	t	b	t	b	t
Physical demands	-0.04	(-0.46)	-0.12	(-0.68)	0.06	(0.34)
Social interaction	0.16	(1.11)	0.47	(1.51)	0.75*	(2.57)
Physical demands X Social interaction	0.06	(0.54)	0.31	(1.35)	0.05	(0.22)
Cognitive function at baseline	-0.64**	(-9.03)	-0.69**	(-11.95)	-0.66**	(-11.16)
Age at baseline	0.004	(0.22)	-0.05	(-1.29)	-0.08*	(-2.08)
Female sex	-0.12	(-0.75)	0.27	(0.82)	0.43	(1.29)
Race, non-white	-0.28+	(-1.79)	-0.61^{+}	(-1.93)	-0.82*	(-2.35)
Education						
Below high school	ref	-	ref	-	ref	-
High school	0.46^{+}	(1.65)	0.17	(0.38)	0.59	(1.48)
Above high school	0.48^{+}	(1.79)	0.42	(0.89)	1.01*	(2.47)
Self-rated health at baseline						
Excellent	ref	-	ref	-	ref	-
Good	-0.04	(-0.27)	0.48	(1.58)	0.22	(0.70)
Fair or poor	-0.05	(-0.17)	-0.42	(-0.72)	-0.58	(-1.13)
Years of follow-up	0.01	(0.05)	-0.87**	(-3.98)	-0.62**	(-3.08)
Total number of jobs held						
One	ref	-	ref	-	ref	-
Two	0.17	(1.02)	-0.52	(-1.54)	-0.17	(-0.51)
More than two	0.06	(0.29)	0.09	(0.26)	0.26	(0.84)
N	253		253		245	
R-squared	0.346		0.408		0.411	

Abbreviations: ECA, Epidemiologic Catchment Area study; MMSE, mini–mental state examination; ref, reference.
$^{+}$ $p<0.1$, * $p<0.05$, ** $p<0.01$.

Chapter 3 Appendix Tables

Table S3.1. Items for job demands and job control in the Baltimore ECA study.

Dimension	Item	Question
Job demands		
Physical demands	1	My job requires lots of physical effort.
	2	My work requires rapid and continuous physical activity.
	3	I am often required to move or lift very heavy objects on my job.
	4	My job requires working very hard.
	5	My job requires working very fast.
	6	I am often required to work for long periods with my body in physically awkward positions.
	7	My job involves a lot of repetitive work.
Psychological demands	1-RC	I have enough time to get the job done.
	2-RC	I am free from conflicting demands that others make.
	3-RC	I am not asked to do an excessive amount of work.
Job control		
Decision authority	1	My job allows me to make a lot of decisions on my own.
	2	I have a lot to say about what happens on my job.
	3-RC	On my job, I have very little freedom to decide how I do my work.
Skill discretion	1	I have an opportunity to develop my own special abilities.
	2	My job requires a high level of skill.
	3	My job requires me to be creative.
	4	I get to do a variety of different things on my job.
	5	My job requires that I learn new things.

Abbreviations: ECA, Epidemiologic Catchment Area study; RC, reverse coding.

Table S3.2. Multiple linear regression models of the association between dichotomized job dimensions at the Baltimore ECA Wave 3 and cognitive changes from the Wave 3 to Wave 4 (Wave 4 minus Wave 3).

	MMSE		Immediate Word Recall		Delayed Word Recall	
	b (95% CI)	*p* value	b (95% CI)	*p* value	b (95% CI)	*p* value
Psychological demands						
Base model	-0.19 (-0.44, 0.06)	0.132	-0.23 (-0.65, 0.20)	0.296	-0.07 (-0.51, 0.38)	0.773
Full model	-0.25 (-0.49, 0.00)	0.048	-0.42 (-0.84, 0.00)	0.050	-0.26 (-0.69, 0.18)	0.252
Physical demands						
Base model	-0.24 (-0.48, 0.00)	0.048	-0.53 (-0.93, -0.12)	0.011	-0.52 (-0.94, -0.09)	0.018
Full model	-0.21 (-0.44, 0.03)	0.081	-0.42 (-0.81, -0.02)	0.041	-0.30 (-0.71, 0.11)	0.153
Decision authority						
Base model	-0.24 (-0.49, 0.01)	0.058	-0.60 (-1.04, -0.16)	0.008	-0.31 (-0.78, 0.16)	0.192
Full model	-0.22 (-0.47, 0.04)	0.093	-0.57 (-1.02, -0.13)	0.012	-0.22 (-0.70, 0.25)	0.353
Skill discretion						
Base model	-0.19 (-0.43, 0.06)	0.131	-0.37 (-0.81, 0.07)	0.095	-0.20 (-0.67, 0.28)	0.414
Full model	-0.06 (-0.31, 0.19)	0.629	-0.15 (-0.60, 0.30)	0.504	0.12 (-0.36, 0.60)	0.619

Notes: Base model adjusted for baseline cognitive function.

Full model adjusted for age, sex, race, education, baseline self-rated health status and baseline cognitive function.

Abbreviations: 95% CI, 95% confidence interval; ECA, Epidemiologic Catchment Area study; MMSE, mini-mental state examination.

Table S3.3. Multiple linear regression models of the association between job strain at the Baltimore ECA Wave 3 and change in the MMSE from the Wave 3 to Wave 4 (Wave 4 minus Wave 3) (n=445).

	Base Model		Full Model	
	b (95% CI)	*p* value	b (95% CI)	*p* value
Job strain				
Low strain	ref	-	ref	-
Passive	-0.37 (-0.73, -0.01)	0.045	-0.34 (-0.69, 0.02)	0.062
Active	-0.31 (-0.57, -0.04)	0.025	-0.31 (-0.58, -0.03)	0.027
High strain	-0.47 (-0.78, -0.16)	0.003	-0.46 (-0.77, -0.14)	0.005
Baseline MMSE	-0.64 (-0.77, -0.52)	<0.001	-0.69 (-0.80, -0.58)	<0.001
Age			-0.22 (-0.47, 0.04)	0.092
Female sex			0.04 (-0.21, 0.28)	0.756
Non-white race			-0.41 (-0.66, -0.16)	0.002
Education				
Below high school			ref	-
High school			0.40 (0.03, 0.77)	0.035
Above high school			0.41 (0.05, 0.77)	0.024
Baseline self-rated health				
Excellent			ref	-
Good			0.09 (-0.16, 0.33)	0.485
Fair or poor			0.05 (-0.35, 0.46)	0.793

Notes: Low strain: low psychological and physical demands and high decision authority;
Passive: low psychological and physical demands and low decision authority;
Active: high psychological or physical demands and high decision authority;
High strain: high psychological or physical demands and low decision authority.

Abbreviations: 95% CI, 95% confidence interval; ECA, Epidemiologic Catchment Area study; MMSE, mini-mental state examination; ref, reference.

Table S3.4. Multiple linear regression models of the association between job strain at the Baltimore ECA Wave 3 and change in the Immediate Word Recall task from the Wave 3 to Wave 4 (Wave 4 minus Wave 3) (n=441).

	Base Model		Full Model	
	b (95% CI)	*p* value	b (95% CI)	*p* value
Job strain				
Low strain	ref	-	ref	-
Passive	-1.14 (-1.86, -0.42)	0.002	-1.15 (-1.89, -0.41)	0.002
Active	-0.79 (-1.29, -0.28)	0.002	-0.84 (-1.33, -0.35)	0.001
High strain	-1.06 (-1.66, -0.46)	0.001	-1.09 (-1.69, -0.49)	<0.001
Baseline Immediate Recall	-0.61 (-0.69, -0.53)	<0.001	-0.65 (-0.73, -0.57)	<0.001
Age			-0.54 (-0.96, -0.13)	0.009
Female sex			0.42 (-0.01, 0.84)	0.056
Non-white race			-0.47 (-0.89, -0.04)	0.031
Education				
Below high school			ref	-
High school			0.57 (-0.02, 1.16)	0.057
Above high school			0.79 (0.20, 1.37)	0.009
Baseline self-rated health				
Excellent			ref	-
Good			0.35 (-0.11, 0.82)	0.138
Fair or poor			0.04 (-0.65, 0.72)	0.914

Notes: Low strain: low psychological and physical demands and high decision authority;
Passive: low psychological and physical demands and low decision authority;
Active: high psychological or physical demands and high decision authority;
High strain: high psychological or physical demands and low decision authority.

Abbreviations: 95% CI, 95% confidence interval; ECA, Epidemiologic Catchment Area study; MMSE, mini-mental state examination; ref, reference.

Table S3.5. Multiple linear regression models of the association between job strain at the Baltimore ECA Wave 3 and change in the Delayed Word Recall task from the Wave 3 to Wave 4 (Wave 4 minus Wave 3) (n=428).

	Base Model		Full Model	
	b (95% CI)	*p* value	b (95% CI)	*p* value
Job strain				
Low strain	ref	-	ref	-
Passive	-0.54 (-1.30, 0.22)	0.161	-0.42 (-1.21, 0.38)	0.301
Active	-0.49 (-1.01, 0.03)	0.066	-0.47 (-0.96, 0.02)	0.061
High strain	-0.66 (-1.29, -0.03)	0.041	-0.58 (-1.20, 0.04)	0.067
Baseline Delayed Recall	-0.60 (-0.69, -0.52)	<0.001	-0.67 (-0.76, -0.59)	<0.001
Age			-0.55 (-0.98, -0.13)	0.011
Female sex			0.54 (0.09, 0.98)	0.018
Non-white race			-0.81 (-1.29, -0.34)	0.001
Education				
Below high school			ref	-
High school			0.31 (-0.32, 0.94)	0.330
Above high school			1.04 (0.40, 1.67)	0.001
Baseline self-rated health				
Excellent			ref	-
Good			0.11 (-0.38, 0.60)	0.665
Fair or poor			-0.23 (-0.94, 0.47)	0.514

Notes: Low strain: low psychological and physical demands and high decision authority;
Passive: low psychological and physical demands and low decision authority;
Active: high psychological or physical demands and high decision authority;
High strain: high psychological or physical demands and low decision authority.

Abbreviations: 95% CI, 95% confidence interval; ECA, Epidemiologic Catchment Area study; MMSE, mini-mental state examination; ref, reference.

Table S3.6. Sensitivity analysis of the association between job strain at the Baltimore ECA Wave 3 and cognitive changes from the Wave 3 to Wave 4 (Wave 4 minus Wave 3). Job control is composed of decision authority and skill discretion.

	MMSE (n=445)		Immediate Word Recall (n=441)		Delayed Word Recall (n=428)	
	b (95% CI)	*p* value	b (95% CI)	*p* value	b (95% CI)	*p* value
Base Model						
Low strain	ref	-	ref	-	ref	-
Passive	-0.47 (-0.86, -0.08)	0.019	-0.56 (-1.33, 0.22)	0.158	-0.15 (-0.92, 0.63)	0.712
Active	-0.32 (-0.58, -0.06)	0.016	-0.57 (-1.06, -0.07)	0.024	-0.33 (-0.85, 0.19)	0.208
High strain	-0.49 (-0.81, -0.17)	0.003	-0.91 (-1.54, -0.27)	0.005	-0.60 (-1.27, 0.06)	0.076
Full Model						
Low strain	ref	-	ref	-	ref	-
Passive	-0.38 (-0.78, 0.02)	0.060	-0.42 (-1.18, 0.34)	0.275	0.11 (-0.68, 0.89)	0.793
Active	-0.32 (-0.58, -0.05)	0.019	-0.60 (-1.08, -0.11)	0.017	-0.31 (-0.80, 0.18)	0.218
High strain	-0.43 (-0.75, -0.11)	0.008	-0.84 (-1.48, -0.20)	0.010	-0.43 (-1.10, 0.24)	0.211

Notes: Job control is a composed of decision authority and skill discretion.

Low strain: low psychological and physical demands and high job control;

Passive: low psychological and physical demands and low job control;

Active: high psychological or physical demands and high job control;

High strain: high psychological or physical demands and low job control.

Base model adjusted for baseline cognitive function.

Full model adjusted for age, sex, race, education, baseline self-rated health status and baseline score of the cognitive measure.

Abbreviations: 95% CI, 95% confidence interval; ECA, Epidemiologic Catchment Area study; MMSE, mini-mental state examination; ref, reference.

Table S3.7. Sensitivity analysis of the association between job strain (psychological demands) at the Baltimore ECA Wave 3 and cognitive changes from the Wave 3 to Wave 4 (Wave 4 minus Wave 3).

	MMSE (n=445)		Immediate Word Recall (n=441)		Delayed Word Recall (n=428)	
	b (95% CI)	*p* value	b (95% CI)	*p* value	b (95% CI)	*p* value
Base Model						
Low strain	ref	-	ref	-	ref	-
Passive	-0.37 (-0.69, -0.05)	0.024	-0.67 (-1.23, -0.11)	0.020	-0.33 (-0.93, 0.26)	0.273
Active	-0.29 (-0.60, 0.02)	0.069	-0.26 (-0.78, 0.25)	0.319	-0.07 (-0.62, 0.47)	0.790
High strain	-0.34 (-0.69, 0.01)	0.056	-0.74 (-1.39, -0.10)	0.023	-0.35 (-1.04, 0.33)	0.307
Full Model						
Low strain	ref	-	ref	-	ref	-
Passive	-0.36 (-0.67, -0.05)	0.024	-0.64 (-1.21, -0.07)	0.027	-0.20 (-0.81, 0.41)	0.514
Active	-0.35 (-0.65, -0.05)	0.024	-0.46 (-0.96, 0.04)	0.072	-0.24 (-0.76, 0.28)	0.364
High strain	-0.37 (-0.73, 0.00)	0.051	-0.91 (-1.55, -0.27)	0.006	-0.48 (-1.15, 0.20)	0.164

Notes: Low strain: low psychological demands and high decision authority;
Passive: low psychological demands and low decision authority;
Active: high psychological demands and high decision authority;
High strain: high psychological demands and low decision authority.

Base model adjusted for baseline cognitive function.

Full model adjusted for age, sex, race, education, baseline self-rated health status and baseline score of the cognitive measure.

Abbreviations: 95% CI, 95% confidence interval; ECA, Epidemiologic Catchment Area study; MMSE, mini-mental state examination; ref, reference.

Table S3.8. Sensitivity analysis of the association between job strain (physical demands) at the Baltimore ECA Wave 3 and cognitive changes from the Wave 3 to Wave 4 (Wave 4 minus Wave 3).

	MMSE (n=445)		Immediate Word Recall (n=441)		Delayed Word Recall (n=428)	
	b (95% CI)	*p* value	b (95% CI)	*p* value	b (95% CI)	*p* value
Base Model						
Low strain	ref	-	ref	-	ref	-
Passive	-0.13 (-0.44, 0.17)	0.387	-0.85 (-1.47, -0.23)	0.007	-0.43 (-1.08, 0.22)	0.195
Active	-0.16 (-0.45, 0.13)	0.291	-0.72 (-1.21, -0.24)	0.003	-0.61 (-1.13, -0.09)	0.021
High strain	-0.54 (-0.94, -0.14)	0.008	-0.97 (-1.59, -0.35)	0.002	-0.74 (-1.39, -0.10)	0.024
Full Model						
Low strain	ref	-	ref	-	ref	-
Passive	-0.11 (-0.42, 0.19)	0.476	-0.90 (-1.54, -0.25)	0.007	-0.40 (-1.07, 0.26)	0.234
Active	-0.13 (-0.40, 0.15)	0.375	-0.66 (-1.13, -0.19)	0.006	-0.44 (-0.92, 0.04)	0.075
High strain	-0.48 (-0.87, -0.09)	0.016	-0.81 (-1.44, -0.19)	0.011	-0.42 (-1.05, 0.22)	0.196

Notes: Low strain: low physical demands and high decision authority;
Passive: low physical demands and low decision authority;
Active: high physical demands and high decision authority;
High strain: high physical demands and low decision authority.

Base Model adjusted for baseline cognitive function.

Full Model adjusted for age, sex, race, education, baseline self-rated health status and baseline score of the cognitive measure.

Abbreviations: 95% CI, 95% confidence interval; ECA, Epidemiologic Catchment Area study; MMSE, mini-mental state examination; ref, reference.

Table S3.9. One-way analysis of variance of the Nam-Powers-Terrie Occupational Status Scores by job strain quadrants.

Row mean-column mean	Low-strain	Passive	Active
Passive	-14.32**	-	-
Active	-7.87*	6.46	-
High-strain	-15.80***	-1.47	-7.93*

Notes: Low strain: low psychological and physical demands and high decision authority;
Passive: low psychological and physical demands and low decision authority;
Active: high psychological or physical demands and high decision authority;
High strain: high psychological or physical demands and low decision authority.

* p <0.05, ** p <0.01, *** p <0.001. p values were from the Bonferroni tests.

Chapter 4 Appendix Tables

Table S4.1. Details of selected HRS questions used in the study.

Variable	Question	Response
History of medical conditions		
Diabetes	Has a doctor ever told you that you have diabetes or high blood sugar?	Yes; No.
Psychiatric problems	Have you ever had or has a doctor ever told you that you have any emotional, nervous, or psychiatric problems?	Yes; No.
Heart disease	Has a doctor ever told you that you had a heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems?	Yes; No.
Labor force status		
	Are you working now, temporarily laid off, unemployed and looking for work, disabled and unable to work, retired, a homemaker, or what? (respondents were allowed to choose all that apply)	Working now; Unemployed and looking for work; Temporarily laid off, on sick or other leave; Disabled; Retired; Homemaker; Other (specify).
	Are you doing any work for pay at the present time?	Yes; No.
	Have you been doing anything to find work during the last four weeks?	Yes; No.
	At this time do you consider yourself partly retired, completely retired, or not retired at all?	Completely retired; Partly retired; Not retired at all; Question not relevant to R, doesn't work for pay or is homemaker, etc.
Why stopped previous job		
	Why did you leave that employer? Did the business close, were you laid off or let go, did you leave to take care of family members, or what? Why did you stop working at that business?	Business closed; Laid off/Let go; Poor health/Disabled; family care; Better job; Quit; Retired; R (family moved); Sold business (own)/closed business (own)/gave business to another person; Strike; Divorce/Separation; Handed over responsibilities to other family members; Transportation; distance to work; To travel; Early retirement incentive/offer; Financially advantageous for R to not work (tax/IRS/Social Security reasons).

Abbreviation: HRS, Health and Retirement Study.

Table S4.2. Sensitivity analysis of a broader definition of insomnia (n=5746). No job exit is the reference group.

	Base Model		Full Model	
	Job Exit due to Poor Health RRR (95% CI)	Job Exit due to Other Reasons RRR (95% CI)	Job Exit due to Poor Health RRR (95% CI)	Job Exit due to Other Reasons RRR (95% CI)
Insomnia				
None	ref	ref	ref	ref
1-2	1.68* (1.05, 2.68)	1.24 (0.98, 1.57)	1.38 (0.83, 2.29)	1.18 (0.92, 1.5)
3-4	2.84*** (1.73, 4.66)	1.36* (1.01, 1.83)	1.65 (0.88, 3.08)	1.20 (0.88, 1.63)
Age				
50-61	ref	ref	ref	ref
62-70	1.11 (0.82, 1.50)	2.74*** (2.24, 3.35)	1.02 (0.71, 1.45)	2.25*** (1.76, 2.88)
Female	0.99 (0.73, 1.36)	1.27* (1.02, 1.58)	1.01 (0.73, 1.39)	1.18 (0.94, 1.49)
Race				
White	ref	ref	ref	ref
Black	1.78** (1.25, 2.53)	1.06 (0.79, 1.42)	1.76** (1.18, 2.63)	1.08 (0.81, 1.46)
Other	1.01 (0.46, 2.20)	0.74 (0.47, 1.15)	0.91 (0.42, 1.97)	0.76 (0.48, 1.20)
Education				
Below high school	2.99*** (1.80, 4.98)	1.68** (1.23, 2.29)	1.86* (1.02, 3.39)	1.68** (1.22, 2.31)
High school	1.57* (1.11, 2.21)	1.29 (1.00, 1.67)	1.31 (0.91, 1.86)	1.31* (1.01, 1.70)
Above high school	ref	ref	ref	ref
Household Income				
Below Q2	2.58*** (1.65, 4.04)	1.04 (0.82, 1.32)	1.46 (0.91, 2.34)	0.90 (0.70, 1.16)
Between Q2 and Q3	1.22 (0.79, 1.87)	0.89 (0.67, 1.19)	0.93 (0.60, 1.45)	0.84 (0.63, 1.13)
Above Q3	ref	ref	ref	ref
Self-rated health status				
Above good			ref	ref
Good			1.49 (0.89, 2.50)	1.17 (0.94, 1.47)
Below good			3.22** (1.74, 5.95)	1.16 (0.82, 1.64)
Depressive symptoms				
None			ref	ref
1-2			1.23 (0.75, 2.04)	1.13 (0.87, 1.45)
3-4			1.39 (0.85, 2.29)	1.02 (0.68, 1.55)

History of medical conditions		
Psychiatric problems	2.06** (1.35, 3.13)	1.40* (1.03, 1.92)
Diabetes	2.04** (1.33, 3.13)	1.25 (0.95, 1.65)
Heart disease	1.01 (0.61, 1.66)	1.08 (0.80, 1.46)
Baseline work status		
Full-time	ref	ref
Part-time	1.74* (1.14, 2.65)	1.65*** (1.26, 2.16)
Partly retired	2.91*** (1.77, 4.79)	2.04*** (1.54, 2.70)
Job requiring much physical effort		
All or almost of the time	1.79 (0.95, 3.37)	0.91 (0.67, 1.25)
Most of the time	1.58 (0.75, 3.34)	0.97 (0.71, 1.33)
Some of the time	1.25 (0.65, 2.37)	0.93 (0.72, 1.20)
None or almost none	ref	ref
Job involving much stress		
Strongly agree	2.03 (0.84, 4.93)	1.01 (0.67, 1.51)
Agree	1.68 (0.7, 4.00)	0.86 (0.58, 1.26)
Disagree	1.66 (0.69, 4.00)	0.93 (0.65, 1.32)
Strongly disagree	ref	ref

Abbreviations: 95% CI, 95% confidence interval; Q2, the second quartile; Q3, the third quartile; ref, reference; RRR, relative risk ratio.
*p<0.05, **p<0.01, ***p<0.001.

Table S4.3. Sensitivity analysis of exiting full-time employment (n=3717). No full-time job exit is the reference group.

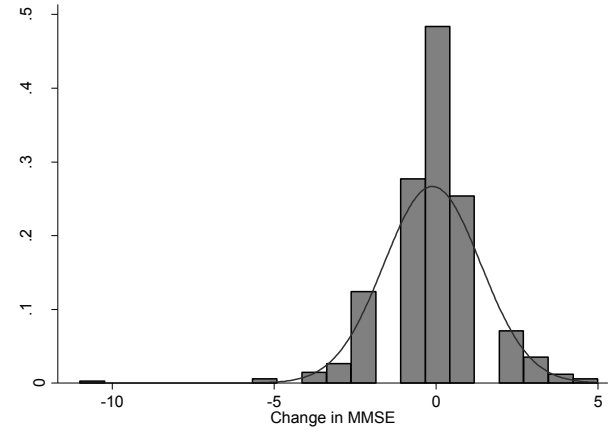
	Base Model		Full Model	
	Job Exit due to Poor Health RRR (95% CI)	Job Exit due to Other Reasons RRR (95% CI)	Job Exit due to Poor Health RRR (95% CI)	Job Exit due to Other Reasons RRR (95% CI)
Insomnia				
None	ref	ref	ref	ref
1-2	1.95** (1.27, 2.97)	1.07 (0.82, 1.41)	1.38 (0.90, 2.12)	1.01 (0.76, 1.34)
3-4	2.12 (0.88, 5.12)	1.29 (0.81, 2.05)	1.12 (0.46, 2.74)	1.14 (0.68, 1.92)
Age				
50-61	ref	ref	ref	ref
62-70	1.35 (0.81, 2.25)	3.26*** (2.58, 4.12)	1.51 (0.89, 2.58)	3.28*** (2.57, 4.18)
Female	1.03 (0.63, 1.68)	1.34 (0.99, 1.80)	1.21 (0.74, 1.96)	1.35* (1.01, 1.80)
Race				
White	ref	ref	ref	ref
Black	2.30** (1.41, 3.76)	1.03** (0.70, 1.52)	1.97** (1.22, 3.17)	1.04 (0.71, 1.52)
Other	1.28 (0.61, 2.71)	0.85 (0.49, 1.49)	1.15 (0.52, 2.52)	0.86 (0.48, 1.53)
Education				
Below high school	2.31* (1.23, 4.35)	2.08** (1.36, 3.16)	1.51 (0.70, 3.27)	2.06** (1.37, 3.10)
High school	1.24 (0.77, 2.00)	1.26 (0.92, 1.72)	0.96 (0.57, 1.6)	1.26 (0.92, 1.72)
Above high school	ref	ref	ref	ref
Household Income				
Below Q2	2.09* (1.19, 3.67)	0.80 (0.57, 1.12)	1.36 (0.76, 2.44)	0.75 (0.52, 1.06)
Between Q2 and Q3	0.97 (0.55, 1.72)	0.68* (0.48, 0.96)	0.76 (0.44, 1.32)	0.65* (0.46, 0.93)
Above Q3	ref	ref	ref	ref
Self-rated health status				
Above good			ref	ref
Good			1.41 (0.74, 2.72)	1.00 (0.75, 1.33)
Below good			3.10** (1.55, 6.21)	1.27 (0.85, 1.91)
Depressive symptoms				
None			ref	ref
1-2			1.45 (0.80, 2.60)	1.07 (0.81, 1.41)
3-4			1.30 (0.67, 2.50)	1.18 (0.78, 1.80)

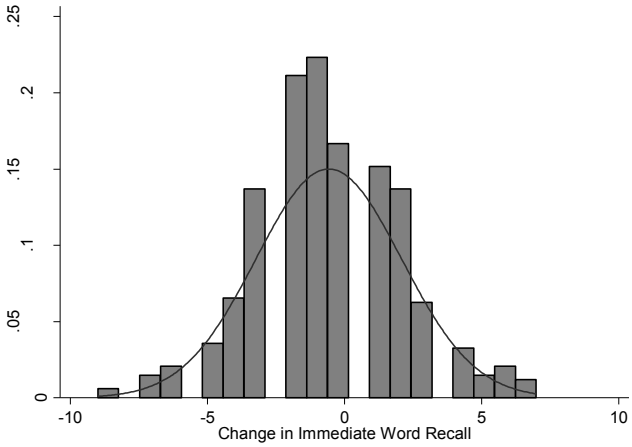
History of medical conditions		
Psychiatric problems	2.62** (1.36, 5.05)	1.41 (0.96, 2.09)
Diabetes	2.27** (1.32, 3.92)	1.24 (0.87, 1.78)
Heart disease	1.23 (0.68, 2.23)	1.06 (0.71, 1.57)
Job requiring much physical effort		
All or almost of the time	2.50* (1.19, 5.24)	0.91 (0.64, 1.28)
Most of the time	1.65 (0.60, 4.53)	0.82 (0.55, 1.21)
Some of the time	1.70 (0.78, 3.68)	1.01 (0.78, 1.30
None or almost none	ref	ref
Job involving much stress		
Strongly agree	2.92 (0.25, 33.64)	1.03 (0.51, 2.06)
Agree	4.02 (0.37, 43.28)	1.01 (0.52, 1.94)
Disagree	3.16 (0.28, 35.21)	1.19 (0.67, 2.12)
Strongly disagree	ref	ref

Abbreviations: 95% CI, 95% confidence interval; Q2, the second quartile; Q3, the third quartile; ref, reference; RRR, relative risk ratio.
*p<0.05, **p<0.01, ***p<0.001.

Chapter 3 Appendix Figures

Figure S3.1. Distribution of cognitive changes from the Baltimore ECA Wave 3 to Wave 4 assessed by the MMSE, Immediate Word Recall and Delayed Word Recall tasks in the study sample (n=445).





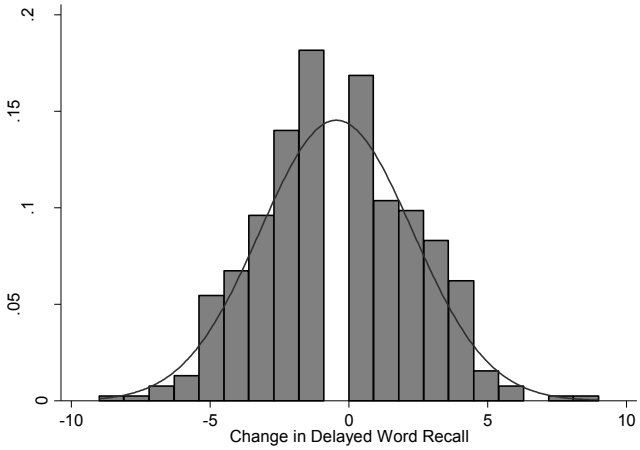


Figure S3.2. Distribution of the four continuous job dimensions in the study sample (n=445).

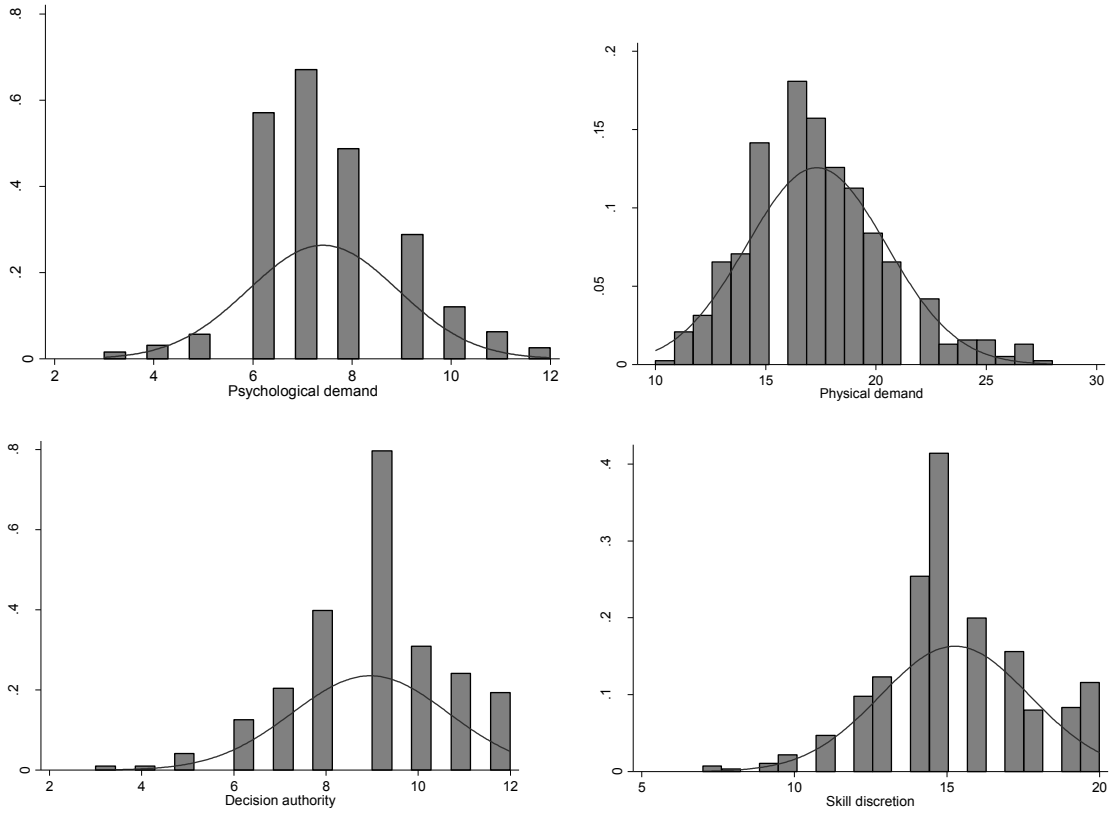
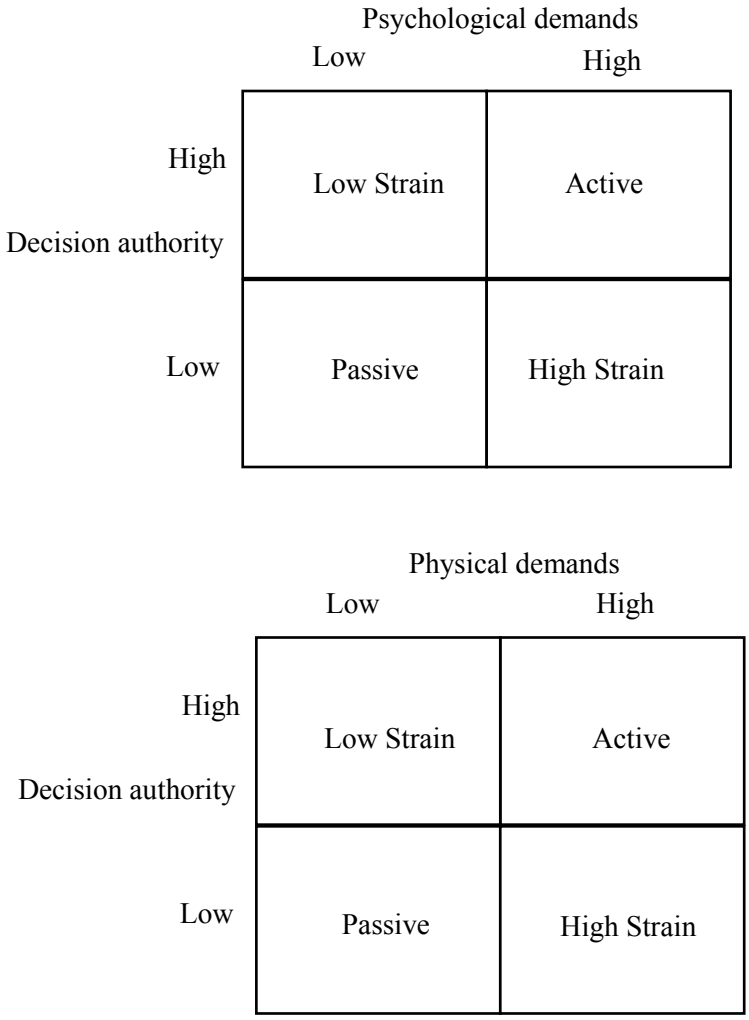
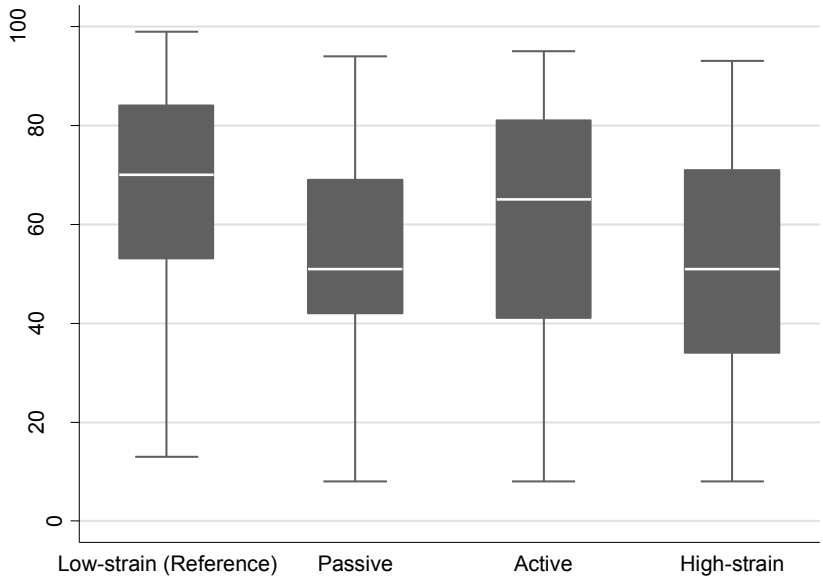


Figure S3.3. Job strain by type of job demands.



Note: The figures were developed based on the job demand-control model (Karasek, 1979).

Figure S3.4. Distribution of the Nam-Powers-Terrie Occupational Status Scores by job strain quadrants in the study sample (n=445).



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RESEAERCH EXPERIENCE

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• Manipulated the longitudinal occupation data from the Health and Retirement Study (HRS), and developed a public-use data file on job characteristics and cumulative occupational exposures by linking the Occupational Information Network database to the HRS;
• Conducted analyses on cumulative effects of occupational exposures on health and healthcare utilization later in life using the HRS and HRS-linked Medicare data.

Research Assistant March 2014- February 2016
Johns Hopkins Bloomberg School of Public Health, Department of Health Policy and Management, Baltimore, MD
• Developed an NIH grant proposal on the economic burden of undiagnosed dementia in the US older adult population, and assisted with the grant submission;
• Conducted literature search and co-authored a literature review on cardiovascular health disparities;
• Manipulated data for a project on cardiovascular health disparities.

Research Assistant September 2013- December 2015
Johns Hopkins Bloomberg School of Public Health, Department of International Health, Baltimore, MD
• Conducted analyses on social determinants of maternal and adolescent health using data from the National Comorbidity Survey Replication Adolescent Supplement and the Boston Birth Cohort study;
• Drafted manuscripts for publication.

Research Assistant June 2011- May 2012
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• Analyzed data for projects on liver cancer research;
• Drafted manuscripts for publication and made conference posters.

Research Assistant August 2009- June 2010
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• Developed and managed databases for clinical research projects;
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• Conducted literature search and assisted with literature review on patient safety indicators for chronic kidney disease.

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• Conducted program evaluation for the Chronic Disease Self-Management Program (CDSMP);
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TEACHING EXPERIENCE

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Lead Teaching Assistant 2015
Johns Hopkins Bloomberg School of Public Health, Department of Health Policy and Management, Baltimore, MD
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Teaching Assistant 2012
Johns Hopkins Bloomberg School of Public Health, Department of Biostatistics, Baltimore, MD
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PUBLICATIONS

Dong, L., Gallo, J.J. (2015). Prevention of Depression in Medical Conditions. In Okereke, O. I. (Ed.) Prevention of Late-Life Depression Current Clinical Challenges and Priorities (pp.33-56). New York, NY: Humana Press.

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WORKS IN PROGRESS

Dong, L, Agnew, J., Mojtabai, R., Surkan, P.J., Spira A.P. Insomnia as a Predictor of Job Exit among Middle-Aged and Older Adults.

Dong, L, Eaton, W.W., Agnew, J., Spira, A.P., Surkan, P.J., Mojtabai, R. Cumulative Effects of Work Activities on Cognitive Decline: Linking Data from the Occupational Information Network to the Baltimore Epidemiologic Catchment Area Follow-up Study.

Dong, L, Eaton, W.W., Agnew, J., Spira, A.P., Surkan, P.J., Mojtabai, R. Job Strain at Midlife and Cognitive Decline Later in Life: Evidence from the Baltimore Epidemiologic Catchment Area Follow-up Study.