

Older Adult Injury Risk Assessment in the Driving and Occupational Environments

Laura Fraade-Blanar

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Reading Committee:

Beth E. Ebel, Chair

Jeanne M. Sears

Kwun Chuen G. Chan

Paul K. Crane

Program Authorized to Offer Degree:

Health Services

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University of Washington

Abstract

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Laura Fraade-Blanar

Chair of the Supervisory Committee:  
Beth E. Ebel, Adjunct Professor  
Health Services

The United States is experiencing a demographic transition as the population of older adults increases. Many older adults continue to work and drive to support and sustain economic and social health. However, for some, the aging process can be accompanied by declines in cognitive and physical capacity which may increase the risk of a collision or injury. This dissertation examined the association between cognitive and physical function and the risk of motor vehicle collision or occupational injury among older adults.

Chapters 2 and 3 explored crash risk associated with cognitive decline and dementia among older drivers. By 2024, 25% of US drivers will be over the age of 65 years. The fatal crash involvement rate among older drivers begins to increase after age 65. Driving simulator and road test studies found lower driving performance associated with lower cognitive function.

In chapter 2, we conducted a retrospective cohort study to examine the association between incremental differences in cognition and crash risk among older drivers without dementia. Cognitive function was measured using the Cognitive Abilities Screening Instrument-Item Response Theory (CASI-IRT) score. Older adult participants were drawn from the Group Health Adult Changes in Thought (ACT) Study. ACT records were merged with Washington State crash and licensure records. Eligible participants were age 65 and above and had an active driver's license. We used a generalized estimating equation model with robust standard errors, clustered

on the individual. Among ACT study participants, there were 23.4 police-reported crashes per 1000 driver-years. The adjusted incident risk ratio of crash, comparing a higher CASI-IRT score to a score one unit lower was 1.28 (95% CI: 1.08, 1.51). The change in CASI-IRT was not significantly associated with an increase in crash risk.

Chapter 3 explored the hazard rate of a crash for older licensed drivers with diagnosed dementia compared to older adults without diagnosis of dementia. This retrospective cohort study used longitudinal clinical and pharmacy records for Group Health members age 65 to 79. Participant records were merged with Washington State police-reported crash records and licensure data from the Washington State Department of Licensing. We assessed the association between diagnosed dementia and crash risk using survival analysis. Dementia was modeled as a time-varying covariate. The overall crash rate was 14.7 per 1,000 driver-years. In a multivariate model, the hazard ratio of crash among those with dementia was 0.56 (95% CI: 0.33, 0.95) relative to older adults without diagnosed dementia.

Chapter 4 focused on the association between the physical health of older workers in relation to the job requirements needed for employment and the risk of occupational injury. For this retrospective cohort study, job demands were assessed both objectively (using data derived from an expert panel available through the Occupational Information Network (O\*NET)), and subjective assessment of job demand skills as reported by the older worker. Participants were drawn from the Health and Retirement study, a longitudinal national survey composed of biennial interviews age 50 and above. Analyses employed a modified Poisson regression model with robust standard errors, clustered on the individual. Overall, the rate of reporting any injury was 22 per 1000 person-years. Individuals with higher objective or subjective physical job demands were at greater risk of an occupational injury. When physical job demands were high, a

mismatch between physical ability and job demands was associated with a two-to-three-fold higher risk of occupational injury.

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## **TABLE OF CONTENTS**

Abstract	page 3
Acknowledgements	page 6
Chapter I: Introduction	page 8
Chapter 2 Cognitive decline and older driver crash risk	page 18
Chapter 3: Diagnosed dementia and the risk of motor vehicle crash among older drivers	page 36
Chapter 4: Relating older worker's injuries to the mismatch between physical ability and job demands	page 49
Chapter 5: Conclusion	page 72

## **CHAPTER 1: INTRODUCTION**

### **BACKGROUND**

#### **Older adults in the United States**

The population of the United States is aging. Between 2012 and 2050, the number of older adults over age 65 years is projected to grow by 100%, reaching 83.7 million. Comparatively, the total United States population is projected to increase only 27% between 2012 and 2050.<sup>1</sup> This shift from a population pyramid to a population rectangle,<sup>2</sup> will have a widespread impact on the nation's economy and health needs<sup>1-3</sup>

#### **Cognitive health and motor vehicle crash risk**

The rate of passenger vehicle fatal crash involvement per 100 million vehicle miles traveled increases starting at age 65-69. Drivers age 85 and above had the highest rate of any age group.<sup>4</sup> One proposed risk factor is cognitive decline or dementia.<sup>5-9</sup> Dementia is an umbrella term for a group of diseases and conditions wherein nerve cells in the brain die or no longer function normally.<sup>10</sup> Cognitive function is a continuum with varying severity of symptoms and underlying pathology. States range from normal aging to prodromal dementia to diagnosed mild dementia to severe dementia.<sup>10-12</sup>

One of nine adults over age 65 has Alzheimer's disease, the most common type of dementia. The number of individuals with dementia is projected to rise as the US population ages.<sup>13</sup> Between 1990 to 2010, the Disability Adjusted Life Years lost as a consequence of dementia increased by 79%.<sup>14</sup>

Guidelines as to when individuals with cognitive decline should stop driving are vague. The National Highway Traffic Safety Administration advises eventual cessation.<sup>15</sup> Department of

Motor Vehicle guidelines vary by state.<sup>15</sup> Washington State has no reporting guidelines for older drivers or physicians,<sup>15</sup> however Oregon suggests ending driving when symptoms are "severe and uncontrollable."<sup>16</sup> Research papers aimed at care providers and non-technical articles for families and drivers emphasize the importance of tapering and eventual cessation as cognition declines, but provide limited guidance as to when specifically to stop driving.<sup>5,17-28</sup> This heterogeneity reflects the lack of evidence-based guidelines for predicting driving risk among older adults.

### **Occupational injury and older workers**

As the population of older adults has increased, the number of US older workers has grown in absolute numbers and as a percentage of the total working population.<sup>29,30</sup> In 2000, 18.2 million older adults were active in the labor force. By 2025, older adult worker participation is projected to reach 31.9 million.<sup>31</sup> This is a result of demographic, health, and social factors, including older eligibility dates for retirement benefits, economic and financial insecurity, and improvements to older adult health and longevity.<sup>32</sup>

Employment provides a livelihood, personal satisfaction, self-autonomy, and self-sufficiency. Loss of the ability to work or forced early retirement due to an injury has far-reaching personal and economic impacts as well as significant costs to society and the economy.<sup>33</sup> The most common reason for an older adult to exit the workforce before age 60 is physical disability, especially among low-wage earners.<sup>34</sup>

### **STUDY QUESTIONS AND CONCEPTUAL MODELS**

**Overarching research question: How do cognitive and physical risk factor associated with the road traffic and occupational environments impact crash and injury risk among older adults?**

This dissertation explored two determinants of older adult quality of life and independence: the ability to safely participate in the workforce and the ability to drive a motor vehicle. Investigating factors related to older adult wellbeing generated results that can be used to inform evidence-based guidelines for healthy aging in the occupational and vehicular settings.

**Aim A: Pre-dementia cognitive decline and older driver (age 65+) crash risk**

Research aims: (1) Examine the association between cognitive function and crash risk among drivers age 65 and above without dementia among a cohort of older adults, and (2) Assess the association between change in cognition function and crash risk.

To answer these questions, we examined the association between crash risk and cognitive function as measured by the Cognitive Abilities Screening Instrument (CASI) from the Adult Changes in Thought (ACT) study.<sup>35</sup> The CASI is an extended version of the commonly used Mini-Mental State Examination (MMSE).<sup>36</sup> We also assessed the impact of a change in CASI score from the previous to the most recent ACT visit on crash risk.

Conceptual model (figure 1.1): We developed a model to explore the relationship between cognitive state and motor vehicle crash risk in a longitudinal cohort study. The model was based on a safe driving and health status model developed by Anstey, Wood, et. al.<sup>8</sup> This model emphasized the multi-factorial nature of older adult health as well as self-monitoring and regulation in influencing driving behavior.<sup>8</sup> Portions of the conceptual model from the Advanced

Cognition Training for Independent and Vital Elderly (ACTIVE) study were also included, chiefly socio-demographic factors and physical function.<sup>37</sup>

Arrows at the top and bottom of the model represent the passage of time. The model contained time-varying and non-time-varying factors in relation to capacity to drive. Non-time-varying covariates included, education and sex, which are associated with crash risk.<sup>38,39</sup> Time-varying covariates included vision, hearing, prescription medication use, comorbidities, physical function, depression, age, and cognitive function.

Vision is a key requirement for driving ability. Generally studies found an association between crash risk and eyesight measures, including visual acuity, useful field of view/field loss, and contrast sensitivity.<sup>8,40-42</sup>

The risk model included prescription medication classes previously demonstrated to be associated with an increase in motor vehicle crash risk<sup>15,43</sup> Some medical conditions such as cardiovascular disease and musculoskeletal disabilities have also been shown to increase crash risk.<sup>39,44-47</sup>

The conceptual model included measures of physical function. Muscle strength, balance, endurance, etc., all can impact ability to drive safely and observe the surrounding environment, although research has been ambivalent about significance.<sup>8,38,39</sup>

Age is another time-varying predictor. Previous studies have found age to be a strong predictor of crash risk, even when health and physical function were taken into account.<sup>8,39,44</sup>

The chief relationship involved cognitive health and crash risk. Cognitive state includes reaction time, attention and focus, ability to plan and coordinate cognitive activity to motor responses, and short-term/long-term memory,<sup>5-9</sup> all of which influence capacity to drive.

No clinical exam, procedure, or laboratory test is widely accepted specifically to evaluate cognition specific to the driving task.<sup>17</sup> Our study used the CASI score, a clinician-reported measure.<sup>35,48</sup> No previous published study has examined the relationship between cognitive function as measured by the CASI and crash risk.

Regarding intermediary outcomes, previous studies have found links between self-regulation and a number of covariates: vision,<sup>49</sup> cognition,<sup>50,51</sup> comorbidities,<sup>52</sup> and sex.<sup>51,52</sup> Data on monitoring, self-regulation, and modifying habits and data on driving exposure were not available, although other research showed monitoring, self-regulation, modifying habits and exposure to be influenced by cognitive state and health factors.<sup>6,8,15,27,52-58</sup> All of these factors may come together to influence crash risk.

### **Aim B: Older driver (age 65+) crash risk and diagnosed dementia**

Research aim: (1) Assess the impact of diagnosed dementia on motor vehicle crash risk among licensed individuals aged 65-79 years.

We assessed the hazard rate of a crash for older licensed drivers with diagnosed dementia compared to those without a diagnosis of dementia.

#### Conceptual model:

Aim B relied upon the same conceptual model as described in Figure 1.1 above. The chief difference in the execution of Aim B lay in the cognitive health measure. Cognition lies along a continuum ranging from normal aging to dementia. Stages represent differences in presence and degree of symptoms and in the underlying neuronal damage to the brain.<sup>10,11</sup> Individuals may not move linearly along this spectrum or progress from one stage to the next.<sup>11,59-61</sup> Aim A examined

incremental differences in cognition from normal aging through prodromal dementia; Aim B bifurcated the spectrum so that normal aging through prodromal dementia was compared to mild through severe diagnosed dementia.

In addition, although potential confounders, data on education, physical function, hearing, and vision were lacking in the dataset used for Aim B.

**Aim C: Older worker (age 50+) injury risk associated with health and workplace factors**

Research aims: (1) Determine the degree to which subjective or objective job demands were associated with injury risk among older workers, (2) Compare subjective and objective job demands in predicting risk of injury, and (3) Explore via interaction the effects of a mismatch between an older worker's self-reported physical ability and job demands (measured subjectively or objectively) and the risk of occupational injury.

We examined the impact of job demands and physical ability on the odds of occupational injury among older workers. Within job types, health conditions may be associated with the ability to safely perform one's work. For example, an individual with weak muscle strength may be at increased risk of injury if their job requires heavy lifting. Job demands were assessed in two ways: 1) subjectively, according to worker report, and 2) objectively, according to a classification system (O\*NET) based upon expert task assessment. This analysis examined the association between objective and subjective job demands, workers' physical ability, and the risk of occupational injury.

Conceptual model (figure 1.2): the conceptual model for Aim C was a combination of the reasoned action approach put forth by Dr. Martin Fishbein,<sup>62</sup> the WHO model for occupational musculoskeletal injuries,<sup>63</sup> and the WHO Healthy Workplace model<sup>64</sup> The latter two were chosen for their emphasis on occupational health and provided some of the content. The WHO occupational musculoskeletal injuries model described the relationship between the workplace and the individual worker.

The reasoned action model provided the overall scaffolding on which this model was constructed. The theory of reasoned action was chosen as it incorporates the worker's intentions and beliefs as well as the role of external factors The model described worker intended actions as being shaped by attitudes, social norms, and beliefs about self-efficacy.<sup>62,65</sup> As reflected in the model, the intention to avoid occupational injury was one motivator, however injury risk is also influenced by other factors, only some of which were under the worker's control.

The "occupation and industry" box represented the objective demands required in a particular occupation or industry. There were two arrows representing associations between "occupation and industry" box and other factors. The first arrow indicates the relationship between occupation and injury, as some industries such as mining and logging have greater injury risks. The second double arrow represented the interaction between objective job demands and the worker's physical ability. For example, an individual with weak muscle strength may be at increased risk of injury if her job required heavy lifting.

Subjective occupational demands were assessed by the self-rated statements from each respondent. In the Health and Retirement Survey (HRS), respondents were asked about the requirements of their job, e.g. lifting heavy loads. As with objective job demands, the interaction

between subjectively-measured job demands and health status is was represented by a double arrow.

Within the human factors section, health state was defined by age, hearing, eyesight, and health state including comorbidities and functional measures (e.g., ability to climb a set of stairs). Aging has consequences related to physical health, senses, and cognition.<sup>34,66-71</sup> For most older adults, vision declines with advancing age, as cataracts, glaucoma, and macular degeneration increase in incidence. Visual changes associated with aging make it harder for an older driver to see objects, worsen night vision and may erode depth perception.<sup>66</sup> Hearing was also of concern—23% of adults age 65 to 75 have age-related hearing loss.<sup>71</sup> This can affect hearing safety signals and instructions.<sup>66</sup> Changes in the inner ear also affect balance,<sup>72</sup> which can result in falls. Diminished senses could translate into increased injury risk.<sup>73</sup>

## **SUMMARY**

This dissertation examined older adult injury risk in the occupational and vehicular environments. Results from these studies aimed to incrementally advance the science of injury prevention for older adults.

Figure 1.1: Conceptual model for Aim A and B: Cognitive function and older driver crash risk

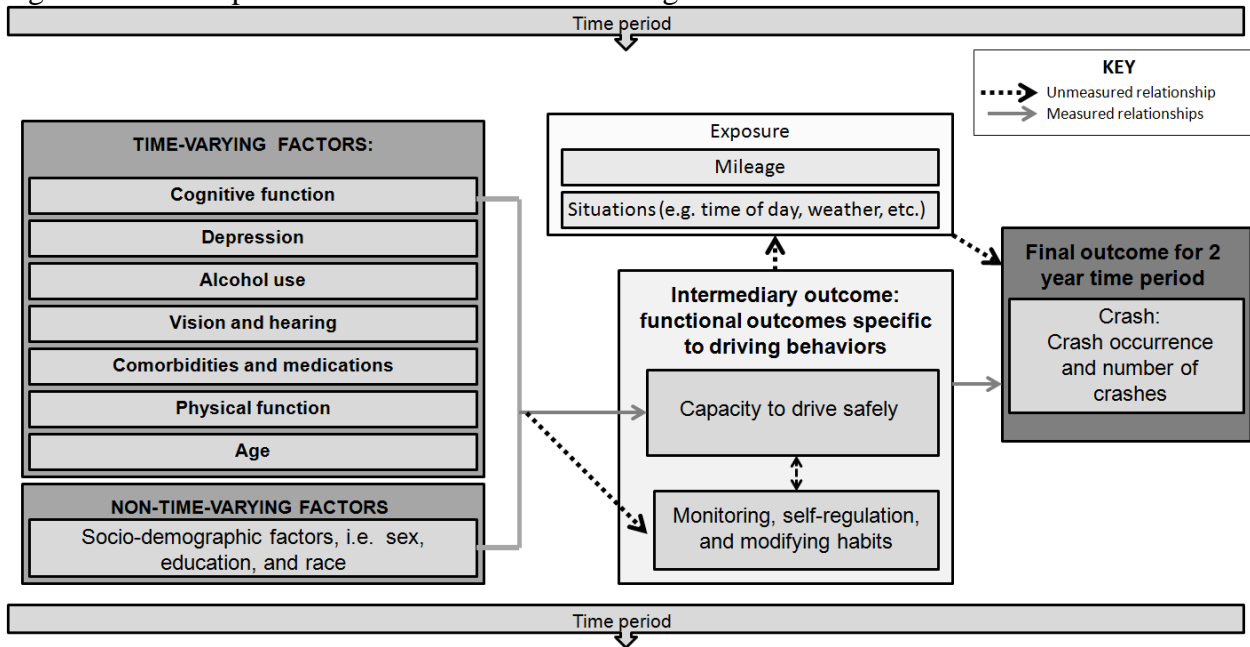
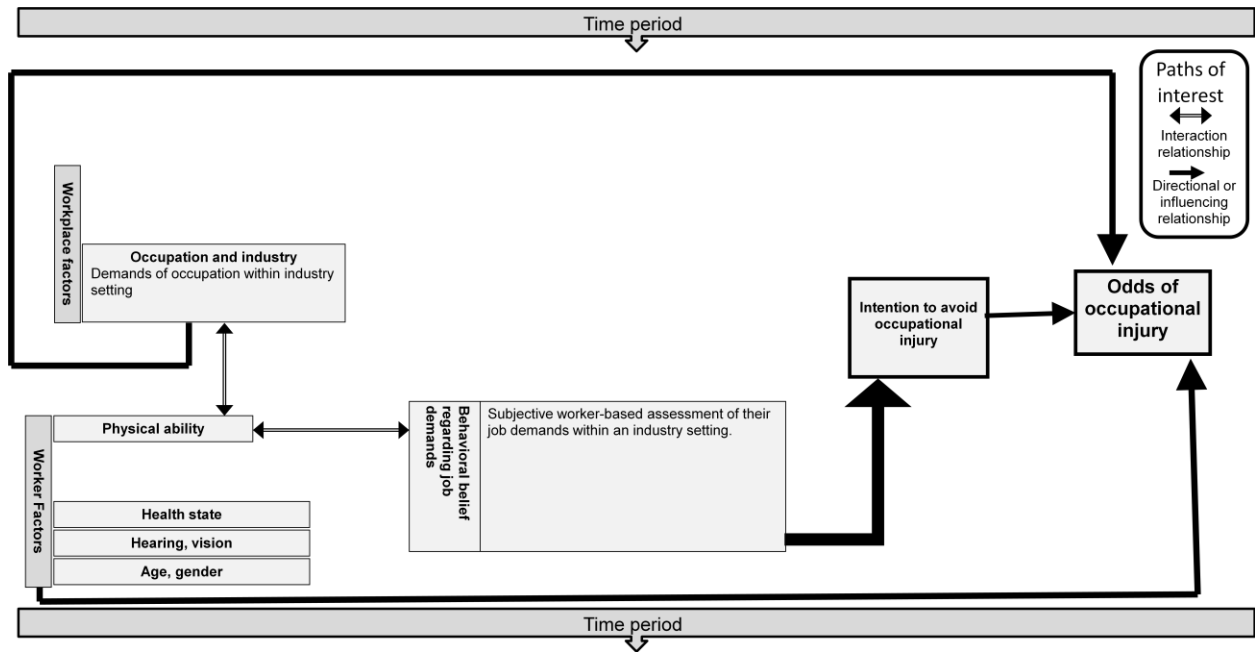


Figure 1.2: Conceptual model for Aim C: Older worker (age 50+) injury risk associated with health and workplace factors



## **CHAPTER 2: COGNITIVE DECLINE AND OLDER DRIVER CRASH RISK**

### **ABSTRACT**

Importance: Older adults are an active and growing segment of U.S. drivers. Cognitive decline may contribute to the higher fatal crash risk per vehicle mile travelled among older drivers compared to other age groups.

Objective: We examined crash risk associated with level of cognitive function and cognitive change among older drivers without dementia.

Design: This was a retrospective secondary analysis of a longitudinal cohort study.

Setting: This study used data from the Adult Changes in Thought (ACT) study merged with Washington State crash reports and licensure records. Data were available from 2002 to 2015.

Participants: Participants were Group Health enrollees from Washington State aged 65 and above with active driver's licenses.

Exposures: Cognitive function was assessed using the Cognitive Abilities Screening Instrument (CASI).

Main Outcome and Measures: The study outcome was police-reported motor vehicle crash. We used a negative binomial generalized estimating equation model with robust standard errors clustered on the individual. Covariates included age, sex, education, alcohol, depression, medical

co-morbidities, eyesight, hearing and physical function. Individuals were censored at the time of dementia diagnosis.

Results: Individual participants (N=2,638) were followed for an average of 7 years, during which 350 (13%) people crashed at least once. Among older drivers, comparing those with higher cognitive function to those with lower function, a one unit lower CASI score was associated with an adjusted incidence rate ratio (IRR) for crash of 1.28 (95% CI 1.08, 1.51). The rate of cognitive decline for an individual was not associated with increased crash risk.

Conclusions and Relevance: Among older licensed drivers without dementia, lower cognitive function was associated with a higher risk of motor vehicle crash.

## INTRODUCTION

In 2010, 85% of adults over age 65 held an active license to operate a motor vehicle.<sup>74</sup> Having the option to drive confers benefits on older adults, including increased life satisfaction.<sup>75,76</sup> Driving cessation is associated with negative health outcomes, including social isolation, depression, challenges for caregivers, and early entry into a long-term care facility.<sup>5,9,15,77,78</sup> However, a motor vehicle crash can be devastating or deadly for older adults and other road users. The older adult fatal crash rate per vehicle-mile-traveled is among the highest of any age group.<sup>4</sup> Older adults may self-regulate driving or cease driving due to health issues.<sup>79,80</sup> Social, logistical, and health factors must be considered as older individuals, families, and health care providers balance safety with the independence of driving.

Cognition impacts crash risk in several ways. Cognitive function influences the ability to perceive hazards in the roadway, process visual cues (e.g. stop lights and turn signals), focus on driving tasks, anticipate other road users' actions, and make quick decisions.<sup>5-9,81,82</sup> Individuals diagnosed with dementia are more likely to get lost, have difficulties at intersections, confuse pedals, maintain speed poorly, stray from designated lanes and set routes, and have poor judgment regarding safety compared to older drivers without dementia.<sup>7,11,17,26,27,41,82-84</sup>

Cognitive impairment may impact capacity to self-monitor and self-regulate driving.<sup>6,8,15,54,58</sup>

The safety risk presented by cognitive impairment cannot be completely eliminated through interventions such as driving habit restrictions or currently available engineering changes to the driving or vehicle environment.<sup>21</sup>

Older adults with prodromal or early stage dementia may be considered able to drive by their healthcare providers and state licensing departments,<sup>15,16</sup> and they may pass driving tests.<sup>11,19,85</sup> Prior studies found that drivers with dementia were at increased risk of crash, although strength

of association varied.<sup>5,7-9,45,86</sup> However, there is a limited understanding of how cognitive impairment prior to dementia translates to crash risk and how clinicians should advise patients and families about recommended driving behavior as cognition changes.<sup>5,9,15,87</sup> One group of studies examined outcomes including driver tests, perceived driving ability, recalled crash ability, or simulated driving rather than real-world crash risk. Another group of studies explored the relationship between cognition and crash risk but had a relatively brief follow-up period or a small sample size, which may have limited the ability to measure changes in cognitive function.<sup>5,7-9,11,25-27,45,55,81,83,87-90</sup>

We examined the association between cognitive function and crash risk among drivers age 65 and above without dementia among a cohort of older adults over a 13 year period. We also assessed the association between the change in cognition function and crash risk.

## **METHODS**

### **Participants**

The Adult Changes in Thought (ACT) study is a longitudinal study of adults aged 65 and older who were recruited from a random sample from Group Health, an integrated health delivery system in Washington State.<sup>91</sup> Enrolled individuals do not have dementia when entering the study, and participants are evaluated biennially for physical performance, health status, behavior, and cognitive functioning. Participants were followed until drop-out, diagnosis of dementia, or death. Cognitive function was assessed by the Cognitive Abilities Screening Instrument (CASI), administered at each study visit.<sup>35,92</sup> CASI scores ranged from 0 to 100, with higher scores indicating better cognition. If the total CASI score was less than 86 points, participants undergo a secondary evaluation to identify dementia. Individuals without dementia

were retained in the study cohort.<sup>91,93-95</sup> The ACT study has a Completeness of Follow Up Index of over 95%.<sup>93</sup>

We linked ACT data from 2002 to 2015 to the Washington State crash database and linked to licensure information from the Washington State Department of Licensing. Participant last names and birth dates were used to generate driver's license identification numbers.<sup>96</sup> We censored individuals at the time when they dropped out of the ACT study, failed to renew their license, or at two years (the average length of time between study visits) after their last ACT visit.

The study was approved by the Group Health Research Institute Human Subjects Review Committee.

## **Measures**

The outcome of interest was a motor vehicle crash on any non-private road within Washington State reported by or to police or Washington State Patrol, as included in the Washington State Department of Transportation crash database.

The primary risk factor of interest, cognitive function, was measured using the CASI. The CASI is an extended version of the Mini-Mental State Examination (MMSE) and Hasegawa Dementia Rating Scale.<sup>35</sup> Testing domains include attention, concentration, orientation, long term memory, short term memory, language, visual construction, list-generating fluency, and abstraction judgement.<sup>35</sup> Because standard CASI scores have curvilinear scaling properties which may reduce validity when evaluating functioning over time,<sup>97</sup> especially in high cognitive functioning individuals,<sup>97,98</sup> we used item response theory (IRT) to score CASI item responses.

The CASI-IRT score has linear scaling properties.<sup>93,97</sup> ACT investigators calibrated the CASI-IRT with the most recent data available up to the fifth visit. CASI-IRT scores are calibrated such that the mean score for the cohort at that time received a score of 0 and the standard deviation was 1. Investigators use item parameters from that time point to obtain scores for each participant at every time point. The range of CASI-IRT values in this study were -3.97 to 1.75. The total standard CASI scores ranged from 17 to 100.

Covariates including demographic and health factors were selected based on a conceptual model drawing from the framework for safe driving and health status from Anstey, Wood, et. al.<sup>8</sup> and the Advanced Cognition Training for Independent and Vital Elderly study.<sup>37</sup> Demographic factors included age, years of education, sex and self-reported race. We adjusted for ACT visit year to account for chronological trends linked to crash risk.

Self-reported health factors included visual or hearing impairment, depressive symptoms (measured using the Centers for Epidemiologic Studies Depression Scale (CES-D) and dichotomized at 10 by ACT), and a current problem with alcohol. An alcohol-related problem was characterized by ACT as the respondent reporting a doctor suggesting a decrease in drinking, aggressive behaviors while intoxicated, 2 or more alcohol-related traffic violations, or social, marital, or work-related issues due to drinking.

Physical function was assessed using a performance-based physical function score (PPF),<sup>94,99</sup> as described in Wang, et. al. 2002.<sup>99</sup> The PPF (range 0-16; higher scores indicating better physical function) is based on grip strength in the dominant hand, five timed chair stands, standing balance, and the average of two 10-foot timed walks.

We adjusted for comorbidities using the RxRisk score. This expansion of the Chronic Disease Score is a chronic comorbidity score that algorithmically combines age, sex, insurance-based

prescription drug coverage, and chronic conditions measured by pharmacy data.<sup>100–102</sup> For example, cardiac disease alone is associated with a weight of 2914.48; being a male age 75 and above is 2842.19; and diabetes is 2229.10.<sup>101</sup> The overall score present was quartiled and modeled as categorical indicators.

We separately adjusted for use of four medication classes previously shown to increase crash risk: sedatives, benzodiazepines, opioids and antipsychotics.<sup>15,103</sup> Individuals were considered users of a medication class if they had filled two or more prescriptions within a four-month period. Medication use was calculated separately for each intra-study visit time period.

### **Statistical analysis**

To assess the association between cognitive function and crash risk, we employed a generalized estimating equations (GEE) analysis with robust standard errors<sup>104</sup> and exchangeable correlation matrix, clustered on the individual. We chose a count-based model as individuals could have multiple crashes in any two-year panel-period. Due to over-dispersion we used a negative binomial distribution.

Each analysis panel was approximately two years - the time between ACT visits. No individual had less than one year elapse between study visits. However, because some panels had unusually long lapses (the longest was 10 years and 93 days), we excluded panels with more than three years lapses, ensuring that panel length was relatively consistent. Excluding exceptionally long panels resulted in a loss of 216 panels (2%).

We explored influential individuals or person-panels via a delta-beta test and a jackknife analysis. Results did not differ when individuals with the most extreme CASI scores or changes in CASI were excluded. We included all remaining panels and subjects in analyses.

Cognitive function was modeled linearly using CASI-IRT scores. We also modeled CASI-IRT scores using cubic splines and ordered categorical analyses to explore possible non-linearity but identified no obvious cut-points or differences in substantive findings.

To assess the impact of change in CASI-IRT rather than cognitive level, we modeled the difference between the previous and current panel's CASI-IRT score within subjects in addition to current CASI-IRT score, both a continuous variables, using a negative binomial GEE model. This analysis excluded baseline visits as previous CASI-IRT were not available.

In an additional analysis, we included a covariate denoting presence of a previous crash during the study. This model included the number of previous panels where a crash could have occurred to adjust for exposure. The first panel period was again excluded.

### **Sensitivity analyses**

Study participants were limited to those with an active driving license, however we were not able to determine whether or how much driving occurred. To explore driving exposure, we conducted a series of sensitivity analyses limited to participants more likely to be active drivers. First, in Washington State, at and after age 70, individuals must renew their licenses in person rather than online and pass a vision test at renewal.<sup>105</sup> A higher proportion of individuals over age 70 who renewed their license may have been likely to actively drive, since they sought licensure in person. Thus, the first analysis included only individuals over age 70. In a second analysis, we excluded individuals who reported using a handivan to arrive at an appointment. A third analysis included only older drivers reporting having no difficulty with activities of daily living (ADL) or instrumental activities of daily living (IADL).

Next we focused on identifying individuals who might be more likely to drive due to a dearth of other options. First, we limited the analysis to individuals without a spouse to serve as a possible alternative driver. We also conducted an analysis excluding individuals using a home health or visiting nurse services or living in a nursing home. Finally, we included only individuals living in rural areas, as determined by scores between 2 (metropolitan area, high commuting) and 10 (rural areas) in the Rural Urban Commuting Area (RUCA) code, a zip-code based measure of urbaneness, population density, and proportion of the population commuting to a more urban area.<sup>106</sup> Individuals with RUCA scores greater than one have less access to public transit and fewer resources within walking distance (e.g., grocery stores and health care facilities).<sup>107–109</sup>

Analyses were performed using STATA, Version 13. 1 (StataCorp, College Station, TX).

## **RESULTS**

### **Demographic characteristics**

The overall sample included 2,638 individuals who were followed for an average of 6.7 years for a total of 18,063 participant-years. Individuals had between one and seven ACT-related study visits.

Baseline characteristics of the study population are shown in Table 2.1. At baseline, the median CASI-IRT score was 0.50 (25th and 75th percentiles were, -0.01 and 0.93). The vast majority of individuals reported no difficulty with ADLs or IADLs. The ADLs and IADLs most frequently cited as causing at least some difficulty were getting out of bed or a chair, shopping for personal items, using the telephone, and light housework (each endorsed 6-15%).

### **Cognition function and crash risk**

Among three hundred and fifty participants (13%), 422 crashes occurred during the study. The crash rate was 23.4 crashes per 1000 participant-years. Participants crashed as many as three times within a panel.

Lower CASI-IRT scores (indicating poorer cognition) were associated with higher crash risk; the IRR was 1.28 (95% CI 1.08, 1.51), adjusted for health and demographic factors, meaning for each unit lower CASI-IRT score there was a 28% higher crash risk (Table 2.2). Previous crash did not have a statistically significant association with current crash risk (IRR= 0.84, 95% CI 0.47, 1.50).

Examining change in cognitive function rather than level, CASI-IRT scores varied from an increase in 2.20 points to a decrease of 3.94 points. The median change between two sequential panels within an individual were decrease of 0.08 points (25th and 75th percentile were -0.49 and 0.28 respectively (figure 2.1)). Adjusted for health and demographic factors and current CASI-IRT, a one unit decrease within an individual in CASI-IRT from the previous panel was not statistically significant (IRR: 1.11, 95% CI 0.87, 1.43). Within this analysis, current CASI-IRT's IRR was 1.32 (95% CI 1.06, 1.64).

Results were relatively robust across the six sensitivity analyses. The IRR point estimates did not differ considerably across analyses (Figure 2.2). However, significance varied.

## **Discussion**

In this large cohort study of older licensed drivers without dementia, a one unit decrease in level of the CASI-IRT was associated with a 28% increase in the risk of motor vehicle crash risk, controlling for age, sex, alcohol use, co-morbidities and medication use. Though we were not able to measure driving exposure, sensitivity analyses suggested that this relationship persisted among subgroups most likely to be driving.

No specific clinical exam, procedure, or laboratory test is widely accepted specifically to evaluate driving and crash risk related to cognitive function.<sup>17</sup> It is difficult to compare results of each approach because of the variety of end-points used in studies, from state-reported or patient-reported crash to simulator results to drive tests,. Using driving tests and simulators, studies found value in a range of methods specific to domains within cognition, including the maze task, Trails A and B, and the Benton Visual Retention Test.<sup>9,11,75,89,110</sup> Evidence for associations between driving performance and habits and the Montreal Cognitive Assessment (MoCA), the global cognition test included in NHTSA's Plan for Older Driver Safety,<sup>15</sup> varies, notably in predictive crash.<sup>111-113</sup> Using data from Maryland Pilot Older Driver Study, cut-offs were established for subsequent crash risk within two years using the Motor-Free Visual Perception Test, the Trails B, and the Useful Field of View among others, but neither cognition nor incremental change in cognitive status measures were reported at baseline or over time.<sup>114</sup> The National Highway Traffic Safety Administration's Assessment of Driving Related Skills (ADReS) battery contains an assessment of visual field and acuity, physical function, Trails B, and the clock-drawing test. Evaluations found no association to crash,<sup>115</sup> and poor specificity and sensitivity in predicting road test performance.<sup>116</sup>

The MMSE is the most widely used measure of cognitive function.<sup>86,117,118</sup> However, a review found mixed results using the MMSE to predict driving performance, with notably poor correlation when cognition was high.<sup>119</sup> The longest, largest study to examine the association between crash risk and incremental change in MMSE score, found no association.<sup>86</sup> This study problematically used self-reported driving exposure and crash outcomes data, but was mechanically similar to our current study.<sup>86</sup>

The CASI and MMSE are very similar in composition and coverage; the both measure global cognition.<sup>118,120</sup> The CASI has several advantages to MMSE which may account for its detection incremental differences in this study. First, the CASI includes testing domains of judgment, visual perception, and verbal fluency.<sup>35,118</sup> Third, the CASI may have slightly better sensitivity and specificity at detecting diagnosed dementia,<sup>48,117,121</sup> Fourth, longitudinal evaluations of cognition within MMSE's (and the standard CASI) can be biased due to the test's curvilinear measurement properties. Using the item response theory decreases this threat to validity.<sup>97</sup> Although an improvement over the MMSE, the CASI is likely not the holy grail of evaluations. More research is needed to understand how best to evaluate and advise older drivers in relation to cognition.

The range of change in CASI-IRT scores showed cognitive decline may progress at different rates between and within people over time. Serial assessment of cognition is recommended.<sup>15</sup>

When we controlled for level of cognition, change since the previous visit was not associated with crash risk. The IRR for CASI-IRT was slightly larger when change from the previous panel's CASI-IRT score was included in the model, suggesting that it really is the level of cognition at the outset of the two year panel driving crash risk, as opposed to the cognitive trajectory. Consequently, cross-sectional examinations could potentially be used for risk stratification in relation to crash risk.

Beyond cognition, only RxRisk score and depression was associated with crash risk in this cohort of older licensed drivers without a diagnosis of dementia. In multivariable models which included the RxRisk, demographic factors, alcohol problems and cognition, we did not find significant associations between other potential risk factors such as physical function, nor with self-reported factors such as drug use, eyesight or hearing. Specific to eyesight and hearing, it

was also possible that objectively measured, rather than self-reported, data were needed. variation in health status for differences to be detected. Alternatively, individuals may be more aware of changes and the crash risk related to eyesight, balance, etc., and hence be more likely to responsibly stop or restrict their driving exposure.

Our study draws its primary strength from its data source, ACT. This mature and representative study has a large sample size with little attrition and detailed health, cognition, and lifestyle data.<sup>95</sup> Because invited ACT participants represent a random sample of patients age 65 and above at Group Health,<sup>122</sup> and because the Group Health patient population resembles the Washington State population in age, sex, and race,<sup>43</sup> results were likely generalizable beyond study participants.

The chief limitation in the present study was the lack of information on driving exposure. We limited inclusion in these analyses to licensed drivers, a common approach taken by other investigators.<sup>26,27,39–41,47,55,80,81,112,114,123–125</sup> However, older adults may be licensed but choose not to drive or to limit driving,<sup>52,56,125,126</sup> especially as cognitive decline and other health conditions advance.<sup>53,54,127</sup> Prior research into driving exposure generated inconsistent results and drew from cross-sectional rather than longitudinal data. Even with these limitations, mild cognitive decline has been linked to decreasing and ceasing driving,<sup>27,54,55</sup> though drivers may not avoid demanding driving situations.<sup>128</sup> Within this study, point estimates of crash risk were very consistent across sensitivity analyses, increasing confidence in findings. However, future research should explore changes in driving habits- both objective and perceived- as cognition declines.

In summary, older drivers with lower cognitive ability were somewhat more likely to sustain a crash; however the rate of cognitive decline was not associated with crash risk. Older drivers

with cognitive impairment, their family members, and clinicians must balance the benefits of autonomy, mobility, and social engagement on the one hand and crash risk on the other as they make decisions on their driving. Results from this study suggest discussions on this balance may be relevant before the development of dementia.

Table 2.1: Demographic information at first visit qualifying for study (N=2,638)

	-1 ≤ CASI-IRT score (N=59)		-1 < CASI-IRT score ≤ 0 (N=604)		0 < CASI-IRT score ≤ 1 (N=1,390)		CASI-IRT score < 1 (N=585)	
	median	25th-75th percentile	median	25th-75th percentile	Median	25th-75th percentile	median	25th-75th percentile
Age (years)	81	77-83	77	72-82	74	69-79	72	68-77
# of years of education*	12	12-16	14	12-16	16	13-16	17	15-18
RxRisk score	3616	2228-5688	3465	2132-5627	3045	2114-4500	2491	2115-3768
Performance-based physical function score (PPF)	8	4.5-10.5	9	7-11	11	8-12	11	9-13
	N	%	N	%	N	%	N	%
Male	29	45%	284	47%	728	52%	370	63%
Race								
White	46	72%	515	85%	1240	89%	551	94%
Black	12	19%	31	5%	34	2%	6	1%
Asian	3	5%	21	3%	55	4%	13	2%
Other	3	5%	39	6%	61	4%	15	3%
Self-reported vision problems	41	64%	382	63%	365	62%	525	59%
Self-reported problem with alcohol	1	2%	30	5%	117	8%	45	8%
Self-reported depression	10	16%	52	9%	97	7%	39	7%
Self-reported hearing problems	17	27%	259	43%	508	37%	194	33%
DOL report of corrective lenses	10	16%	82	14%	273	20%	103	18%
Any Crash during study	11	17%	78	13%	185	13%	76	13%

Table 2.2. Incident rate ratio of crash among older drivers, clustered on the individual with robust standard errors, adjusted for year of ACT visit

	IRR	95 % CI	p-value
CASI-IRT score <sup>^</sup>	1.28	1.09 , 1.51	<0.01
Medication classes			0.76
Benzodiazepine	0.83	0.54 , 1.35	
Opioids	1.08	0.83 , 1.40	
Sedatives	0.95	0.53 , 1.69	
Anti-psychotics	0.71	0.27 , 1.87	
Depression	1.26	1.01 , 1.56	0.04
Performance-based Physical function	1.02	0.99 , 1.05	0.29
RxRisk			<0.01
Quartile 1:1119 to 2132	reference		
Quartile 2: 2132 to 3146	1.61	1.09 , 2.37	
Quartile 3:3146 to 4543	1.58	1.06 , 2.36	
Quartile 4: 4543 to 52970	1.86	1.23 , 2.80	
Age (years)	0.98	0.96 , 1.01	0.12
Education (years)	1.04	0.99 , 1.06	0.26
Female (vs. male)	0.80	0.71 , 1.10	0.27
Race			0.48
White	reference		
Black	1.00	0.58 , 1.73	
Asian	1.47	0.90 , 2.39	
Other	0.93	0.51 , 1.70	
Vision problems	1.09	0.87 , 1.35	0.45
Hearing problems	0.91	0.73 , 1.12	0.37
Alcohol problems	0.72	0.46 , 1.13	0.15

<sup>^</sup>CASI has been formatted here to represent a one unit change downward in cognition score, rather than a one unit change upward

Figure 2.1. Box plot of the change of CASI-IRT scores between panels, stratified by subsequent crash (e.g. the difference between the CASI-IRT score for a January 1, 2002 visit from a January 1, 2000 visit, stratified by crash status during 2002 and 2003)

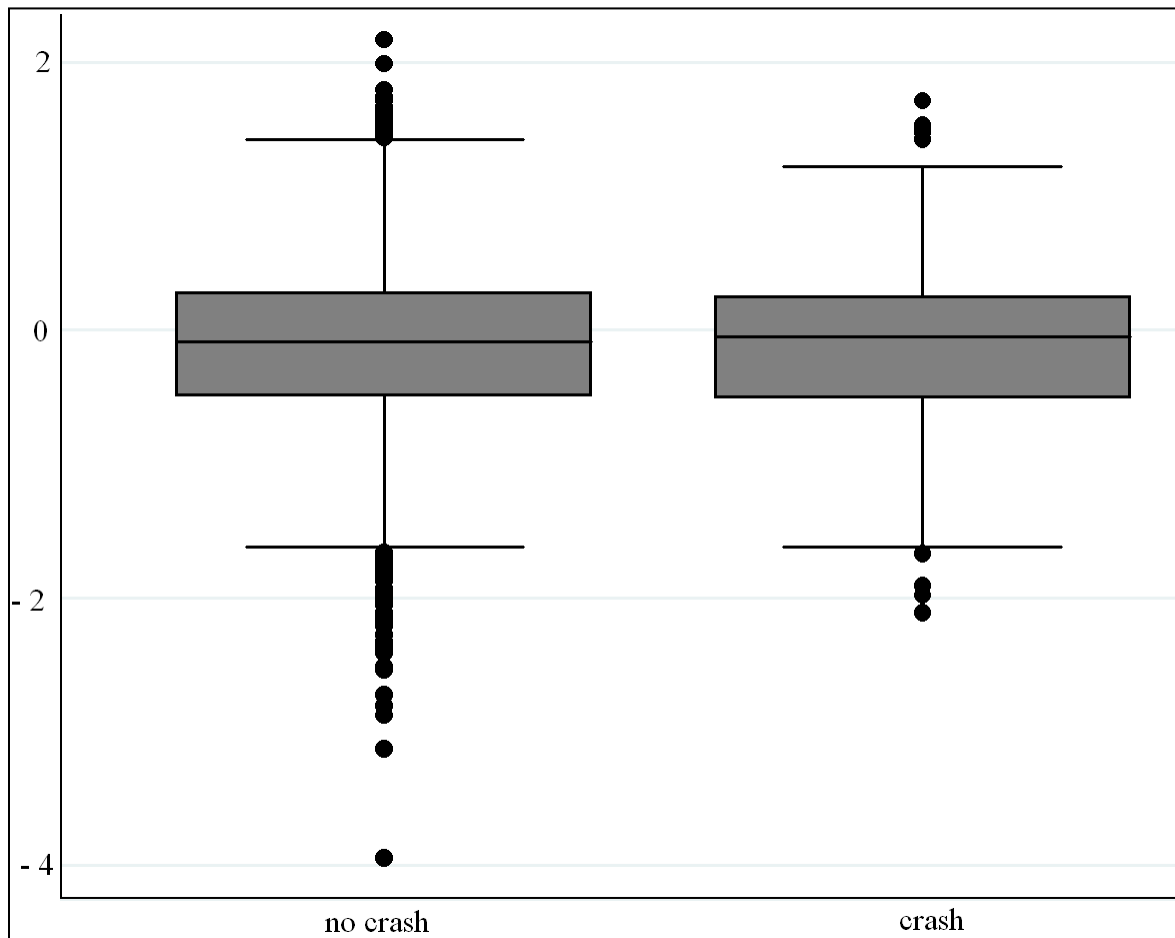
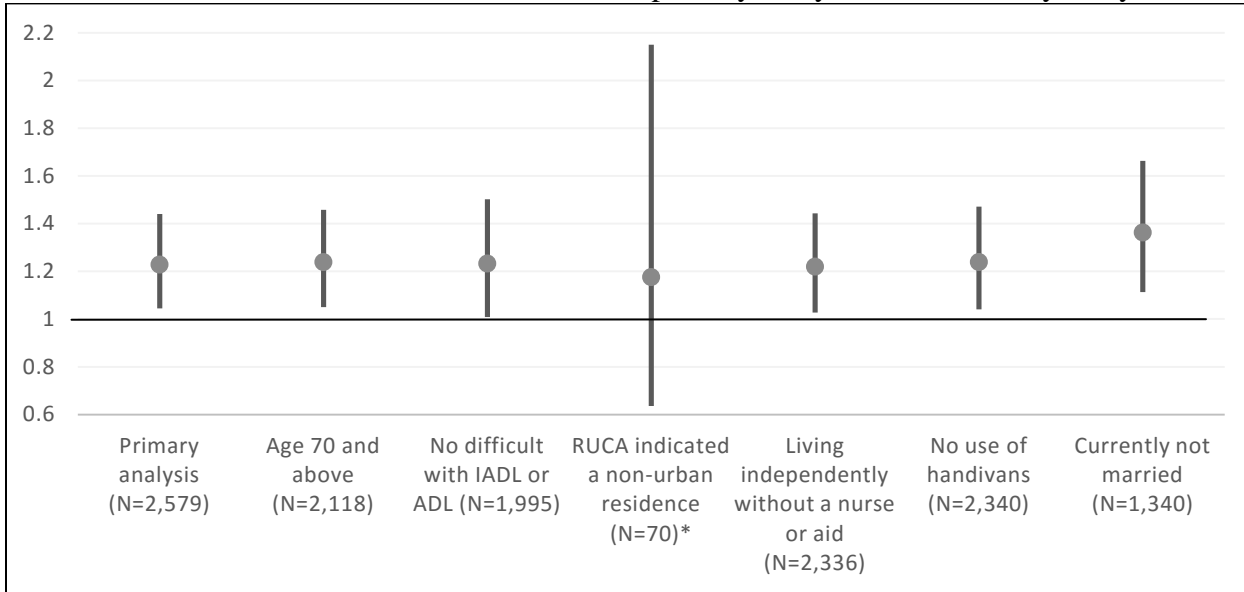


Figure 2.2. Point estimates and confidence intervals for the adjusted IRR of crash associated with a one unit difference downward in CASI-IRT: results for the primary analysis and sensitivity analyses



\*This model represent unadjusted analyses. Because of the small number of clusters and large number of covariates, the adjusted models failed to converge.

\*\*N refers to the number of clusters

## **CHAPTER 3: DIAGNOSED DEMENTIA AND THE RISK OF MOTOR VEHICLE CRASH AMONG OLDER DRIVERS**

### **ABSTRACT**

Objective: Older adults are an active and growing segment of U.S. drivers. Previous research found dementia may be associated with impaired driving ability. The study aimed to estimate the motor vehicle crash risk following diagnosis of dementia among older drivers.

Design: Retrospective cohort study.

Setting: Data came from Group Health (GH), a Washington State health maintenance organization.

Participants: Research participants were members of GH, aged 65 to 79 during the study, and living in Washington State from 1999-2009. We merged participant health records with police-reported crash and licensure records.

Measurements: We estimated the risk of crash for older drivers diagnosed with dementia compared to older drivers without diagnosis of dementia. Hazard rate ratios for crash were estimated in a Cox proportional hazards model with robust standard errors, accounting for recurrent events. Multivariate models were adjusted for age, sex, diagnosis of alcohol abuse, depression, comorbidities, and medications.

Results: We identified 29,730 eligible individuals. 5.8% were diagnosed with dementia before or during the study. The crash rate was 14.7 per 1,000 driver-years. In a multivariate model, the hazard ratio of crash among those with dementia was 0.56 (95% CI 0.33, 0.95) compared to those without.

Conclusion: Previous research showed dementia to be associated with impaired driving ability. The observed reduction in crash risk may result from protective steps to limit driving among older adults diagnosed with dementia. Future research should examine if discussions about driving at time of dementia diagnosis can reduce exposure and decrease crash risk.

## INTRODUCTION

In 2013, 17% of all licensed drivers were age 65 and above, a 15% increase from 2004.<sup>129</sup> Research supports the health benefits of driving for older adults and the concomitant negative impact of curtailed driving, including associations with depression, social isolation, and entry into a long-term care facility.<sup>5,9,77</sup> Many older adults self-regulate driving by taking shorter trips, driving only during the day, or ceasing to drive.<sup>53,80,130</sup>

A motor vehicle crash may be devastating or fatal for frail older adults and other road users.<sup>131,132</sup> The annual rate of motor vehicle crash deaths among adults age 65 and above in 2014 was 12.3 per 100,000 population, almost the same as the crash death rate for individuals age 16 to 64. Yet the passenger vehicle fatal crash involvement rate per vehicle mile traveled among drivers age 65 and above is high, second only to drivers age 16 to 29.<sup>4</sup> One contributor to this high rate may be cognitive decline or dementia.<sup>5-9</sup>

State Departments of Motor Vehicles, the National Highway Traffic Safety Administration (NHTSA), medical associations, and technical and non-technical articles generally support limiting and eventual cessation of driving in individuals with dementia.<sup>15,17-19,22</sup> Studies have found that cognitive impairment increased crash risk, although the strength and significance of the associations varied.<sup>5,17,23-28</sup> Lab- and road-based research has found that dementia can impair driving skill through decreased perception of hazards and processing of visual cues, diminished attention, and impaired decision-making.<sup>5-9,81</sup> Older drivers with cognitive decline may become lost, have difficulties negotiating intersections, and may stray from designated lanes and customary routes.<sup>7,17,26,27,41,82,83</sup>

Research on dementia and crash risk has been limited by the method of crash ascertainment, brief follow-up time, use of driving simulators,<sup>26,45,90</sup> small samples<sup>5,7-9,27,55,81-83,87</sup> and/or measures of cognition with limited relevance in the clinical setting.<sup>55,81,86</sup> Little naturalistic research exists using data routinely generated and collected from surveillance and health systems on cognition and crash. Researchers have stressed the need for longitudinal cohort studies with large sample sizes and reliable dementia and crash information.<sup>82,87</sup>

This study aimed to determine the impact of diagnosed dementia on motor vehicle crash risk among licensed individuals aged 65-79 years.

## **METHODS**

### **Data sources**

Study participants were Washington state residents 65 to 79 years of age during the study period, and enrolled at Group Health (GH), a Washington State health maintenance organization, for at least one year between January 1, 2003 and December 31, 2009. GH enrollees broadly resemble Washington State residents with respect to age, sex, and race.<sup>43</sup> Using patient names and birthdates,<sup>43,96</sup> we generated our analytic dataset by combining records from three sources: (1) electronic health records and prescription data from GH, (2) drivers license records from the Washington State Department of Licensing, and (3) crash reports from the Washington State Department of Transportation. The latter includes all crashes on any non-private road within Washington State reported by or to police or Washington State Patrol.<sup>43</sup>

All participants had an active Washington State driving license. Electronic crash and license records were available for the period January 1, 2003 to December 31, 2009. Medical encounter diagnosis codes were available from January 1, 1999 to December 31, 2009. We treated 2003, when all data were available, as study start.

This study was approved by Group Health Research Institute Research and Human Subjects Review.

### Data

The primary exposure variable of interest was dementia diagnosis. The date of diagnosis was considered to be either the earliest dementia-related ICD-9-CM code in the medical visit records or earliest prescription for an anti-dementia medication [donepezil (brand name Aricept) or memantine (brand name Namenda)]. GH has a prescription drug formulary that does not permit use of these medications to treat mild cognitive impairment. ICD9-CM codes indicating Alzheimer's disease and similar dementias included 294.1, 294.10, 294.11, 294.31, 294.8, 294.80, 331, 331.0, 331.1, 331.11, 331.19, 331.2, 331.7, 331.82, 331.89, 331.9, and 294. Senile dementia and vascular dementia (ICD-9-CM codes 290.0-290.9) were not included in the case definition as codes for these diagnoses were not made available to the study team for these analyses.

The outcome of interest was police-reported crash occurring in Washington State where the GHC member was the driver.

Potential confounders included age at study entry, year of study entry, sex, comorbidities, diagnosis of depression, alcohol use disorders recorded in the electronic medical record, and certain classes of medications known to be associated with crash risk. For each participant, the Charlson Comorbidity index was calculated at study entry to account for chronic comorbidities. Although the Charlson index adjusts for dementia, there is no overlap between the ICD9-CM codes identifying dementia within the Charlson (senile and vascular dementias, 290.0-290.9) and the codes available in this data set. We used ICD-9-CM codes as proxy measures to identify diagnoses of alcohol-related illness (i.e. codes 303 to 303.96) and depression (i.e. codes 296 to 296.9, and 300 to 300.94).

We controlled for potential confounding from four medication classes that have been associated with increased crash risk: sedatives, benzodiazepines, opioids, and antipsychotics.<sup>15,103</sup> Individuals were considered to have taken a medication if two or more prescriptions were filled within a four-month period. Among participants diagnosed with dementia during the study, medication use was determined separately before and after dementia diagnosis.

## **Statistical analysis**

This was a retrospective cohort study examining crash risk for older licensed drivers with diagnosed dementia, compared to those without a diagnosis of dementia. We treated 2003 as the study start, with 1999-2002 as a pre-study period during which diagnosis information was gathered. Because observation time varied between individuals, we used survival analysis methods. We divided individuals into three groups: (1) patients with no diagnosis of dementia within four years prior to the study and during the study period (1999-2009); (2) patients diagnosed with dementia within the 4-year period prior to the study (1999-2002), (3) patients diagnosed with dementia during the study period (2003-2009).

We estimated the hazard ratio for a crash using a Cox proportional hazards model where the exposure of interest was dementia diagnosis. We used the Anderson-Gill approach to account for recurrent crashes.<sup>133,134</sup> We incorporated time-varying exposure status (dementia diagnosis) and robust standard errors. We censored data at age 80, death, disenrollment in GH, study end, or loss of or failure to renew driver's license. We tested the proportional hazards assumption using Schoenfeld residual-based plots and tests; the assumption was satisfied for all models

### **Sensitivity analyses**

We conducted three additional analyses. All three used a Cox proportional hazard model adjusted for the same covariates as the primary model.

First, we theorized that individuals in non-urban areas may have greater need to drive due to diminished availability of resources within walking distance (e.g. grocery stores and health care facilities)<sup>107,109</sup> and decreased availability and thus use of public transit.<sup>108</sup> We performed stratified analyses based on Rural-Urban Commuting Code (RUCA), which is a coding system based on ZIP codes rating urbanity, population density, and proportion of the population commuting to a more urban area. We analyzed individuals in a metropolitan area core (RUCA scores of 1) separately from those living in a ZIP code with a RUCA score between 2 (metropolitan area, high commuting) and 10 (rural areas).<sup>106</sup>

Second, we examined crash risk among older drivers newly diagnosed with dementia to minimize differences in disease severity. For this analysis we used an inception study design. The inception study design may also reduce the risk of miscategorization of cognitive state by excluding the pre-diagnosis time period when cognitive impairment may already have been present. The rate of crash for group 1 (no dementia diagnosis) was compared to the rate of crash in the post-diagnosis period for group 3 (drivers diagnosed with dementia during the study); in this analysis we excluded the people who were diagnosed with dementia immediately before the study (group 2)

Third, we hypothesized that a high-risk crash period exists immediately prior to the formal diagnosis of dementia. During this period an individual may have impaired driving but may not yet have restricted driving behaviors. We limited analysis to incident cases (group 3- drivers diagnosed with dementia during the study) and explored whether the diagnosis of dementia was associated with a change in crash risk, using the timeframe from one year before diagnosis until one year after diagnosis.

We used Stata, Version 13.1 (StataCorp, College Station, TX) for all analyses.

## RESULTS

Among 29,730 study participants, 827 were diagnosed with dementia before the study start and 886 during the study. Individuals who had or who developed dementia were older on average at the start of the study, had more co-morbid diagnoses, and were more likely to have an ICD-9-CM code relating to alcoholism and depression (Table 3.1). The groups did not differ significantly by sex.

The overall crash rate was 14.7 crashes per 1,000 licensed driver-years. There were 32 crashes over 3,546 years of study time following dementia diagnosis, or 9.0 crashes per 1,000 person-years. 1,385 crashes occurred among individuals without a diagnosis of dementia or in the period prior to diagnosis during 88,143 years of study time, or 15.7 crashes per 1,000 person-years. Among individuals who crashed, eight crashed three times during the study, 103 crashed twice, and the remainder crashed once.

In our primary analyses, the unadjusted hazard ratio (HR) of crash after dementia diagnosis (diagnosed during or before the study) was 0.55 (95% CI 0.33,0.89). In a multivariate model adjusted for demographic variables and comorbidities, the hazard ratio for crash was 0.56 (95% CI 0.33 to 0.94) (Table 3.2).

In the sensitivity analysis using RUCA, 3,340 participants lived in metropolitan core areas, and 6,383 lived in less urban areas or rural areas. We used data from all groups. Among older drivers living in urban metropolitan areas (RUCA equal to 1), the adjusted hazard ratio of crash among those with a dementia diagnosis, compared to those without a dementia diagnosis, was 0.50 (95% CI 0.28, 0.91). Among those with

less urban residences (RUCA greater than 1), individuals with a dementia diagnosis, compared with individuals without a dementia diagnosis, had an adjusted hazard ratio of crash of 0.88 (95% CI 0.30, 2.62).

We also estimated the risk of crash immediately following dementia diagnosis (using data from those diagnosed during the study (group 3) compared to those never diagnosed (group 1) using an inception design. Adjusted for age, co-morbidities, depression, alcohol use, and medication use, the hazard ratio per licensed driver was similar to the rate found in our primary analyses, though this did not reach statistical significance (HR = 0.60, 95% CI 0.35, 1.02).

We found no association between dementia diagnosis and crash risk during the year following diagnosis of dementia (HR = 1.07, 95% CI 0.19, 5.99) compared to up one year prior to diagnosis among those diagnosed during the study (group 3).

## **DISCUSSION**

Our primary findings suggest that despite impaired driving skill, patients with dementia have a lower risk of crash compared to those without dementia. This finding may initially seem counter-intuitive, as several studies have demonstrated that drivers with cognitive impairment have poor performance on road tests and simulated driving scenarios.<sup>55,81</sup> Nevertheless, in the observational context, two longitudinal studies did not find an increased crash risk associated with cognitive impairment,<sup>81,86</sup> and indeed in the larger of these studies,<sup>86</sup> the crash hazard point estimate was lower in more advanced stages of dementia. We suspect that our findings, which demonstrated lower crash risk for people diagnosed with dementia, may reflect purposeful changes in driving habits among some older adults diagnosed with dementia. Our results suggest that lower risk associated with lower driving exposure among older drivers with dementia may more than offset the higher risk associated with decline in driving abilities.

Older adults, possibly influenced by their family or caregivers, may restrict driving following diagnosis of dementia, resulting in a reduction in crash risk. We looked for and did not find evidence in support of temporal changes in crash risk. In our inception design analyses, our results were similar as in our primary analyses,

which suggests that people with newly acquired dementia diagnoses had similar crash risk as people with more established dementia diagnoses. We also did not see differences in rates from the year immediately prior to or the year immediately following dementia diagnosis. Future research with larger numbers of people with dementia diagnoses - especially studies that have access to driving behavior - will be needed to ascertain temporal trends in driving risk around the time of dementia diagnosis.

Future research on driving habits among older adults may consider technologic approaches to accurately measure driving time and distance in addition to driving skill and crash risk. Monitoring using cell phone applications, using in-vehicle technology such as cameras, accelerometers, and yaw rate sensors, or using personal actigraphs, presents important opportunities for research on older adult driving habits. Future studies capturing driving performance and crash risk among individuals with cognitive impairment or dementia may identify additional risk and protective factors to guide decision making about driving with older adults.

Factors other than diminished driving exposure may also contribute to the lower risk of crash we observed among older drivers with dementia. People with dementia may fail to inform police of a crash or may be more likely to have a non-reportable crash. In Washington State, a collision report is not needed if there are no injuries and damages do not exceed \$1000. Crashes in private parking lots or outside of Washington state are also not included in state Department of Transportation crash data.

As we had theorized, we found a lower risk of crash among urban-dwelling older adults with dementia, but not among suburban or rural residents. It may be easier for urban dwellers to reduce their driving hours due to greater availability of public transportation and support services (e.g., grocery delivery services). It would be interesting to study whether crash risk could be further reduced for people with dementia in less urban areas with the provision of additional services that could enable reduced driving exposure.

Results from the sensitivity analyses using an inception design and using only individuals diagnosed during the study did not show a relationship between new diagnosis of dementia and crash risk. However, there were few crashes recorded among drivers with dementia, which limited power to find differences.

Our study has a number of limitations. First, all participants had an active driver's license, but we were not able to verify whether and how much they drove a vehicle. An older adult may have renewed his or her license without the intention to drive. In addition, study participants may curtail driving before the license renewal date. There is evidence that poor cognitive functioning is related to driving cessation.<sup>53,54</sup> Among those who continue to drive, exposure decreases while self-limiting increases.<sup>27,52,55-57</sup> A study of individuals from an Alzheimer's Disease Research Center registry using self-reported mileage found that compared to individuals with no dementia, annual mileage was 15% lower among those with very mild Alzheimer's Disease, and 46% lower among those with mild Alzheimer's Disease.<sup>27</sup> A small study found 45% lower self-reported weekly mileage comparing individuals with dementia to those without.<sup>135</sup> Self-reported mileage among older adults is often inaccurate,<sup>58</sup> an issue which may be particularly pronounced in those with dementia.

A second limitation was that despite the relatively large sample size and a long period of follow-up, both the exposure (dementia) and the outcome (crash) were relatively rare, which impacted power. Third, an individual diagnosed with dementia before the study period but for whom no dementia diagnosis was noted at subsequent GH interactions could potentially have been misclassified as not having dementia in our analyses. Fourth, we controlled for four medication classes known to independently increase crash risk among drivers. Medication use was assessed by two separate pharmacy records indicating that a prescription had been filled within a four-month period, but we were not able to ascertain whether filled prescriptions were used nor exactly when the medications were taken. Our approach adjusted for general exposure to high-risk medication categories rather than for specific periods of use. Last, this study's operational definition of dementia had two shortcomings: (A) the ICD9-CM codes related to dementia within the data set were not comprehensive. Notably codes for vascular dementia were not available, and (B) ICD9-CM codes identifying dementia diagnoses in general and dementia subtypes in particular are notoriously inaccurate.<sup>136,137</sup> These two issues biased results toward the null.

## **Conclusion**

The older adult population of the U.S. is growing rapidly- in 2013 14% of US citizens were age 65 or older.<sup>129</sup> Lack of disease-modifying treatments may lead some care providers to view dementia as a less important clinical entity compared to other health issues facing their older patients.<sup>15</sup> Yet assessing cognition among older adults and advising them on the risk of crash associated with declining cognitive function are central to discussions between care providers, older adults, and families on how to maximize older patients' independence while preserving individual and public safety. More research is needed to ensure providers have the relevant data for evidence-based care of the older driver.

As adults age, they may face new transportation challenges in meeting social, logistical, and medical needs. More research is needed to identify cognitive decline which may impact traffic safety for older adults and other road users. Studies are needed that measure self-regulation of driving behavior and exposure which may mitigate risk. Older adults may benefit from new and creative approaches for meeting transportation needs and enabling active social engagement in order to support their physical and social well-being.

Table 3.1: Demographic and health information (n= 29,730)

	Group 1: No dementia (N= 28,015)		Group 2: Dementia diagnosed before study start (N=827)		Group 3: Dementia diagnosed during study (N= 886)	
	N	%	N	%	N	%
Motor Vehicle Crash <sup>#+</sup>	1,241	4	16	2	41	5
Female	15,320	55	452	55	484	55
Age Group <sup>*##+</sup>						
65-69	11,437	41	161	19	286	32
70-74	12,040	43	498	60	458	52
75-79	4,538	16	168	20	144	16
Charlson Co-Morbidity score <sup>*##+</sup>						
0	20,160	72	449	54	546	61
1 to 4	4,255	15	194	23	187	21
5 to 9	2,248	8	100	12	86	10
10+	1,350	5	84	10	69	8
Benzodiazepine use <sup>*##+</sup>	2,942	11	183	22	64	7
Opioid use <sup>*##+</sup>	8,068	29	270	33	156	18
Sedative use <sup>*##+</sup>	1,304	5	76	9	25	3
Antipsychotic use <sup>*##+</sup>	418	1	229	28	31	3
Alcohol-related diagnosis <sup>#+</sup>	267	1	41	5	13	1
Depression-related diagnosis <sup>*##+</sup>	3,198	11	336	41	248	28

\*statistically significant difference between groups 1 and 2 (P-value<0.05)

#statistically significant difference between groups 1 and 3 (P-value<0.05)

+statistically significant difference between groups 2 and 3 (P-value<0.05)

Table 3.2: Hazard ratio for motor vehicle crash in multivariate analysis using data from all diagnosis groups (group 1, 2, and 3)

	Hazard ratio	95% CI		P-value
Dementia diagnosis	0.56	0.33,	0.94	0.029
Female	0.66	0.59,	0.73	<0.001
Age	0.99	0.98,	1.01	0.52
Benzodiazepine	1.07	0.90,	1.28	0.44
Sedatives	0.93	0.73,	1.19	0.57
Opioids	0.98	0.87,	1.11	0.8
Antipsychotics	0.68	0.42,	1.1	0.12
Alcohol-related diagnosis	1.26	0.82,	1.93	0.29
Depression-related diagnosis	1.2	1.02,	1.42	0.031
Charlson co-morbidity index				
0		Reference category		
1	1.16	1.00,	1.34	0.045
2	0.9	0.72,	1.13	0.35
3+	0.96	0.72,	1.29	0.81
Year of study entry	0.97	0.92,	1.02	0.2

## **CHAPTER 4: RELATING OLDER WORKER'S INJURIES TO THE MISMATCH BETWEEN PHYSICAL ABILITY AND JOB DEMANDS**

### **ABSTRACT**

**Objective:** We examined the association between job demand and occupational injury among older workers.

**Methods:** Participants were workers aged 50+ enrolled in the Health and Retirement Study, 2010-2014.

Participants reported physical ability within three domains: physical effort, stooping/kneeling/crouching, and lifting. To measure subjective job demand, participants rated their job's demands within domains. We generated objective job demand measures through the Occupational Information Network (O\*NET). Using Poisson regression, we modeled the association between physical ability, job demand, and self-reported occupational injury. A second model explored interaction between job demand and physical ability.

**Results:** The injury rate was 22 /1,000 worker-years. Higher job demand was associated with increased injury risk. Within high job demands, lower physical ability was associated with increased injury risk.

**Conclusions:** Older workers whose physical abilities do not meet job demands face increased injury risk.

## INTRODUCTION

The population of older workers is growing; more older adults are now in the workforce than at any time since the turn of the century.<sup>138</sup> As of May 2016, 19% of Americans age 65 and above were employed. In addition, employed adults age 65 and above are working longer hours, with 64% working full-time in 2016.<sup>138</sup> Older workers have lower injury rates relative to younger and middle-aged workers, but when injuries occur, they are more serious and more costly.<sup>30,139,140</sup> Following injury, older workers require more time off,<sup>141</sup> are less likely to be offered modified work or to be recommended rehabilitation post-injury,<sup>142</sup> and are less likely to ever return to work compared to younger workers.<sup>33</sup> In a 2015 study, 11% of older workers reported they intended to retire early as a consequence of prior injury.<sup>143</sup> Among individuals aged 51 to 61 years receiving Social Security Disability Insurance, 37% were disabled due to a workplace injury or illness.<sup>144</sup>

Aging-related health changes impact occupational injury risk.<sup>34,66-71,145</sup> Older adults have a higher incidence and prevalence of chronic diseases.<sup>145</sup> Declines in vision and hearing may limit the ability to perceive safety hazards and safety measures, or interfere with processing work-related instructions.<sup>66,72</sup> Age-related changes in cardiovascular and musculoskeletal systems<sup>145-148</sup> and bone density<sup>66</sup> may impact dexterity, reaction to stress, and strength.<sup>34,66-70,149</sup>

Beyond health status, occupational injury risk is influenced by job demand, defined as occupational expectations or the physical requirements involved in performing a job.<sup>150</sup> Using data from 1992 and 1994 panels of the Health and Retirement Study (HRS), researchers found that among respondents age 51 to 61 excluding farmers, respondent-based subjective assessment of the importance of hearing, vision and physical job demands showed a strong relationship with occupational injury rates.<sup>151-153</sup> Objective measures of job demand based upon occupational titles have been generated using the Canadian National Occupational Classification (NOC) system and the Occupational Information Network (O\*NET).<sup>141,154-156</sup> Studies demonstrated an informative and statistically significant association between high physical job demand as measured by O\*NET and the Canadian NOC and adverse occupational outcomes.<sup>141,154-156</sup>

Researchers have theorized that a mismatch or imbalance between the worker's physical abilities/capabilities and job demands, specifically if the job has demands that the worker cannot physically meet, could adversely influence health outcomes, above and beyond job demand alone.<sup>33,66,143,157-160</sup> Matching worker abilities with occupation-specific needs<sup>72</sup> may reduce occupational injury risk, allowing older adults to work longer and more safely.

The aims of this study were to: (1) determine the degree to which subjective or objective job demands were associated with injury risk among older workers, (2) compare subjective and objective job demands in predicting risk of injury, and (3) explore via interaction the effects of a mismatch between an older worker's self-reported physical ability and job demands (measured subjectively or objectively) and the risk of occupational injury.

## **METHODS**

### **Data Sources and Sample**

This study was a retrospective secondary analysis of longitudinal survey data from the Health and Retirement Survey (HRS), a study of Americans aged 50 years and older. The HRS is sponsored by the National Institute on Aging (grant number NIA U01AG009740) and is conducted by the University of Michigan.<sup>161</sup> The study's content and methods have been documented elsewhere.<sup>162-164</sup> Briefly, the study began in 1992, with additional participant cohorts added in subsequent panels.<sup>165</sup> Telephone or in-person interviews are conducted with study participants every two years.<sup>3333</sup> The study has maintained a response rate over 75% in all groups except Hispanics.<sup>166</sup> The HRS survey gathers data on health, employment, and demographic variables.

Our study used HRS data from the 2010, 2012, and 2014 panels. HRS occupational injury data came from the subsequent panel (e.g. 2012 health data was analyzed with 2014 injury data) to ensure temporality. We restricted the analysis to individuals actively working full-time, working part-time, or working part-time but who stated an intention to retire shortly.

O\*NET is an online database detailing 277 occupational attributes of 974 jobs,<sup>167</sup> and is sponsored by the United States Department of Labor/Employment and Training Administration.<sup>168</sup> O\*NET provides day-to-day task descriptions, work environment details, and skill requirements for the typical worker.<sup>169</sup>

O\*NET was sponsored by the United States Department of Labor/Employment and Training Administration and developed by the North Carolina Department of Commerce.<sup>168</sup> A literature review found O\*NET's occupation characteristics to be a useful and underused source in analyzing relationships between occupational characteristics and health outcomes.<sup>170</sup>

O\*NET categorizes occupations via the 2010 Standard Occupation Codes (SOC), while HRS uses Census occupation codes.<sup>171</sup> To link O\*NET's descriptions of job demand with the HRS data, we used a United States Census Bureau crosswalk<sup>172</sup> between O\*NET 2010 SOCs and the HRS 2010 Census occupation codes.<sup>171</sup> Of the 487 Census occupation codes present in the HRS, 72% exactly matched SOC codes in O\*NET. We manually mapped an additional 20%. For example, the Census category 8350, "tailors, dressmakers, and sewers," was matched to "tailors, dressmakers, and custom sewers," SOC 51-6052. We excluded the remaining 8% of Census occupation codes that we were unable to cross-walk to an SOC, resulting in a loss of 3% (n=156) of HRS participants.

This study was approved by University of Washington Human Subjects Division.

## **Measurement**

For this study, we defined an occupational injury using HRS data as "an injury at work that required special medical attention or treatment or interfered with work activities."<sup>173</sup> The HRS contains no data on the severity or outcome of worker-reported injury. Occupational injury data were collected from the survey following collection of health, occupation title, and job demand data to ensure these metrics were not influenced by injury occurrence. For example, the 2012 physical ability and job demand responses were used to assess the risk of injury occurrence as reported in the 2014 interview.

Primary factors of interest fell into three domains: physical effort; lifting heavy objects; and stooping, kneeling, or crouching. Each domain was assessed by three metrics: (1) self-reported physical ability, (2) subjective HRS-based job demand, and (3) objective O\*NET-based job demand (see Figure 4.1 and Appendix 4.A).

HRS respondents rated their physical ability specific to each domain. We dichotomized responses such that individuals reporting no difficulty with the activity were categorized as having high physical ability, and individuals reporting difficulty or inability were categorized as having low physical ability (details for each metric can be found in Appendix 4.A).

Subjective job demand was assessed by asking HRS respondents to rate how often their job required "*lots of physical effort*," "*lifting heavy loads*," and "*stooping, kneeling, or crouching*," ranging from "all or almost all the time" to "none of the time."<sup>173</sup> Responses were dichotomized so that "*all or almost all the time*" and "*most of the time*" were considered high job demands, and "*some of the time*," "*none or almost none of the time*," and "*does not apply*" were low job demands.

We then mapped each physical ability metric to objective job demand from O\*NET. In O\*NET, objective job demand was measured by scales including level (how proficient one must be at an activity to perform the job), context (frequency of an activity during work in that job), and/or importance (how central an activity or ability is to a job).<sup>174</sup>

We selected O\*NET demands (listed in Appendix 4.A) from examination of the possible O\*NET demand descriptions and the available literature. Multiple objective job demands matched to the subjective job demand within the physical effort and lifting heavy objects domains. Within each domain we assessed objective job demands for consistency using Cronbach's Alpha. The alphas were above 0.7<sup>175</sup> so we took a mean of the demands within a scale (i.e. within context, within importance, and within level).<sup>176</sup>

Objective job demand metrics were continuous rather than categorical so we dichotomized the context and importance scales (both range from 1 to 5) at 2.5 and the level scale (which ranges from 0 to 7) at 3. The cut-points were chosen intrinsically (based on the scale's interpretation) rather than extrinsically (based on the

values present in the data, e.g. the median) to be consistent with the subjective job demand dichotomization (see Appendix 4.A).<sup>154,177</sup>

Covariates included age, sex, and health measures. We converted age to a categorical variable in increments (50-55, 56-60, 61-65, 66+). Comorbidity was measured by the number of serious diseases (i.e., high blood pressure, diabetes, cancer, lung disease, heart disease, stroke, psychiatric problems, and arthritis) diagnosed by a physician.<sup>178</sup> Regression models also included a composite measure of fine motor skills (e.g., picking up a dime, eating), and a composite measure of mobility (e.g., walking several blocks, climbing stairs). The value of each composite measure represents the number of listed activities with which an individual reported difficulty. The comorbidity count and the mobility and fine motor skills composite measures were generated by RAND using HRS data.<sup>179</sup> Regressions were also adjusted for self-reported hearing and vision, dichotomized as "good" and above versus "fair" and below.<sup>152</sup> Lastly, we included work status (working full-time compared to part-time or semi-retired).

## **Statistical Analysis**

Modified Poisson regression models for binary outcomes<sup>180,181</sup> were used to test the association between objective and subjective job demands and occupational injury in the subsequent time period. We used robust variance estimates<sup>104</sup> and clustered on the level of the individual to account for participants included in multiple study periods. Pearson's goodness-of-fit tests were not significant, suggesting reasonable model fit for Poisson models. Within each domain (physical effort; lifting heavy objects; and stooping, kneeling, crouching), we generated separate models (1) with physical ability alone, (2) with physical ability and subjective job demand, and (3) with physical ability and objective job demand. We compared the information content of each set of models using the Akaike Information Criterion (AIC). AIC provides a means for comparing the fit of models having the same dependent variable, but differing independent variables. A lower score indicates comparatively better fit.<sup>182,183</sup>

We used interaction terms to examine the association between a mismatch between self-reported physical ability and job demand (measured subjectively or objectively) and the risk of occupational injury. Relative risks were reported for each combination of physical ability and job demand: (1) high physical ability/low job demand (reference group), (2) high physical ability/high job demand, (3) low physical ability/low job demand, and (4) low physical ability/high job demand.

All regressions were adjusted for age, sex, number of comorbidities, mobility, fine muscle strength, hearing, eyesight, and working status. Analyses were performed using STATA Version 13.1 (StataCorp, College Station, TX).

## **RESULTS**

### **Sample description**

The linked sample contained data from 7,386 surveys collected from 5,586 individuals. Overall, 313 individuals reported one or more occupational injuries (6%), with an rate of reporting any occupational injury at 22 per 1,000 person-years.

The length of job tenure ranged from 0 to 78 years, with a median of 15 years. Almost all individuals were under age 65 when they entered the study (Table 4.1). Individuals who sustained at least one occupational injury during the study generally resembled those who did not sustain an injury, with two exceptions—those in younger age categories and who worked full-time were more likely to report an occupational injury (Table 4.1).

In regression analysis (unadjusted for job demand, occupation, or industry), there were statistically significant associations between occupational injury and age, number of comorbidities, hearing, and working part-time (Appendix 4.B). Workers age 61-65 and 66 and above were at 40% lower risk of occupational injury compared to workers age 50-55.

### **Job demand and physical ability**

As Table 4.1 displays, results for self-reported physical abilities showed statistically significant differences in percentage injured for large muscle strength, lifting heavy objects, and stooping, kneeling or crouching. Occupational injuries were more common among those who reported low physical ability compared to those who reported high physical ability.

As shown in Figure 4.2, the mean and quartiles of subjectively-assessed job demands were generally higher than objective assessments from O\*NET. Table 4.2 presents the proportion of individuals with an occupational injury according to job demand metrics within each domain. The proportion of respondents reporting occupational injuries was higher in each case for those with high job demands compared to those with low job demands. There were low, positive correlations (0.03 to 0.37) between subjectively-assessed and objectively-assessed job demands within domains.

Table 4.3 shows results from models of the association among physical ability, subjective job demand, objective job demand, and occupational injury, adjusted for the health factors in Appendix 4.B. With the exception of physical ability relating to lifting, all job demand and physical ability metrics were significantly associated with occupational injury. For example, within Table 4.3 model 11, respondents stating that their job required frequent stooping, kneeling or crouching had almost double the risk of occupational injury compared to those stating their job rarely or never required stooping, kneeling or crouching, adjusted for physical ability (and factors listed in Appendix 4.B). Respondents stating they had no difficulty stooping, kneeling or crouching had 36% lower risk of occupational injury, adjusted for subjective job demand (and factors listed in Appendix 4.B). The AIC was lowest in models that included objective job demand for all 3 domains. The coefficient for physical ability was consistent across models that included and that excluded terms for job demand, suggesting that job demand did not have an influence on the importance of physical ability.

### **Job demand and physical ability interaction**

The models presented in Figure 4.3 shows for each domain a strong, statistically significant interaction between physical ability and job demand such that, compared to the safest situation (low job demand/high

physical ability), individuals with high job demand/low physical ability were at 2.21 to 3.91 times as great a risk of occupational injury. The heavy lifting domain within the subjective job demand metric was an exception- results were in the same direction as for the other domains but not statistically significant.

To assess if low physical ability was associated with higher injury risk compared to high physical ability when job demand was high (comparing a mismatch to a match within job demands), we changed the reference category to those with high job demand/high physical ability. The resultant model showed that compared to those with job demand and physical ability in agreement and both high, those with high job demand but low physical ability had a higher increased risk of occupational injury within the physical effort and stooping, kneeling, or crouching domains, subjective demand and objective demand- level scale metrics (RR 1.47-2.17, p-values <0.01) (data not shown).

## **DISCUSSION**

In this large cohort of older workers, respondents who reported higher levels of physical ability had lower risk of occupational injury than those who reported lower levels of physical ability. Conversely, people with higher levels of subjective and objective job demands had a higher risk of occupational injury than those with lower levels of subjective and objective job demands. These findings agreed with previous studies using O\*NET and other job demand-evaluation systems, which found higher objectively-measured physical job demands to be associated with adverse outcomes, including more costly workers compensation claims,<sup>177</sup> delayed return-to-work,<sup>141</sup> and occupational injury.<sup>154-156</sup> Additionally, results showed a large, statistically significant elevated risk of occupational injury among those with high job demands/low physical ability compared to both high job demand/high ability and low job demand/high physical ability.

Although the importance of matching job demand with physical ability has been hypothesized,<sup>33,66,143,157,160</sup> few studies have examined how occupational injury risk may be associated with a mismatch between physical ability and job demand. Our findings emphasize that in situations of high job demand for physical effort, low physical ability is associated with increased risk of occupational injury, more so than in situations when job

demand and physical ability are both high. Efforts to improve the match between occupational demand and physical ability may be particularly important for older adults because of the greater adverse outcomes associated with an occupational injury in that population, though initiatives to ameliorate the effects of a mismatch between job requirements and worker physical ability may benefit workers of all ages.

Within the domain of heavy lifting, the risk of injury was not significantly different in those with high job demand/low ability mismatch compared to those with high job demand and high physical ability, although the same direction of effect was present. It is possible that workers were able to customize their jobs to their own physical abilities within this domain. For example, lifting patients presents a challenge to nurses, a group which compared to other hospital workers, is at higher risk of occupational injury.<sup>184,185</sup> Nurses may avoid manually lifting patients, instead using patient handling equipment or lift teams.<sup>184</sup> Consequently, although lifting is a central requirement of their job, nurses may customize the job demand to their physical abilities.

There are generally two ways to ameliorate occupational injury risk when there is a mismatch between the demands of the job and the abilities of the worker: either improve physical health (or slow the rate of health decline) or adjust job demand. The former supports the potential benefits of workplace fitness programs and other worker health initiatives.<sup>160</sup> Profession and industry-specific studies have found a reduction in occupational injury rates after implementation of workplace health promotion programs that focus on exercise, stress reduction, quality of life, and health conditions.<sup>186-188</sup> Within the latter, physical job demand can be reduced by increased mechanization, ergonomic adjustment, or other functional modifications.<sup>33,189</sup>

An additional option was illustrated by a study in which isometric strength tests were used for new manufacturing employees whose jobs required heavy lifting. The subsequent injury rate among new employees of all ages qualified by this method was one third that of employees qualifying by traditional medical exam.<sup>190</sup> Tailoring or creating job qualification exams specifically to frequent or important physical demands could ensure the new worker's ability meets said demands. However, instituting these exams may be ethically and logistically impossible for current workers, a group which represents a sizable contingent within the older worker population. For example, HRS respondents within this study had a mean of 17 years working at their

current job. Conversely, workplace health promotion programs and functional modifications may benefit all workers.

Because our study used survey data, older adults were not randomly assigned to retire or work. Known as the healthy worker effect,<sup>33,191</sup> many workers with poor health may have retired while many older workers may have self-selected into jobs they could physically perform.<sup>141</sup> This could be considered self-matching physical ability and job demand.<sup>190</sup> Managerial oversight and responsiveness and environmental modifications have been shown to contribute to making workplaces older-worker friendly.<sup>66,70,149</sup> These same factors may make self-matching possible.

Regarding the comparison of job demand metrics in predicting risk of injury, models with physical ability and objective job demand appeared to fit the data better as indicated by lower AICs compared to models based on physical ability and subjective job demand metrics or physical ability alone. This better fit could reflect the different aspects of job demand measured by subjective and objective job demands. Subjective job demand measures self-rated frequency with which a worker performs a physical action.<sup>179</sup> Within objective job demand, the level scale relates to the required rigor or expertise needed, the importance scale to how critical an action is to a job, and the context scale to the regularity of doing an action. It is possible that the self-rated frequency (from subjective demand) is less related to occupational injury risk compared to or how intensively they do it (from the objective demand, level scale) or how central the action is to the job (from objective demand, importance scale). Within the importance scale, greater task-specific importance may make it difficult for the worker to off-load or modify the task if it becomes too physically job demanding to perform safely. Within the level scale, in terms of intensiveness of an action, older adults on average have reduced oxygen uptake<sup>66</sup> which, in association with other changes in health, may impact stamina and physical strength.<sup>34,66-70,149</sup> High intensity activities may be particularly hazardous for older workers. In terms of injury prevention, the results of the AIC comparison emphasizes the need to look beyond frequency of task to intensiveness or importance of a task when considering risk.

Additionally, while models including objective metrics appeared to be more informative than subjective metrics, all models with job demand metrics were more informative than models with physical ability alone. This reinforces the importance of incorporating some objective or subjective measure of job demands, in addition to physical ability, in future research on occupational injuries. Using AIC to compare job demands showed that O\*NET can provide demand measures through occupation codes. This study demonstrates that O\*NET can be a valuable resource for studies using databases that do not contain measures of job demand. Furthermore, O\*NET's wealth of job descriptions provides details on occupational characteristics that may not be otherwise available to researchers.

### **Strengths and limitations**

This study's strength rests with the links between physical ability and job demand, with the latter measured from the personal (subjective) within HRS and the expert (objective) perspective measured in O\*NET. These data sources also limit the study. HRS gathers no data on severity or mechanism of occupational injuries. This limits the ability to make a more detailed assessment of occupational injury risk. Reported injuries were nonfatal but were severe enough to be recalled at the next HRS study visit up to two years later. There is no other measure available to us to classify minor versus major injuries. Due to the potential for recall bias, the exposure data likely capture a higher proportion of severe injuries than minor injuries. While HRS does include data on the number of occupational injuries, we did not use this count as repeated injuries may relate to injury severity (e.g. a person with a minor injury may proceed to have other minor injuries while a person with a very severe injury may not be able to return to work and sustain another injury).

Health measures, including eyesight, hearing, and physical ability were self-reported. While including information about these factors in our models can be considered a study strength, self-reported health measures, notably among older adults, can be inaccurate.<sup>192</sup> Furthermore, some individuals may have changed jobs between the collection of ability, job demand, and occupation title data, and then sustaining an occupational injury in an unrelated job.

Lastly, HRS and O\*NET metrics could have shortcomings with content and structural validity. Although some areas of the objective job demand metrics have been used and validated by other studies (see Appendix 4.A), other objective metrics and the subjective HRS metrics have not. Although most metrics were clearly and narrowly defined, it is possible that the items, individually and when combined by scale, may not fully represent the construct of interest. In addition, O\*NET provides exposure ratings for the average worker, based on average assessments. These assessments could misclassify exposure for an individual worker, even if it accurately represents exposure within the job category overall.<sup>193,194</sup>

## **CONCLUSION**

This study suggests that older workers' physical ability and job demand are associated with risk of injury. In particular, mismatch between physical ability and job demand was associated with higher risk of occupational injury. Because older workers are more vulnerable to labor market issues and severe, costly injury,<sup>195</sup> studying these issues within an age-specific context may be important. An examination of the job characteristics associated with injury and the most common physical activities among older workers may also be useful.

Preventing occupational injuries may help to keep workers healthier and active in the workforce, decrease job stress and turnover intent, and increase job satisfaction.<sup>196</sup> Understanding determinants of injury among older adults, and orienting workplace health initiatives accordingly, increases our ability to retain and protect these workers in the workforce.

Figure 4.1: Diagram of the relationships between data and key phraseology used

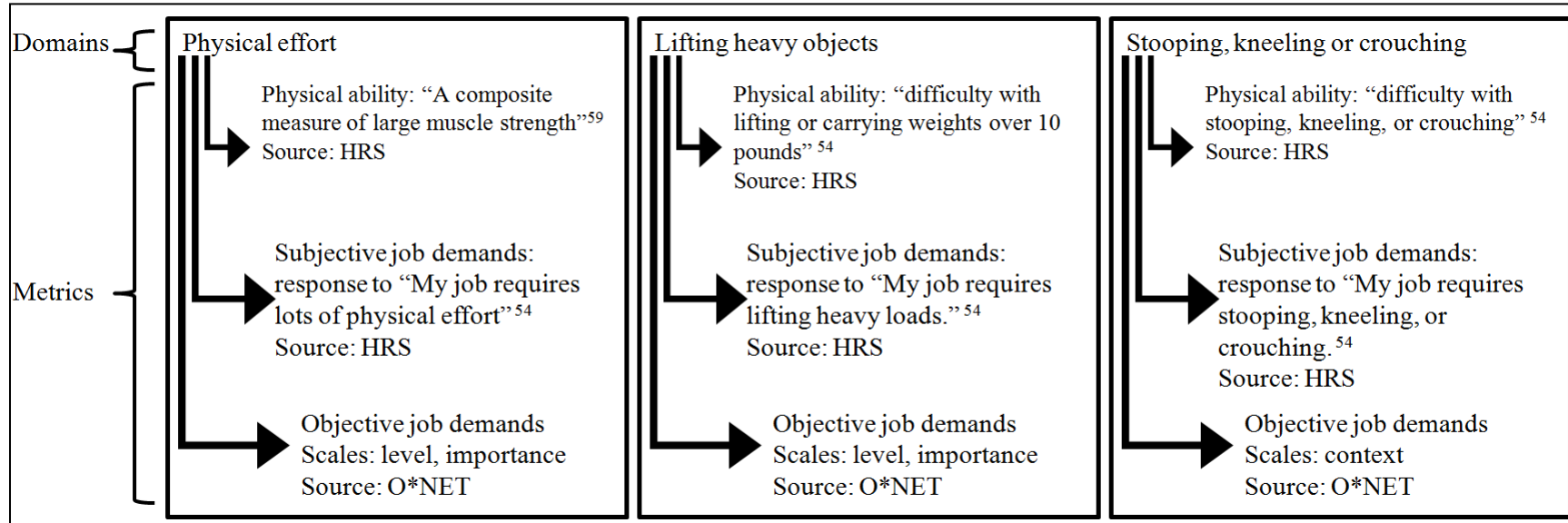


Table 4.1. Survey respondent characteristics at study entry, comparing those who sustained an occupational injury at some time during the study years to those who never sustained an occupational injury

<b>Health, demographic, and work characteristics</b>				
	Sample size (N=5,586)	No injury (N=5,273)	Injured (N=313)	p-value <sup>^</sup>
Age at first year of study inclusion				p<0.01
50-55	2,156	92.95%	7.05%	
56-60	1,622	93.65%	6.35%	
61-65	782	97.19%	2.81%	
66+	1,026	96.49%	3.51%	
Sex				0.22
Male	2,776	94.02%	5.98%	
Female	2,810	94.77%	5.23%	
Hearing				0.16
Excellent-very good- good	4,836	93.32%	6.68%	
Fair poor-legally deaf	750	94.58%	5.42%	
Eyesight				0.29
Excellent-very good-good	4,569	93.73%	6.27%	
Fair poor-legally blind	1,017	94.54%	5.46%	
Count of medical conditions*				0.11
0	1,655	94.68%	5.32%	
1	1,787	95.24%	4.76%	
2+	2,144	93.47%	6.53%	
Difficulty with mobility <sup>Ω</sup>				0.21
Difficulty with 0 to 2 activities	5,312	94.48%	5.52%	
Difficulty with 3 to 5 activities	274	92.70%	7.30%	
Difficulty with fine motor skills <sup>μ</sup>				0.91
Difficulty with 0 to 1 activities	5,553	99.41%	99.36%	
Difficulty with 2 to 3 activities	33	93.94%	0.64%	
Working status				<0.01
Full-time	3,683	93.65%	6.35%	
Part-time	1,903	95.85%	4.15%	
<b>Physical ability<sup>∞</sup></b>				
Difficulty with large muscle strength <sup>#</sup>				<0.01
Difficulty with 0 to 1 activities	4,312	95.11%	4.89%	
Difficulty with 2 to 4 activities	1,274	91.99%	8.01%	
Difficulty lifting heavy objects				0.01
No difficulty	5,047	94.65%	5.35%	
Yes difficulty	539	92.01%	7.99%	
Difficulty stooping, kneeling, or crouching				<0.01
No difficulty	3,892	95.25%	4.75%	
Yes difficulty	1,694	92.55%	7.45%	

<sup>^</sup>p-value represents the results of a chi-squared test of homogeneity

\*This is a composite measure of how many diseases the respondent has ever been diagnosed with by a doctor. Diseases include high blood pressure, diabetes, cancer, lung disease, heart disease, stroke, psychiatric problems, and arthritis

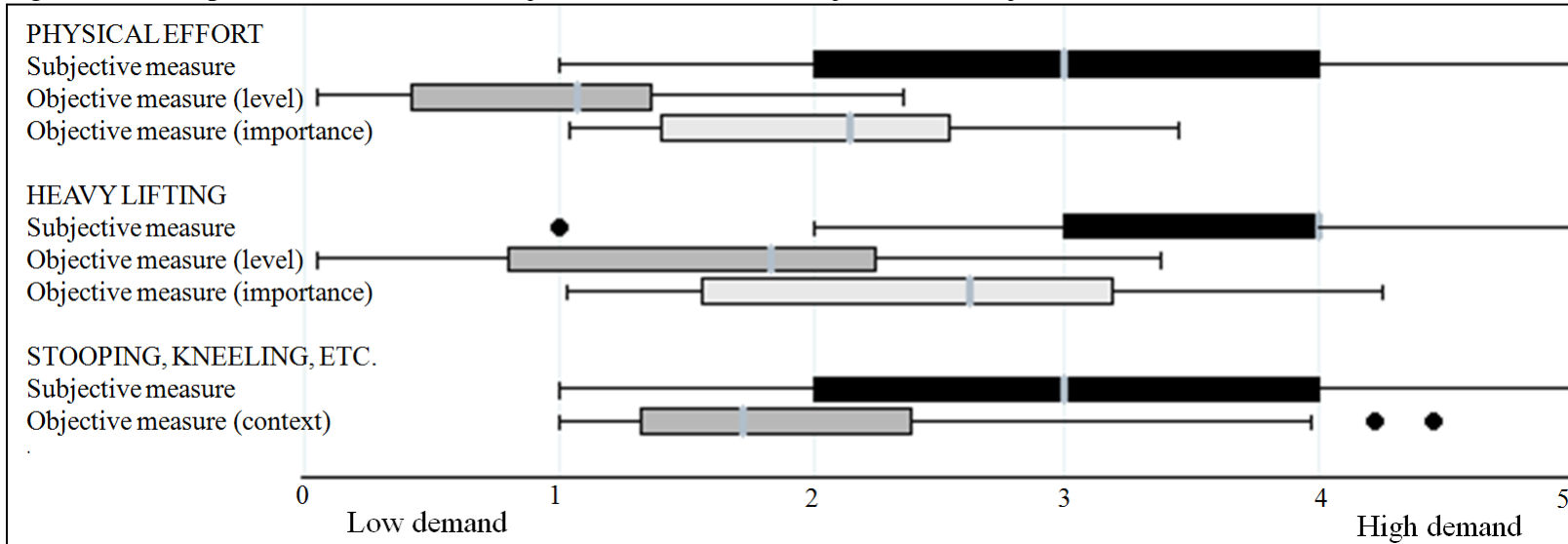
<sup>Ω</sup> This is a composite measure of mobility. It is the number of activities a respondent has difficulty doing: walking a block, walking several blocks, walking across a room, climbing a flight of stairs, and climbing several flights of stairs.

"This is a composite measure of fine muscle strength. It is the number of activities a respondent has difficulty doing: picking up a dime, eating, and dressing activities.

<sup>∞</sup>High physical ability includes "no difficulty" and "difficulty with 0 to 1 items." Low physical ability includes "yes difficulty" and "difficulty with 2 to 4 items."

#This is a composite measure of large muscle strength. It is the number of activities a respondent has difficulty doing: sitting for 2 hrs., getting up from a chair, stooping, kneeling or crouching, and pushing or pulling large objects.

Figure 4.2: Box plot of the distribution of job demand metrics, subjective and objective



The level scale ranges from 0 to 7 on O\*NET. In order for it to align with the other metrics here, which use a 1 to 5 range, it has been recalibrated. These metrics were dichotomized within the analysis. They were presented here to show the range and differences in responses.

Table 4.2: Percent of respondents with an occupational injury by job demand

Demand metrics	Physical domain					
	Physical effort		Lifting heavy objects		Stooping, kneeling, or crouching	
	low job demand	high job demand	low job demand	high job demand	low job demand	high job demand
HRS Respondent-based subjectively-assessed job demand	4%	9%	5%	9%	5%	9%
O*NET-based objectively-assessed job demand						
level scale	5%	12%	4%	8%	N/A	N/A
importance scale	5%	8%	4%	7%	N/A	N/A
context scale	N/A	N/A	N/A	N/A	5%	8%

Table 4.3. Comparison of models, adjusted for covariates in Appendix 4.B (i.e. comorbidities, sex, difficulty with mobility, difficulty with fine motor skills, hearing, eyesight, age, and working status)

Physical ability and job demand by domain*		RR	95% CI		P-value	AIC
BASE MODEL	Model 1: Job demand or physical abilities metrics not included	NA	NA	NA	NA	2624
PHYSICAL EFFORT	Model 2: High physical ability*	0.57	0.44	, 0.74	<0.01	2609
	Model 3: High physical ability* High subjective job demand <sup>Ω</sup>	0.62	0.48	, 0.80	<0.01	2490
		2.22	1.76	, 2.80	<0.01	
	Model 4: High physical ability* Objective job demand (level scale) <sup>Ω</sup>	0.55	0.42	, 0.71	<0.01	2484
		1.91	1.29	, 2.84	<0.01	
Model 5: High physical ability* Objective job demand (importance scale) <sup>Ω</sup>	0.56	0.43	, 0.73	<0.01	2473	
	1.70	1.35	, 2.15	<0.01		
LIFTING HEAVY OBJECTS	Model 6: High physical ability*	0.73	0.51	, 1.04	0.08	2623
	Model 7: High physical ability* High Subjective job demand <sup>Ω</sup>	0.74	0.52	, 1.07	0.11	2535
		1.72	1.35	, 2.17	<0.01	
	Model 8: High physical ability* High Objective job demand (level scale) <sup>Ω</sup>	0.71	0.50	, 1.03	0.07	2474
		2.00	1.58	, 2.53	<0.01	
Model 9: High physical ability* Objective job demand (importance scale) <sup>Ω</sup>	0.72	0.50	, 1.04	0.08	2472	
	2.07	1.61	, 2.65	<0.01		
STOOPING, KNEELING, OR CROUCHING	Model 10: High physical ability*	0.64	0.50	, 0.81	<0.01	2602
	Model 11: High physical ability* High Subjective job demand <sup>Ω</sup>	0.64	0.50	, 0.81	<0.01	2501
		1.91	1.52	, 2.40	<0.01	
Model 12: High physical ability* High Objective job demand (context scale) <sup>Ω</sup>	0.62	0.48	, 0.79	<0.01	2465	
		1.65	1.29	, 2.11	<0.01	

All models were adjusted for the variables in Appendix 4.B

\*reference group: low physical ability

<sup>Ω</sup> reference group: low job demand

Figure 4.3: Table of relative risk of occupational injury associated with the match between job demand and concomitant physical ability, adjusted for health factors\*\*

	subjective job demand		objective job demand (level scale)		objective job demand (importance scale)		objective job demand (context scale)	
	high job demand	low job demand	high job demand	low job demand	high job demand	low job demand	high job demand	low job demand
<b>PHYSICAL EFFORT</b>								
High physical ability	2.25*	<b>reference</b>	1.80*	<b>reference</b>	1.96*	<b>reference</b>	n/a	n/a
Low physical ability	3.60*	1.69*	3.91*	1.78*	2.72*	2.11*	n/a	n/a
<b>LIFTING HEAVY OBJECTS</b>								
High physical ability	1.46	<b>reference</b>	2.23*	<b>reference</b>	2.32*	<b>reference</b>	n/a	n/a
Low physical ability	1.90	1.80*	2.21*	2.12*	2.40*	2.32*	n/a	n/a
<b>STOOPING, KNEELING, OR CROUCHING</b>								
High physical ability	2.00*	<b>reference</b>	n/a	n/a	n/a	n/a	2.07*	<b>reference</b>
Low physical ability	2.94*	1.65*	n/a	n/a	n/a	n/a	2.26*	1.96*

All models were adjusted for the variables in Appendix 4.B

\*statistically significant (p-value <0.05) relative risk compared to "high physical ability/high job demand"

Appendix 4.A: A list of each grouped physical ability/job demand interplay, subjective job demands from HRS, and objective job demands from O\*NET domains response recoding

<b>Domain</b>	<b>HRS physical ability*</b>	<b>HRS Respondent-based subjectively-assessed job demand*</b>	<b>O*NET based objectively-assessed job demand<sup>#</sup></b>
<b>PHYSICAL EFFORT</b>	"A composite measure of large muscle strength created by RAND. It is the number of activities a respondent has difficulty doing: sitting for 2 hrs., getting up from a chair, stooping, kneeling or crouching, and pushing or pulling large objects. For each activity, 0 meant the respondent had no difficulty with the activity and 1 meant difficulty" <sup>∞</sup>	"Individuals respond to the following prompt: Thinking of your job, please tell me how often this statement is true: My job requires lots of physical effort. 1. all or almost all the time 1. most of the time 0. some of the time 0. none or almost none of the time 0. does not apply Missing (excluded): Don't Know, Not Ascertained, Refused, Inapplicable); Partial Interview" <sup>Ω</sup>	"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." <sup>154,197,198</sup> (level and importance scales) "Dynamic Strength — The ability to exert muscle force repeatedly or continuously over time. This involves muscular endurance and resistance to muscle fatigue." (level and importance scales) "Explosive Strength — The ability to use short bursts of muscle force to propel oneself (as in jumping or sprinting), or to throw an object." (level and importance scales) "Stamina — The ability to exert yourself physically over long periods of time without getting winded or out of breath." (level and importance scales) "Trunk Strength — The ability to use your abdominal and lower back muscles to support part of the body repeatedly or continuously over time without 'giving out' or fatiguing." (level and importance scales)

<b>LIFTING HEAVY OBJECTS</b>	<p><i>"Individuals respond to the following prompt:</i> Because of a health problem do you have any difficulty with lifting or carrying weights over 10 pounds, like a heavy bag of groceries? 1. no 0. yes 0. can't do 0. don't do Missing (excluded): don't know, refuse, inapplicable"<sup>Ω</sup></p>	<p><i>"Individuals respond to the following prompt:</i> Thinking of your job, please tell me how often this statement is true: My job requires lifting heavy loads. 1. all or almost all the time 1. most of the time 0. some of the time 0. none or almost none of the time 0. does not apply Missing (excluded): Don't Know, Not Ascertained, Refused, Inapplicable), Partial Interview"<sup>Ω</sup></p>	<p><i>"Handling and Moving Objects — Using hands and arms in handling, installing, positioning, and moving materials, and manipulating things" (importance and level scales) "Static Strength — The ability to exert maximum muscle force to lift, push, pull, or carry objects."<sup>154,193,197</sup> (importance and level scales)</i></p>
<b>STOOPING, KNEELING, OR CROUCHING</b>	<p><i>"Individuals respond to the following prompt:</i> Because of a health problem do you have any difficulty with stooping, kneeling, or crouching? 1. no 0. yes 0. can't do 0. don't do Missing (excluded): don't know refuse, inapplicable"<sup>Ω</sup></p>	<p><i>"Individuals respond to the following prompt:</i> Thinking of your job, please tell me how often this statement is true: My job requires stooping, kneeling, or crouching. 1. all or almost all the time 1. most of the time 0. some of the time 0. none or almost none of the time 0. does not apply Missing (excluded): Don't Know, Not Ascertained, Refused, Inapplicable), Partial Interview"<sup>Ω</sup></p>	<p><i>"Spend Time Kneeling, Crouching, Stooping, or Crawling — How much does this job require kneeling, crouching, stooping or crawling?"<sup>154,199,200</sup> (context scale)</i></p>

\*HRS descriptions of job demands for all three subjective job demand descriptions and physical ability for two domains (except for physical effort) came from the HRS codebook.<sup>173</sup> The description of the physical ability for physical effort is quoted from RAND<sup>179</sup>

#O\*NET's description of workplace attributes came from the O\*NET website<sup>169,201</sup>

"The context and importance scales from O\*NET's objective measures are continuous and dichotomized at 2.5, so that 1.0 to 2.49 can be considered "low frequency/importance " and 2.5 to 5.0 can be considered "high importance" The level scales from O\*NET's objective measures is also continuous and dichotomized at 3, so that 0 to 3.0 can be considered "low demand" and 4.01 to 7 can be considered "high demand"

<sup>Ω</sup> HRS responses represented here were made binary. The coding represented here was assigned by this study and not by the HRS.

<sup>∞</sup>Responses made binary by dichotomizing at 2 so that 0 to 1 was coded as 1 and 2 through 4 were coded as 0. We chose to dichotomize based on the codebook's listed possible responses rather than individuals' responses (e.g. using the mean or median) to generate a metric extrinsic to the data, consistent with other metric.

Appendix 4.B. Multivariate base model of covariates and their association with occupational injury in subsequent injury.

	relative risk	95% CI		p-value
Comorbidities (count)	1.18	1.08	1.30	<0.01
Female (vs. male)	0.89	0.72	1.11	0.32
Difficulty with mobility	0.93	0.58	1.51	0.78
Difficulty with fine motor skills	0.83	0.28	2.48	0.74
Hearing*	0.67	0.51	0.88	<0.01
Eyesight^	1.07	0.80	1.43	0.64
Work part-time ((reference: full-time)	0.68	0.51	0.90	<0.01
Age (yrs.)				<0.01
50-55	reference			
56-60	0.87	0.68	1.12	
61-65	0.40	0.26	0.62	
66+	0.40	0.27	0.61	

This table does not include primary variables of interest (e.g. physical ability and job demand)

\*excellent-very good-good vs. fair poor-legally deaf (reference)

^excellent-very good-good vs. fair poor-legally blind (reference)

## **CHAPTER 5: CONCLUSION**

This dissertation investigated risk factors for vehicle crash among older adult drivers and occupational injury risk among older workers. In Aim A (chapter 2), we reported findings on the association between cognition and the risk of motor vehicle crash among older drivers without dementia. Older adults had a 28% higher (95% CI 1.08-1.51) crash risk associated with a one unit lower CASI-IRT score. Aim B (Chapter 3) examined the association between dementia diagnosis and crash risk among older adult drivers. Participants were members of Group Health. Health records were merged with Washington State crash and licensure data. Older adults with diagnosed dementia were paradoxically at lower crash risk (HR= 0.56, 95% CI 0.33, 0.95). In Aim C (Chapter 4), we explored the association between job demands, physical ability, and older worker occupational injury within physical domains using data from the HRS and O\*NET. Results showed that when job demands were high, a mismatch between physical ability and job demands was associated with higher risk of occupational injury.

## **DISCUSSION**

### **Older Drivers**

Results from Aim A (Chapter 2) suggested that crash risk differed by level of cognition in the pre-diagnosis stages of dementia. This finding was particularly persuasive because of the decrease in crash risk after dementia diagnosis seen in Chapter 3 (Aim B), suggesting diagnosis may have generated risk reduction actions by reducing exposure, although other possible explanations exist.

Objectively gathered exposure data is needed to confirm that reduced exposure is fueling the lower crash risk seen in Chapter 3 (Aim B), while minimally impacting the results in Chapter 2

(Aim A). Both Chapters 2 and 3 (Aims A and B) presented crash risk per licensed driver-year, not per mile driven. Within Chapter 2 (Aim A), exposure may not have differed widely within individuals over time as they had not received a diagnosis of dementia.

Beyond these studies, there is a general need for longitudinal exposure data on mileage, driving habits, and driving abilities. Merging exposure data with health and lifestyle data would yield a wealth of information on how driving habits adapt to life course changes, and how the older driver and their family's daily life adapts to changing risk related to driving ability. Technologies, notably through smartphone apps, could allow relatively easy, low-cost monitoring options to assess driving exposure and habits. These apps may be used in conjunction with ongoing studies of cognition and health.

Within the field of older driver crash prevention, at least six categories of stakeholders exist: older drivers, their families, care providers including clinicians, nurses, and occupational therapists, state Department of Motor Vehicles (DMVs), other road users, and medical and vehicle insurers. Results from Aim B were consistent with the possibility that discussions on driving attenuation and cessation may already be taking place among these stakeholders. However, results from Aim A and B provided no information on how driving decisions were made, if the actions were appropriate to the current crash risk, and on the long term impact of this decision on drivers and their families. A small qualitative study found that six months after driving cessation due to dementia, older drivers and their families both expressed extreme dissatisfaction with how the decision to cease driving was made, and with current transportation arrangements.<sup>202</sup>

A set of standards, both general and personalized to the older driver, could act as signposts to empower the driver and their families to start discussions on driving and to articulate priorities.

Akin to a living will, such a plan generated before a health crisis occurs allows more objectivity, more time to identify potential resources, and overall presents a strength-based approach to driving safety. This plan will likely require modifications over time as needs, priorities, abilities, circumstances, and preferences change. This recommendation relies on signposts which research has yet to generate. Further investigation in early markers of decline in driving ability, e.g. minor collisions, is needed. Results from Aim A, which support cross-sectional assessment of crash risk related to cognition function measures, suggest that such signposts are identifiable.

In addition, care provider-older driver discussions of driving attenuation and cessation may benefit from a strong, clinically relevant, minimally burdensome, minimally invasive, cost-efficient safe-driving estimation tool for older drivers. The estimation tool must have high sensitivity and specificity and require little to no special equipment, such as a driving track or simulator. It is likely that no such tool currently exists.

We do not yet know how to fully realize the utility of the fourth stakeholder category, DMVs, in improving older driver safety. Over half of U.S. states have laws specific to licensure among older adults,<sup>203</sup> although only in-person license renewal has been shown to reduce crashes, and then only among individuals age 85 and above.<sup>204</sup> Experiments in California and Maryland with license cognitive screening pilot programs set within state DMVs at license renewal led respectively to no and limited success at identifying drivers with a cognitive impairment impacting driving ability.<sup>23,114,205,206</sup>

An ideal system would provide coordination and communication between older adults, their families, DMVs, and care providers. The question of how to deliver the necessary triage, evaluation, referral, and short- or long-term planning is complicated. Although advances have

been made in older driver health, considerable research is required to understand how best to integrate these systems, efficiently, equitably, and effectively.<sup>207</sup>

Last, as stated in Chapters 2 and 3 (Aims A and B), although ceasing to drive nullifies crash risk, there is a concomitant increase in risk of other negative health outcomes. Current alternative transportation options include public transit, paratransit, busing and taxiing services from community-based organizations, taxis, and ride-share programs such as Uber and Silver Ride. However if driving reduction and cessation are endorsed as a solution to the issue of crash risk associated with declining health, there is a need for data to evaluate how well these transportation options meet older adults' needs, in terms of availability, safety, and customization. Notably, these transportation options may leave behind the poor and people living in rural settings.

### **Older workers**

Aim C (Chapter 4) findings showed a strong relationship between physical ability, job demands and occupational injury risk. Our findings emphasized the importance of including job demand measures in occupational health research, demonstrated that these job demand measures can be derived from O\*NET, and showed that O\*NET job demands are at least as informative as self-reported job demands in predicting occupational injury. In Aim C (Chapter 4) we demonstrated the risk inherent in a mismatch between job demands and physical ability. We considered several attenuation strategies within the Discussion section.

Although work environment, physical ability, and job demands impact all workers, because older workers are more vulnerable to labor market issues and severe, costly injury,<sup>195</sup> studying these issues within an age-specific context is vital. Preventing occupational injuries not only

contributes to keeping workers healthy and active in the workforce, but also may decrease job stress and turnover intent while increasing job satisfaction.<sup>196</sup> Understanding determinants of injury among older adults increases our ability to retain and protect these workers in the workforce.

One of the mechanisms discussed in Aim C to attenuate the negative effect of a mismatch was workplace health promotion programs. Profession-, injury-, and industry-specific studies have found a relationship between managerial safety leadership, workplace fairness, cooperative employer attitude, safety diligence, workplace social support, and ergonomic practices with return to work post injury and decreased incidence of occupational injury.<sup>208-210</sup> Although theorized to be especially beneficial,<sup>72</sup> workplace factors and programs relating to injury reduction specific to older workers remain relatively unexplored.<sup>66,70,146</sup> Future research in this area could prove fruitful.

Similar to Aims A and B, there is also the need for accurate exposure measures in occupational injury. Although over two-thirds of older workers are employed full-time,<sup>138</sup> hours worked among part-time workers and detailed task-specific exposure data among all workers would facilitate a more thorough understanding of occupational injury risk.

## **SIGNIFICANCE**

This dissertation expanded the knowledge base and contributed to the science of injury prevention for this rapidly growing group of Americans. Older adult injury prevention is a relatively nascent field of research. The need to continue to perform foundational research, notably informed by exposure measures, is great.

Currently aging people, their families, their caregivers, their employers, their clinicians, their colleagues, people who share the road with them, insurance companies, and state licensing and regulatory agencies -- all these stakeholders are operating with incomplete and unsatisfactory evidence to make important individual-level and societal-level decisions. The present analyses have provided some glimpses of what that evidence might look like. Much more needs to be done to address these critical questions to enhance the quality and quantity of life for older people.

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