An Evaluation of Sitting Time and Physical Inactivity on Back Pain and Productivity Loss Among Services Sector Workers

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Abstract

Within the workplace, the relationship between sedentary behaviors and back pain, and the impacts on worker productivity remain unclear.

Data from a 2010 employee health assessment survey was utilized to evaluate the impact of sitting time and physical inactivity on back pain and productivity loss in a sample of public administration industry (e.g., services sector) workers. Directed Acyclic Graphs (DAGs) informed multivariate logistical models within two cross-sectional studies that 1) established a sedentary risk profile for back pain and 2) evaluated the interactive effect of physical inactivity and sitting on back pain and productivity loss.

Results from this study suggest that both non-modifiable factors, such as age, gender, education, and job classification, and modifiable factors, such as sedentary behaviors, high BMI and tobacco use, are important when designing health promotion programs to prevent and treat back pain in a working population. Results also suggest that prolonged sitting time has an interactive effect with physical inactivity, and therefore, when assessing risk in an employee population, employers should consider both physical activity and sedentary exposures at work and during leisure to gain a complete understanding of total worker exposures.

Results support the National Institute for Occupational Safety and Health's Total Worker Health™ strategy by informing the direction of future research aimed at utilizing health risk assessment screening tools for occupational back pain and interventions that extend healthy lives of workers and reduce the burdens of illness and disability.

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Chapter 1. Introduction

The National Institute for Occupational Safety and Health (NIOSH) reports that musculoskeletal injuries, including back injuries, are a priority for the National Occupational Research Agenda (NORA) and the U.S. Services Sector. (1) Appendix A details the major industries within the services sector, and the number of workers within each industry nationally. The study sample is a representation of the public administration industry of the services sector, which includes over 4.0 million workers nationwide.

Chronic back pain is associated with poor health-related quality of life in working populations. (2-6) Although the etiology of back pain is complex and not fully understood, (7) it is well established that sedentary behavior is associated with back pain. (8, 9) Employer-based programs that promote physical activity, ambulation, and/or periodic standing are particularly valuable because they improve employee productivity and reduce short-term disability leave, employee turnover, absenteeism, and healthcare costs. (10-13) Sedentary behavior is characterized by sitting or reclining and requires less than or equal to 1.5 METs (multiples of the basal metabolic rate) (14) and is now understood to be a health risk that is additional to, and distinct from, too little exercise and warrants further investigation on its relationship to back pain in a working population.

Because both work-related factors and health factors beyond the workplace contribute to health and safety problems, (15, 16) it is important to measure both work and non-work exposures to sedentary behaviors in employee populations. Current research on sedentary behaviors is dominated by a focus on obesity prevention and has been associated with negative effects on metabolic, bone, vascular health, and total mortality, (17, 18) in addition to cardiovascular and metabolic diseases, cancer, and psychosomatic problems. (19-21)

Sitting and Back Pain

In addition to heavy physical work, heavy or frequent lifting, non-neutral postures, and exposure to whole body vibration, sitting (as a function of sedentary job type) is a commonly cited occupational behavior associated with low back pain, (22) yet empirical findings from studies on the adult working population do not clearly reveal the causal pathway of this specific sedentary behavior on the outcome of back pain. (23-27) Some of the ambiguity may be explained by the "U-shaped" relationship physical activity has with back pain (i.e., too little physical activity, as in sedentary lifestyle, and/or too much physical activity, as in overexertion from strenuous activities). (28, 29) In an effort to understand how to reduce sedentary behaviors such as sitting in the workplace, recent studies have focused on how to engage employees in physical activity programs to get them moving more inside and outside of the workplace. Primary outcomes investigated have included obesity, (20, 30-32) diabetes, (30, 33) cardiovascular disease, and (12, 21, 30, 33, 34) and all cause mortality. (18-20, 35) Within the workplace, breaks in prolonged sitting time (e.g., from periodic standing or ambulating) have been associated with lower health risks and related to waist circumference, body mass index (BMI), triglyceride levels, and 2-hour plasma glucose levels, (36, 37) but the effects of sedentary behaviors such as sitting and physical inactivity on back pain are unclear.

Physical Inactivity and Sitting Time

One of the growing areas of research includes the distinction between the risk factor of not being physically active (i.e., meeting a guideline) and sedentary behavior (i.e., sitting too much) as they pertain to chronic health outcomes, (12, 18-20, 22, 30, 34, 38-51) but the relationship between physical activity and back pain is not linear and therefore measuring physical *in*activity by not meeting guidelines likely fails to capture the full relationship as it pertains to back pain.

Several authors have published systematic reviews of primary research on sedentary behaviors, including sitting, and back pain in the workplace, but results thus far have been inconsistent on the causal association in the adult working population. (24, 52, 53) The conflicting results of these reviews are likely due to the different populations and settings being studied (e.g., adolescents in a school setting versus working adults) and the inconsistency in how sedentary behavior is measured (e.g., television watching, physical activity guidelines, or prolonged sitting time). Furthermore, studies that use physical activity guidelines to capture sedentary behaviors in workers could be missing activity patterns in the workplace or during leisure time. (38, 41, 41, 49) Because sitting is a *very specific behavior* while not meeting physical inactivity guidelines refers to a *broader risk factor that may be addressed by several different behaviors*, they should not be used interchangeably; further research on the distinction and interactions between the two is warranted.

Sedentary Behavior and Productivity Loss

Health-related productivity loss occurs when health conditions increase work-related absences (absenteeism) and/or decrease performance while at work (presenteeism), creating a substantial economic burden on industry. (54, 55) Research has shown that among all preventable chronic conditions, injuries to the back are among the most costly in terms of productivity loss (9, 22, 55-57) yet to the author's knowledge, the literature on estimating total health-related productivity loss (e.g., absenteeism and presenteeism) attributable to the exposure of prolonged sitting (as opposed to back injuries) is lacking, particularly for public administration employees workers within the services sector.

An overarching goal of occupational health and safety research is to increase employees' health-related quality of life and reduce employers' costs related to preventable chronic health problems and disability in the workforce. The overall objective of this study, and a step toward attainment of the overarching goal, is to quantify the relationships between prolonged sitting, physical inactivity, back pain, and productivity loss within a working population. The contribution of this study is unique because it addresses NIOSH's Total Worker Health strategy goals. (15, 58) The study findings will contribute to planning and evaluation of worksite interventions for the selected workforce and may be translatable to practice in comparable worker populations.

Chapter 2. Background and Significance

Public Health Significance

Musculoskeletal disorders of the back are the most costly injuries in terms of excess absenteeism, presenteeism, and disability among workers (9) and are caused by a multitude of factors, many of which cannot be changed. (79) Due to technological advances, job tasks are becoming increasingly sedentary, causing prolonged periods of sitting and low levels of occupational physical activity, which predisposes employees to musculoskeletal problems. (59) Sitting is an amenable behavior associated with back pain, and because many workers spend more than half of their entire work day seated, the workplace is a key community venue for the promotion of physical activity and the reduction of sedentary time. (22, 59) The development of effective intervention strategies has been hampered by limited information on occupational behaviors amenable to change (e.g., sitting). (60)

Physical inactivity and too much sitting have been shown to be independently hazardous to human health in terms of morbidity and mortality (12, 30, 61, 62) and are associated with the most prevalent and costly chronic health outcomes such as back problems, heart disease, and diabetes. (13, 19, 44, 46) Although it is accepted that those who are inactive are also sedentary, workers might be physically active during leisure time, but experience prolonged sitting while at work because of sedentary job duties or vice versa. (44) This is known as the "active couch (or 'desk') potato phenomenon" which can be prevented by periodic standing or ambulating to avoid prolonged sitting. (12, 13, 44)

Health assessments are intended to gain information on the overall and group-specific prevalence of particular health events in a given population (i.e., services sector employees), with the purpose of helping organize resources to guide decision-making processes (e.g., sit-stand desks, physical activity programs, etc.). (63) The dataset utilized for this study consists of survey responses from employees of one Midwestern public administration employer who completed a health assessment in November, 2010. Preliminary analyses of the data indicated a high proportion of employees met physical activity guidelines relative to the nation (72% vs. 48%, respectively), yet 40% experienced back pain and, on average, spent 34 hours sitting in a usual week. (64, 65) The discrepancy between seemingly active employees and high prevalence of back pain could be explained by the "active couch (or 'desk') potato phenomenon." Furthermore, sedentary lifestyle is a known risk factor for back pain in the general working population, yet currently no definitive recommendations exist on how long people should sit or how often people should break up their sitting time. (39, 49) Because research on sitting time and back pain is ambiguous, this topic warrants investigation. (53, 66)

Physiology of Back Pain from Sitting

Sitting in a chair for long periods of time can be damaging to the physical human body because it impedes movement, which is optimal for healthy muscles and joints. (67) Compared to standing, the body position required for sitting puts added load on the (lumbar) spine so the longer a person sits, the more load is placed on the spine, potentially causing back injury and/or pain. (26) Furthermore, bone joints are lubricated by synovial fluid, which is maintained by movement. Movement is also necessary to maintain healthy joint cartilage and normal muscle tone, and lack of healthy joints and muscle tone is not always symptomatic (e.g., with pain). However, pain can be caused from nerve and/or tendon tightness or injuries due to static postures such as sitting at a computer and working a mouse for long periods of time. This posture and activity can cause tightness in neck muscles, which can spasm and wrap around the median nerve that runs from the neck to the hand, causing pain. (67) Because nerves and tendons are viscoelastic, the greater the velocity of stretch applied to them, the less stretch is available; this lack of stretch capability applies stress on the nerves, causing pain. (68) The physiology of back pain from sitting is complex and it is not entirely clear whether the solution is to move more or sit less (or both), particularly in an occupational setting. This suggests biological plausibility of the interaction between sitting time and physical inactivity.

Theoretical Frameworks

Total Worker Health

The NIOSH TWH™ program supports research that integrates occupational safety and health protection with health promotion, and views best practices as those that address health risks from both the physical and organizational work environment and individual behavior. The program is based on the theory that integrating or coordinating occupational safety and health with health promotion may increase program participation and effectiveness and may also benefit the broader context of work organization and environment (69) as well as improve the health and wellbeing of workers, families and communities**.** (15) Evidence supporting TWH™ -inspired programs is growing as summarized in three papers in the 2012 NIOSH Research Compendium. (16) Furthermore, a 2012 NIOSH blog post described how, as an organization, NIOSH is adapting findings from recent research (35) to their own workforce by launching an internal pilot program to explore the use of sit and stand work stations to reduce sedentary behavior among NIOSH workers. (70) Issues related to TWH™ are listed on the NIOSH website (15) and displayed in Figure 1**.**

One component of TWH™ addresses the need for research on the connections between health, productivity, and disability. From the perspective of a company, demonstrating the financial impact of risk behaviors and health conditions is critical for developing budgetary priorities, including the amounts allocated for employee benefits such as health insurance, health promotion programs, and disease management interventions. (56) Few authors (57, 71, 72) have quantified the economic costs of sedentary behavior in a setting. Oldridge, et. al's (2008) multinational study reported the proportions of direct health costs due to physical inactivity ranged 1.5% to 3%. (73) Cadilhac, et. al (2011) predicted cost savings associated with reductions in sedentary lifestyles and showed a savings of 2% in associated health care costs, absenteeism, and household productivity when sedentary lifestyle was reduced by 10% nationally, especially in government workers. (74) Pronk, et. al (2012) evaluated a sit-stand desk on measures of employee performance and found that use of sit-stand desks and reductions in sitting time were correlated with improved outcomes for upper back and neck pain as well as various mood states, including happiness and productivity. (22) Research on sedentary behavior and back pain on productivity thus far has focused on the cost of general and specific health outcomes (e.g., mortality, cardiovascular disease, diabetes, stroke, and back pain) (9, 55, 75, 76) as a function of sedentary behavior, not costs specifically attributable to sedentary behavior as the exposure. Within the occupational back pain literature, authors are increasingly measuring productivity loss as absenteeism (e.g., days of self-reported absence from work or sick days) due to back pain or musculoskeletal conditions (77-83) and/or presenteeism (e.g., not working up to full potential) due to back pain, (82-84) although this is still a relatively new topic within the occupational health setting. Therefore, tying a measure of productivity (e.g., that includes a dollar amount) to the impact of prolonged sitting and presenting the potential cost burden of modifiable behaviors can be extremely useful to employers.

Transtheoretical Model of Behavior Change

The Transtheoretical Model of behavior change (TTM) is a dynamic stage- and process-based health behavior theory developed by James O. Prochaska in 1977 and is based on intentions to change within a certain time period, usually six months. (85) The TTM can be used as a framework to plan and evaluate health promotion interventions in a workplace setting, and includes core concepts related to stages of change, processes of change, decisional balance, self-efficacy, and temptation. Having the ability to identify what "stage of change" an employee is in has been found to be helpful in tailoring physical activity interventions in employee populations. (86) Furthermore, certain covert and overt processes can be practiced or encouraged in the transition from one stage to another. In order to make decisions, an individual employee can weigh pros and cons and eventually reduce ambivalence towards positive change, which is called “decisional balance.” A core concept of the TTM is self-efficacy, a term for the level of confidence an individual has about initiating, or maintaining a behavior. The TTM addresses the issue of temptation, a reflection of the intensity of urges to go back to the baseline behavior during difficult situations. (87) In the workplace, an employee’s stage, level of self-efficacy, and temptation are often assessed by questionnaire, and processes can be utilized within an intervention such as a health coaching program to target employees where they are in terms of “readiness” to change. Using this model may help employers decide which types of programs may be most cost effective by targeting those who are ready to make changes to manage their health.

Literature Gaps

The gaps in the literature, which this study addresses, include those related to the etiology of occupational back pain, the distinction between physical inactivity, which can be addressed with increasing physical activity levels, and sitting time, which can be addressed by sitting less, and the impact of productivity in the workplace. The critical review of the literature in Chapter 3 indicates research on back pain as an outcome from the interplay of sedentary behaviors, prolonged sitting, and physical inactivity (e.g., sitting), particularly in the workplace, is minimal and inconclusive. Also lacking in the literature are documented costs of back pain specifically attributable to sedentary behaviors (e.g., sitting) in a working population. Because sedentary behavior, particularly sitting, is a behavior (i.e., and therefore, is amenable to change), determining the potential cost burden of sitting in terms of productivity (e.g., absenteeism and presenteeism), is valuable for employers, potentially creating a business case for change. The literature on this topic is scarce and particularly uncommon in occupational settings.

Unique Contribution

Employers can use the results of this research to inform cost-effective interventions aimed at reducing the prevalence of the most costly chronic health conditions, which can improve the overall productivity and quality of life of their workforce. (88) The contribution is significant because it is the first attempt at quantifying the relationship between prolonged sitting, physical inactivity, and back pain, and calculating the associated productivity loss in an employee population. The results also support the NIOSH TWH™ strategy by informing the direction of future research aimed at utilizing health risk assessment screening tools for occupational back pain and informing future research on interventions that extend healthy lives of workers and reduce the burdens of illness and disability.

Evidence is growing that environmental interventions, such as contemporary workstations that require intermittent standing or very slow walking, can double energy expenditure throughout the day and that employees enjoy using them, support their use, and wish they had the option to sit less at work. (88, 89) A growing interest in reducing the demand for health services, fueled by rising health care costs, is accelerating the need to identify appropriate prevention strategies. A paradigm shift in how physical activity is promoted within the workplace is underway, and this study provides data on the potential value of the scientific innovation of the "move more, sit less" approach. (12, 13, 18, 19, 30, 43, 44, 46) This paradigm shift may reduce the burden of injury and illness and improve the quality of life of workers experiencing back pain. Conceptualizing sedentary behavior to include physical inactivity and sitting time inside and outside of the workplace represents a NIOSH Total Worker Health (TWH)^{TM} strategy to address the preventable chronic health problems affecting a large proportion of workers.

Chapter 3. Systematic Literature Review

The Interplay of Sedentary Job, Physical Inactivity and Sitting Behavior on Back Pain in the Workplace: A Systematic Review

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Introduction

Prior to performing research studies on sedentary behaviors and back pain in the workplace, it is imperative to describe the current state of the literature pertaining to the topic, including gaps in the evidence that may be filled with future research. A focused research question was utilized to identify studies that assessed the impact of sedentary behaviors on back pain in the workplace. Studies were solicited based on *a priori* eligibility criteria and assessed for content and methodological quality. Results present gaps in the literature and a discussion of recommendations for future studies to address these gaps.

Motivation for Review

The significance of the problem

Injuries to the back exceed $50 billion per year in the United States (9, 55, 90, 91) yet cost effective programs to address back pain in the workplace are lacking. (12, 92) Furthermore, the development of effective intervention strategies has been hampered by limited information on occupational behaviors that are amenable to change (e.g., sitting) and programs tend to be physical activity-based and not targeted to sitting. (60) Recognized risk factors for back pain are: female gender, poor general health status, family history of back pain, psychosomatic patterns (such as poor job satisfaction (93, 94)), time spent sitting watching television, history of spinal trauma, intense physical activity, practicing competitive sports, and older age. (95) The purpose of this review is to increase our understanding of the impact of sedentary behaviors such as sitting and physical inactivity on the outcome of back pain as measured occurring in workplace populations. The secondary goal is to assess the methodological quality of published interventions aimed at improving back pain among sedentary workers.

Description of the exposure/intervention

Sitting (as a function of sedentary job type) is a commonly-cited occupational behavior associated with low back pain, (7, 22, 23, 29, 38, 42, 96-99) yet empirical findings from studies on the adult working population do not clearly reveal the causality of sedentary behavior on the outcome of back pain. (23-27) A growing area of research investigates the distinction between the risk factor of not being physically active (i.e., not meeting a guideline) and sedentary behavior (i.e., sitting too much) in association with chronic health outcomes, (12, 18-20, 22, 30, 34, 38-51) but the relationship between physical activity and back pain is not linear and therefore measuring physical inactivity by not meeting guidelines likely fails to capture the full relationship as it pertains to back pain.

The "U-shaped" relation between physical activity and back pain may explain some of the ambiguity in the literature on the association activity has with back pain (i.e., too little physical activity, as in sedentary lifestyle, and/or too much physical activity, as in overexertion from strenuous activities). (29) Ambiguity might be further explained by the lack of evidence on intervention programs that integrate health protection (i.e., in the workplace) and health promotion (i.e., in the home/community). Because both work-related factors and health factors beyond the workplace contribute to health and safety problems, (15, 16) it is important to measure both work and non-work exposures to sedentary behaviors in employee populations.

Previous Reviews

Roffey, et. al (2010) reviewed five studies on sitting and low back pain and reported strong, consistent evidence for no association between occupational sitting and low back pain utilizing Bradford Hill criteria for causality, and suggested sitting does not independently cause low back pain. (52) While Roffey and colleagues (2010) were specific and comprehensive in terms of reaching representative articles relevant to occupational sitting and back pain, they only included articles up through 2007, and the exclusion criteria may have been too restrictive as it prevented the inclusion of studies with sample sizes less than 30, treatment-only studies, and those related to non-specific back pain. Kwon, et. al (2011) utilized the same causality criteria to evaluate 24 occupational physical activity and sedentary behaviors (including the Roffey, et. al (2010) article on sitting) and found the overall evidence was conflicting on the causal relationship between low back pain and exposures to various occupational physical activity categories (manual handling/assisting patients, awkward postures, carrying, sitting, standing and walking). (24) Chen, et al (2009) evaluated eight cohort and case control studies published between 1998 and 2006 that assessed sedentary behaviors inside and outside of the workplace on the outcome of low back pain, (53) and reported inconclusive results with the exception for one particularly rigorous study that found a positive association between sedentary behavior and occupational back pain in adolescents. (100) Chen, et al (2009) reported on exposures inside and outside of the workplace, but they did not restrict the population to working-aged adults and only reviewed three occupational studies and therefore the conclusions may not be applicable to occupational back pain. Only Kwon, et al (2011) reported on both sedentary and physical activity behaviors in the workplace, but they also did not restrict the studies reviewed to working-aged adults and did not consider exposures outside of the workplace.

Contribution

Previous reviews that have focused on assessing the association between various sedentary behaviors on the outcome of back pain within the workplace are minimal and inconclusive. The contribution of this review is 1) an assessment of the current state of published studies that focus on sedentary behaviors and back pain in the workplace and 2) evidence on the joint contribution that both workplace and non-workplace exposures have on back health.

Research Question

The overall research question guiding the literature review was “Does prolonged sitting and/or physical inactivity cause back pain among workers with sedentary jobs?” Two key questions (KQ) informed the results of the overall research question:

KQ1*:* How are sedentary job, physical inactivity and sitting behavior conceptualized in occupational studies addressing back pain?

KQ2*:* How do interventions to address sedentary behavior differ from those that address physical activity in employees with back pain?

Methods

Search strategy for identification of studies

The general review methods included identifying potential links between exposures/interventions and relevant health outcomes, using inclusion criteria to search for studies, evaluating effectiveness of the interventions, and evaluating the content and quality of each study and the overall body of evidence. The Cochrane Handbook for Systematic Reviews of Interventions (101, 102) was used to guide the development of a review protocol, overall and key questions, database selection, search terminology, and bias and quality assessment. PubMed, Business Insurance, and RefWorks databases were utilized to search for studies related to the key questions. Key words and MeSH terms included: sitting, prolonged sitting, sitting time, sedentary (MeSH), occupation (MeSH), back pain (MeSH), physical activity (MeSH), exercise, and motor activity (MeSH). Review articles and editorials were excluded from the literature review, although they were utilized to "snowball" for primary research citations. "Gray" literature (i.e., unpublished) was not included in this review.

Selection of studies

From the search results, potentially eligible studies were reviewed to determine relevance to the "Population, Intervention/Exposure, Comparison, Outcome, Timing, Setting" (PICOTS) framework (103) specified in Table 1. Titles and abstracts were screened for eligibility first, and then full text. Date of search, search terminology, number of articles retrieved, and exported text file names were tracked in a separate spreadsheet. Articles were stored and organized in RefWorks™ Bibliographic Management Software (http://www.refworks.com). A detailed spreadsheet was used to organize the extracted data.

Data extraction and management

The reviewer abstracted and recorded each study's aims, methods, sample characteristics, results, and conclusions, (including whether or not the author(s) regarded the study as having demonstrated favorable, negative, or null results). (104) Also tracked were authors' definitions of back pain, physical activity, prolonged sitting, and sedentary (lifestyle and/or job), and productivity (loss). The literature is presented chronologically to depict the ascending historical evolution of the designs and methods of studies on the topic to present. Individual and overall quality of this body of literature was evaluated both qualitatively and quantitatively using guidance from the Cochrane Handbook (101), and a recently published literature review in an occupational health journal. (104)

Study methodology was assessed in two steps. First, the average scores were computed for type of study design (3, 2, 1, or 0 for high, moderate, low, and very low, respectively) and methods to address bias within the study design (0, 1, 2 for high, moderate, and low, respectively). These two scores were averaged to create "study design quality." The scores were averaged, rather than added, because risk of bias is often a function of study design and therefore they are not mutually exclusive and should not be added together. Next, the interventions were scored for quality based on the sum of two factors: accessible at the workplace, not at the workplace (e.g., home-based), or both (0, 1, and 2, respectively), and whether the mode of delivery was "active" (e.g., requiring workers to physically engage in an activity or "passive" (e.g., not requiring active engagement, but rather an environmental approach such as ergonomic adjustable workstations), or combined (0, 1, and 2, respectively). If no intervention was tested, a score of "na" (not applicable) was given, which translated into a zero for the component of intervention quality. The sum of the two accessibility and mode scores was used, rather than the average, because they are mutually exclusive and should not be averaged. The "na" scores were given equal weight as those with zero values because non-intervention studies will inherently be of poorer quality compared to those with interventions. It also allows for systematic evaluation of all studies, regardless of study design. The overall quality of the evidence score was calculated by adding the overall quality scores for study and intervention quality.

Favorability of Results

Individual study results were deemed "favorable," "null," or "unfavorable" for the associations reported between sedentary behaviors and physical activity on the outcome of back pain, and whether authors identified causal (i.e., towards back pain), null, or protective effects, respectively.

Results

Figure 2 displays the study flow chart. Initial searches resulted in 298 articles. After removing duplicates and screening titles, abstracts and full text for eligibility, 280 were eliminated yielding a final sample of 18 articles for review. Of the full-text articles, studies were excluded based on study design (n = 14), (P) non-employee population (n = 10), (I) non-sedentary intervention/exposure (n = 2), (O) non-back pain outcome (n = 1), (S) non-occupational setting (n = 6), or because the article was not accessible (e.g., non-English language) (n = 11). Publication dates ranged 1989 to 2013. Results are summarized by key question and PICOTS.

Table 2 summarizes descriptive characteristics of the articles for KQ1. Articles represent 24 years of research from 1989 to 2013. Sample sizes ranged from 22 (105) to 2,183(106) with a mean of 284 workers. Workers were from Australia, (107-110) Finland, (79, 81, 106, 111) the United States, (22, 112, 113) France, (114) Hong Kong, (115) India, (105) Japan, (116) Spain, (117) Poland, (118) and Switzerland. (119) Sedentary jobs were mostly office/administrative workers. (22, 81, 106, 106, 108, 110-113, 117-119) Physically demanding (i.e., active) jobs were described as skilled and semi-skilled, (111) machine operators, (106) manual workers, (109) forestry workers, (79) nurses, (81) assembly line workers, (114) construction site managers, (105) loggers, (81) hairdressers, (81) police officers(81) farmers, (81) and nursery school and kindergarten teachers. (116) Study designs were pre/post exposure or intervention, (22, 81, 107, 108, 112, 113, 120) randomized controlled trials, (79, 114, 116, 117) prospective cohorts, (118) case control, (119) longitudinal, (111) cross-sectional, (106, 109, 115) and one case study. (105) Five studies utilized solely self-administered questionnaires as the primary tool for measuring exposures and/or outcomes, (105, 106, 113, 116, 117) while others additionally incorporated: participant logs, (22, 110) physical exams or assessments, (111, 112) medical records, (79) magnetic resonance imaging (MRI), (119) or an activity monitor. (108)

KQ 1: How are sedentary job, physical inactivity and sitting behavior conceptualized in occupational studies addressing back pain?

Conceptualizing Sedentary Behavior and Physical Inactivity

The evaluation begins with a discussion of the favorability of the studies' results. Of the 18 articles identified, eleven reported favorable results, (22, 106-110, 112, 113, 115, 117, 118) and one reported null results for the protective effect of physical activity, and for the causal association between sitting and back pain. (119) Seven reported favorable results for physical activity being protective on the outcome of back pain. (79, 81, 109, 111, 114, 116, 117) The one null study reported no difference in recurrent low back pain symptomatology between physically demanding occupations (nurses) and predominantly sitting jobs (administrative workers) within the same industry.(119)

Of the 18 articles identified, sedentary was conceptualized as a function of job type in nine studies. Sitting was specifically conceptualized in 7 studies as: prolonged sitting (undefined), (22, 107, 115), high static load (based on 6-point score), (110) hours per week at home and work, (109) usual versus slumped sitting, (109) computer use for 4 or more hours per day. (113) Alkhajah, et al, (2012) did not define sitting, but chose 35 minutes per 8-hour workday as a clinically meaningful difference between the intervention (adjustable workstation) and the control group (no intervention).(108) Physical activity measurements were conceptualized as meeting guidelines, (22, 114) non-purposeful movement, (107) leisure time physical activity, (81, 105, 106, 109, 111, 114, 115, 117) postural strength and flexibility, (109, 119) metabolic equivalents (METs), (105, 121) participation in an exercise program, (116, 117) or all motor activity combined. (108) It is the reviewer's assumption that physical inactivity would be conceptualized as the inverse of the mentioned physical activity descriptions.

Benefits of physical activity were reported for workers regardless of job exposure; however the types of physical activities shown to be beneficial were conceptually different. For example, among sedentary workers, interventions focused more on reducing sedentary time (e.g., sitting) or incorporating short bursts of activity rather than on structured physical activity or meeting guidelines, (22, 107, 108, 110) whereas studies on employees with physically demanding jobs focused more on the measurement of "regular" physical activity during leisure time. (79, 105, 106, 109, 111, 114, 116, 117, 122) Riihimaki, et al (1989) reported sciatic pain was more common among machine operators and carpenters compared to office workers, however office workers were the only group that displayed significant associations between driving a car and sciatica. This indicates non-work exposures to sitting play a role in back pain, and may vary based on activity levels while at work. (106) Vocationally-oriented medical rehabilitation (VOMR) courses improved leisure time activity among those with strenuous labor jobs and had a beneficial effect on subjective pain in farmers, loggers, police officers and hairdressers (81) consistent with the aforementioned "U-shaped" distribution physical activity has on back pain.

KQ 2: How do interventions to address sedentary behavior differ from those that address physical activity in employees with back pain?

Delivery and Accessibility

Of the twelve studies utilizing interventions, nine included onsite interventions were considered "active" requiring workers to engage in an activity (i.e., computer/web-based) or "passive" not requiring active engagement, but rather an environmental approach (i.e., ergonomic adjustable workstation). Computer/web-based programs were geared towards motivating employees to move or exercise, (107) providing daily exercises and proper sitting techniques, (117) prompting employees to take breaks from sitting, (110) or customizing personal strength and flexibility exercises. (114) Ergonomic interventions involved employees' use of flexible, moveable, and/or adjustable workspace furniture (22, 108, 112, 113, 118) Of the three studies involving interventions offsite, all were active; two were located at offsite clinical rehabilitation centers and provided either back exercise rehabilitation, moderate physical activity program, or self-care, (79) or vocationally oriented medical rehabilitation (VOMR) courses designed to educate and motivate workers to avoid back injury through various physical activities. (81) The third offsite intervention was home-based and utilized a DVD with simple yoga instructions.(116)

Comparison

Of the six pre/post studies, three included a control group that received no intervention, (108, 110, 113) one had a comparison group that received the same intervention, but it was delivered by an active (vs. passive) mode, (107) and two used practice-based designs with no comparison group. (22, 112) Of the two prospective cohort studies, one compared the same intervention among four dynamic occupations (81, 118) and one compared short- verses long-term effects of the intervention. (118) Of the non-intervention studies, employees with no history of back pain served as controls in the case control study, (119) and matched controls on the basis of work activity were used in one cross-sectional study. (109) Non-control comparison groups were selected based on job type and included dynamic vs. sedentary (106) and blue vs. white collar.(111)

Outcome

Of the sixteen articles that included back pain as an outcome, seven studies measured pain frequency and/or intensity, (79, 79, 81, 106, 112, 114, 118, 119) five measured functional disability, (79, 106, 114, 117, 119) three used a combined measure of musculoskeletal pain not specific to back pain, (105, 108, 113), one created a back morbidity score based on low back symptoms and clinical findings, (111) one assessed back muscle endurance, (109) and three described upper or lower back pain but did not further define it. (22, 115, 116)

Quality Assessment

The quality assessment for individual studies is displayed in Table 3. Study quality scores ranged from 1.0 to 3.0 with an average of 1.8 out of a total possible of 3.0, indicating low to moderate overall study quality. Intervention quality scores ranged from 1.0 to 3.0 with an average of 1.6 out of a total possible of 4.0, indicating low quality. The overall quality of the evidence ranged from 1.0 to 4.5 out of a possible 7.0, indicating moderate overall study quality. Figure 3 displays the overall quality of the evidence over time as measured by study design and intervention quality and indicates an upward trend.

Discussion

Data from eighteen occupational studies representing 24 years of research on physical inactivity and/or sitting behavior were extracted to answer key questions related to methodology and intervention quality. Results indicate physical inactivity and sedentary behaviors are distinct exposures, with unique contributions to back pain in workers. Results indicate programs implemented in the workplace were more common than those conducted outside of the workplace. The body of literature reveals an overall lack of uniformity in the measurement of physical activity and sedentary behaviors, as well as the definition of back pain as an outcome. Studies were set in ten different countries representing a diverse array of industries and occupations. Study designs overall were of moderate quality, interventions were of low quality, and the overall quality of evidence was deemed moderate suggesting the need for more high-quality research.

Incorporating physical activity, whether on the job or off the job, produced favorable results among workers regardless of sedentary work or high physical load, however the types of activities that employees benefitted from (e.g., simple movements, breaks in sitting, muscle endurance, or standard physical activity) varied based on whether jobs were sedentary or physically active. This is because the effect of exercising is likely to be different from that of work-related physical activity. (111) O'Sullivan, et. al (2006) found that poor back muscle endurance was correlated with both increased sitting time and low physical activity levels, (109) which highlights the multifactorial nature of back pain and the importance of integrating health promotion (e.g., physical activity) with health protection (e.g., ergonomics) within the workplace. This supports the growing need for integration of health promotion with health protection as put forth by the National Occupational Health and Safety Total Worker Health™ research agenda (15, 16). Also needed are studies that assess the combined effect of work- and non-work exposures to sedentary behavior in order to conceptualize "total worker" risks for back pain.

Although several studies noted favorable results from either active or passive interventions, none of the studies from this review utilized both active and passive modes of intervention. This reflects a need for further practice-based research related to sedentary behavior and back pain as health promotion strategies that combine both active and passive delivery systems are among the "best processes" guidelines for health promotion because of the potential to increase the health promotion capacity within a community or workplace setting. (123) One example is the incorporation of a sit-stand workstation (active), plus computer-delivered prompts to use it (passive). Nassif, et al (2011) tested tailored exercise therapy in manual workers with jobs leading to awkward postures and found the program was effective in the experimental group compared to the control group in the short-term (2-months) at improving back function and pain, but the effect dropped to null after 6 months, likely due to inadequate sample size. (114) The results of their study highlight the need for sustainable programs that are tailored to the individual worker. There is also a need for research on supporting the integration of the delivery of health services within occupational settings. An example would be incorporating structured exercise therapy along with tailored ergonomic workstations. Such programs could lead to the creation of new employee habits, which could evolve into sustainable behavior change in and outside of the workplace. (107)

The investigation by Pandey, et. al (2012) found that the construction site managers worked an average of 9.4 hours per day and 58.5 hours per week, which exceeded national and international standards and may have predisposed workers to their musculoskeletal disorders. (105) These findings highlight a key message that needs to be related to employers based on their perceptions of work time, productivity, and health outcomes. Although working long hours can increase worker productivity in the short-term, working longer than normal hours is not sustainable for most workers and leads to decreased productivity over time and subsequently higher prevalence of poor health outcomes, such as back pain. Additional research is needed to gain a more complete understanding of the relationship between activity level, back pain and productivity loss.

Results from this review suggest a need for further research within specific industries and occupations in order to gain a better representation of exposures to sedentary behavior and its relationship with back pain in the workplace.

Chapter 4. Research Design and Methods

The central hypothesis of this research was that prolonged periods of sitting and physical inactivity interact to increase risk of back pain and increase health-related productivity loss among employees. This hypothesis was formulated based on existing knowledge of the preventative and inverse relationship between physical activity and back pain, (10, 26, 59, 124), and the established inverse associations between back pain and productivity. (8, 9, 92) To attain the objectives of our hypothesis we pursued three aims:

Aim 1. Evaluate the association of worker and workplace factors with back pain in a population of services sector workers.

Aim 2: Estimate the independent effects and interaction between physical inactivity, sitting time, and the outcome of interest, back pain.

Aim 3. Quantify health-related productivity loss attributable to sedentary risk and back pain.

Figure 4 outlines the conceptual model showcasing the aims of the study and the theoretical relationship between back pain, sitting, physical inactivity, and productivity in an employee population. The conceptual model informed the causal models which informed the analytical plan. Definitions of selected variables are listed in Table 4. This Chapter describes methodology that is also summarized in Chapter 5 and Chapter 6.

Data Collection and Sample

A large governmental employer (i.e., public administration industry) implemented an employee health and well-being program including an individual-level health assessment to characterize the health risks of its workforce and to identify intervention opportunities for disease prevention and minimizing productivity losses. This program was implemented by HealthPartners Health & Well-Being Solutions under the name JourneyWell® and all data collected was managed by HealthPartners. All employees in the dataset had access to wellness and health promotion programs. The incentive structure for completing the health assessment was a $5 copayment reduction if they completed the survey and agreed to receive one phone call from a health coach.

Survey questions were adapted from existing questionnaires such as the Behavior Risk Factor Surveillance System (125) (BRFSS) questionnaire and the Work Productivity and Activity Impairment (WPAI) questionnaire. (126) 2010 was the first year these employees were asked specifically about sitting time in a health assessment. Because no current validated questionnaire existed to measure workplace sitting, personal communication with experts in assessing sedentary behaviors including sitting time were utilized for questions specific to sitting time, which have since been validated and published in the scientific literature. (41, 44) The BRFSS measures were determined to be moderately valid and reliable for sedentary lifestyle and intense leisure-time physical activity (127). The questions on physical activity have been shown to accurately classify groups of adults into the levels recommended for vigorous activity. (128) Constructs of the WPAI (i.e., not general health (GH)) questionnaire were determined to be a valid measurement of work impairment due to perceived physical and emotional (e.g., pain) for health reasons, although self-administered questionnaires had lower construct validity compared to interviewer-administered (129) Studies on the validity of productivity measures related to sedentary behavior and/or back pain are nonexistent to the authors' knowledge.

In November 2010, 35,474 out of 51,366 completed the health assessment (70% response). Pregnant women, students, and retirees were excluded from these analyses (n = 483). Because data from aim 2 and aim 3 utilized a sample based on the same 2 x 2 table, the sample size for aims 2 and 3 was slightly smaller than aim 1 because it included only those with non-missing responses to questions related to productivity measures (assessed in aim 3), (i.e. 2,032 fewer employees than aim 1.) Responses from these survey data served as the sole data source for this study. The employee sample was highly educated (61% earned an undergraduate or graduate degree), middle aged (64% aged 40-59), mostly non-Hispanic White (91%), and female (55%). In addition, 40% of employees reported experiencing back pain and 72% met physical activity guidelines. (130) Health assessment questions for the key variables in this study are located in Appendix B. To protect the privacy of the employees, the contractual agreement between the Midwest employer and HealthPartners allowed access to a de-identified, retrospective secondary dataset. (129) Because the dataset was de-identified, the study was exempted from continuing review by the Institutional Review Boards of the HealthPartners® Institute for Education and Research and the University of Minnesota.

Back pain was analyzed as a binary outcome; a value of one was given to a response of “always” or “sometimes” and a value of zero was given to a response of “rarely” or “never” to the question “How often to you experience back pain?” This was the sole survey question assessing back pain. Information on history of back injury and pain severity were not asked in the health assessment, and were not otherwise available for these analyses.

To assess health-related productivity loss, employees were asked “During the past 7 days (not including today), how many hours did you miss from work because of your health problems? Include hours you missed on sick days, times you went in late, left early, etc., because of your health problems.” Employees were also asked to report total hours worked and time away from work for non-health reasons in the past week, which were used to calculate the percentage of time lost due to health. Heath-related absenteeism (“absenteeism”) was defined as the number of hours absent from work due to health problems out of the total number of hours worked and missed, representing a percent of time lost from work due to health problems. Absenteeism was then converted into opportunity cost to the employer defined as the cost of labor forgone due to health related absenteeism, which is a term used in other occupational studies assessing absence-related productivity loss attributable to sedentary behaviors. (72, 74)

Non-modifiable covariates include age, gender, race, education, and job type. Age was categorized by 10-year increments from 20 to 60 years and 5-year increments to represent the pre-retirement and retirement aged employees as separate entities. Race was categorized as “White,” “non-White” and “unknown” because of the high prevalence of White employees. “Unknown” race included those who responded “other,” “choose not to answer,” or “unknown” to the question about race. Although information on ethnicity was collected in the questionnaire (e.g., Hispanic or not), it was not included as a covariate in these analyses because the prevalence of employees reporting Hispanic ethnicity was very low (e.g., < 2 %) and results presented by ethnicity could have jeopardized employee confidentiality. Because the population was highly educated overall, the education variable was categorized into those with and without a 4-year degree. Employees self-selected into one of the following job classifications: labor or production, administrative, professional/management, sales, service, skilled craft, technician, other (student and retired classifications were excluded). These responses were further classified into one of four categories: administrative, professional/ management, labor or production, and other.

Modifiable covariates included: physical inactivity, total sitting time, prolonged sitting at work, body mass index (BMI), and tobacco use. With the exception of BMI, all covariates were analyzed as binary (yes/no). BMI was calculated based on height in feet and weight in pounds then converted to kg/m^2 and divided into five BMI categories: healthy (18.5 – 24.9), overweight (25.0 – 29.9), obese (30.0 – 44.9), severely obese ($\geq$

45.0), and underweight (< 18.5). BMI categories were adapted from the Centers for Disease Control and Prevention for adults over age 20. (131) Because no standard measure for sitting time was available, responses to questions on sitting time were dichotomized by the median response for this sample. Descriptions on the modifiable covariates are in Table 5.

Each *modifiable* and *non-modifiable* covariate was analyzed within a unique logistic model based on potential confounders and assumptions about causality on the outcome of back pain identified by drawing directed acyclic graphs (DAGs). (132, 133) All DAGs are shown in Appendix C. The purpose of using DAGs in observational studies is to ensure the statistical models address the aims of the study by understanding causal concepts. (132-136) DAGs visually display the underlying assumptions of the relationships between the exposure of interest, covariates, and the outcome of interest. Logistic regression models for each covariate were created on the binary outcome of back pain. All analyses were performed using Stata® version 11 located on a secured computer at HealthPartners™ headquarters in Bloomington, Minnesota. The final statistical programming code for all study aims is located in Appendix E.

An additional exposure we evaluated was employees' readiness to manage back pain by levels of a covariate (e.g., BMI) on the outcome of back pain. Employees' readiness to manage back pain was assessed by asking the question "How ready are you to make changes to manage your back pain" with five selection options ranging from Precontemplation (i.e., "Changes are not necessary") to Maintenance (i.e., "I have made changes and maintained changes for six or more months") as depicted in the Transtheoretical Model of Behavior Change (TTM) (see Table 6). Categories of readiness were created based on employee responses: 1) ready to manage back pain and 2) not ready to manage back pain. This allowed comparisons of readiness to manage back pain by levels of a covariate (e.g., BMI) on the outcome of back pain. Identifying employees' readiness to change among the subgroup of employees with comorbid overweight or obesity could help employers target programs to those most at risk and tailor programs based on stage of change. (137) Psychosomatic indicators, such as feeling stressed or depressed and poor job satisfaction, can be both risk factors and consequences of low back pain. (114) However it is our assumption that such indicators are "upstream" from the exposures and covariates included in the conceptual model and Directed Acyclic Graphs (DAGs), and therefore were not included in the statistical model as potential confounders. We also evaluated readiness to manage back pain to inform intervention opportunities.

Study Design and Analyses

A cross-sectional study design was utilized for all three aims. For aim 1, a sedentary risk profile for back pain was determined based on the variables listed in the conceptual model (Figure 4). Logistic regression models were estimated to produce prevalence odds ratios and 95% confidence intervals estimating associations on the outcome of back pain for aims 1 and 2. For aims 2 and 3, logistic regression was used to estimate odds ratios and 95% confidence intervals, and contingency (i.e., 2x2) tables were utilized to categorize study participants into four sedentary risk categories by joint sitting exposures and physical inactivity status. For aim 3, productivity loss was estimated using questions adapted from a validated questionnaire. (126) Using the product of percentage of absenteeism and average employee salary, employer costs of labor forgone were estimated for each sedentary risk category and stratified by back pain.

Assumptions

In addition to the assumptions of causality represented by directional arrows in the conceptual model and DAGs, it was assumed that sedentary job is a separate classification from sedentary behavior with unique sets of risks, as sedentary behavior can be a function of sedentary job. Although back pain has been shown to be a risk factor for sedentary behavior due to fear of movement and pain, (138) we assumed the association between sedentary behavior and back pain is unidirectional, i.e., increased sedentary behavior increases back pain. Also, based on the "U-shaped" relation physical activity has with back pain (29), it is also our assumption that neither the relation between physical inactivity status nor the relation between sitting time and back pain are linear. Another assumption is that if disability from back pain is reduced, health-related productivity loss, as measured by absenteeism, will also be reduced. (83) Finally, "psychosomatic indicators," such as feeling stressed or depressed and poor job satisfaction, can be both risk factors and consequences of low back pain, (114) however it is our assumption that such indicators are "upstream" from the exposures and covariates included in the conceptual model and DAGs, and therefore were not included in the statistical model as potential confounders.

Aim 1. Evaluate the association of worker and workplace factors with back pain in a population of public administration workers.

A risk profile for back pain among workers in the services sector had yet to be defined and thus the objective of this aim was to 1) to identify work and workplace risk factors for back pain, and 2) to estimate the impact of sitting time on the outcome of back pain in a sample of services sector (e.g., public administration) workers. We tested the hypothesis that the risk for back pain among employees exposed to sedentary risk factors such as high overall sitting time, prolonged sitting at work (a specific type of sedentary behavior), (22) not meeting physical activity guidelines, older age, female gender, higher Body Mass Index (BMI), and tobacco use will have a higher odds of back pain. We also evaluated readiness to manage back pain to inform intervention opportunities.

Study Design and Analysis

A cross-sectional design was utilized to establish a sedentary risk profile for back pain and to estimate the impact of sitting time on back pain among services sector employees who completed the health assessment survey. After excluding pregnant women, retirees and students (n = 483), 34,991 employees were included in the sample for aim 1. DAGs informed the univariate and multivariate logistic models (Appendix C). Odds ratios and 95% confidence intervals were presented to compare risk of back pain by non-modifiable and modifiable, and individual and work-related factors. Readiness to manage back pain was assessed among all employees by back pain status.

Results from aim 1 are reported in Chapter 5: "The Impact of Sitting Time and Physical Inactivity on Back Pain: A Sedentary Risk Profile for Services Sector Workers."

Aim 2: Estimate the independent effects and interaction between physical inactivity, sitting time, and the outcome of interest, back pain.

The occurrence (and recurrence) of back problems is likely to due to interactive effects of multiple factors. (139) Although physical inactivity and too much sitting have been shown to be independently hazardous to human health in terms of morbidity and mortality (12, 30, 38, 50, 61, 62) and are associated with the most prevalent and costly chronic health outcomes, the interactive effects have not been evaluated on the outcome of back pain.(13, 19, 44, 46) Therefore, the objective of aim 2 was to compare the independent and interactive effects of exposures to sitting (e.g., prolonged sitting time at work) and physical inactivity (e.g., not meeting guidelines) among employees with and without back pain. In this study, exploring the relationship of *prolonged* sitting, as opposed to *total* sitting time, is meaningful; although total sitting time may be a more comprehensive measure of total worker exposure to sitting, it does not account for the effect of static posture, which is known to be associated with back pain. (112, 140-144) We tested the hypothesis that sitting would have an interactive effect with physical inactivity ("inactivity") on the outcome of back pain after controlling for age, gender, race, education, job type, body mass index (BMI), tobacco use, total sitting time and perceived access to safety resources. This hypothesis was formulated based on results from aim 1, and existing knowledge of the preventative and inverse relationships between physical activity and back pain. (10, 26, 59, 124)

Study Design and Analysis

As in aim 1, DAGs identified potential confounders based on causal assumptions for each exposure (Figure C. 1 and Figure C. 2 in Appendix C). The covariates in the statistical model for prolonged sitting and physical inactivity were age, job type, BMI, tobacco use, total sitting time and perceived access to safety resources.

Figure 5 shows the 2x2 table and equation of probability assumptions of the "sedentary risk categories" of sedentary life (S+I+), sedentary job ("desk potato") (S+I-), sedentary leisure ("couch potato") (S-I+), and active life (S-I-) on back pain. A cross-sectional study design was utilized to assess the independent and interactive effects of sitting exposures and of not meeting physical activity guidelines on the outcome of back pain.

Logistic regression produced odds ratios and 95% confidence intervals to estimate the associations between sedentary risk categories and the binary outcome of back pain and to evaluate all possible interaction effects for 32,959 services sector workers. Resulting odds ratios were first represented as a comparison of sedentary risk categories relative to the theoretical best-case interactive scenario, "active life," because these employees were assumed to have the lowest risk for back pain. To further explore the relationships between the exposure of prolonged sitting and inactivity, and because the target audience is employees who sit for prolonged periods of time, the results were also presented using sedentary job ("desk potato") as the referent group. Results were presented in tables with univariate and multivariate statistics to compare the independent and interactive effects of prolonged sitting and inactivity.

Results for aims 2 and 3 are reported in Chapter 6: "The Interactive Effect of Prolonged Sitting and Physical Inactivity and Productivity Loss of Due to Sedentary Risk in a Sample of Services Sector Workers with Back Pain."

Aim 3. Quantify health-related productivity loss attributable to sedentary risk and back pain.

In addition to the overall cost burden of back pain, it is critical for employers to know the potential cost burden attributable to sitting and inactivity because they are both modifiable behaviors and therefore costs associated with them could be mitigated. The objective of this aim was to estimate employee productivity loss attributable to sedentary risk in employees with and without back pain. We tested the hypothesis that increased sedentary risk, as defined by sedentary risk categories and probability assumptions in aim 2, is associated with productivity loss due to health problems, as measured by absenteeism and opportunity costs.

Questions from the WPAI-GH questionnaire were utilized to assess absenteeism as an indicator of health-related productivity loss ("productivity loss"). (126) Employees were asked "During the past 7 days (not including today), how many hours did you miss from work because of your health problems? Include hours you missed on sick days, times you went in late, left early, etc., because of your health problems." Employees were also asked to report total hours worked and time away from work for non-health reasons in the past week (see Work and Health questions in Appendix B). Responses from these questions were used to capture health-related absenteeism ("absenteeism") as a direct indicator of productivity loss. Absenteeism was defined as the number of hours absent from work due to health problems out of the total number of hours worked and missed, and was essentially a percent of time lost from work due to health problems. Absenteeism was then converted into opportunity cost (e.g., to the employer) defined as the cost of labor forgone due to health related absenteeism. Opportunity costs have been conceptualized in other assessing absence-related productivity loss attributable to sedentary behaviors in the workplace. (72, 74) The average employee salary in 2010 was $52,000 per year. The distribution of salaries by job classification was unavailable. This dollar amount was used to calculate the opportunity cost of absenteeism per employee per year due to health problems.

Chapter 5. Paper 1

The Impact of Sitting Time and Physical Inactivity on Back Pain: A Sedentary Risk Profile for Services Sector Workers

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Introduction

Cost of injuries to the back exceed $50 billion per year in the United States, (9, 55, 90, 91) yet cost-effective programs to address back pain in the workplace are lacking. (12, 92) Furthermore, the development of effective intervention strategies has been hampered by limited information on occupational behaviors that are amenable to change (e.g., sitting). (60) Due to technological advances, job tasks are becoming increasingly sedentary, causing prolonged periods of sitting and low levels of occupational physical activity, which predisposes employees to musculoskeletal problems. (59) Many workers spend more than half of their entire workday seated; this makes the workplace a key community venue for the promotion of physical activity and the reduction of sedentary time. (22, 59)

In addition to heavy physical work, heavy or frequent lifting, non-neutral postures, and exposure to whole body vibration, sitting (as a function of sedentary job type) is a commonly cited occupational behavior associated with low back pain, (7, 22, 23, 29, 38, 42, 97-99) yet empirical findings from studies on the adult working population do not clearly reveal the causality of sedentary behavior on the outcome of occupational back pain. (23-27) Within the workplace, breaks in prolonged sitting time (e.g., from periodic standing or ambulating) have been associated with lower health risks and related to waist circumference, body mass index (BMI), triglyceride levels, and 2-hour plasma glucose levels, (36, 37) but research on back pain from prolonged sitting is minimal. To further elucidate the association between sitting and back pain, we evaluated self-reported back pain prevalence and prolonged sitting time in a large cohort of workers with highly variable job types and sitting behavior.

Methods

Data Source

In November 2010, 34,991 public administration employees from one Midwestern services sector company completed a self-administered health assessment questionnaire (70% response rate) as participants in a nationally accredited health and wellness program. Responses from this questionnaire are the sole data source for this study. A cross-sectional study design was utilized to establish a back pain risk profile and to estimate the impact of sitting time on back pain. The study population included public administration workers from a Midwestern Services Sector employer in the U.S. (N = 51,366). All employees in this sample had access to a comprehensive wellness and health promotion program and were enrolled in an employer-sponsored health plan. Pregnant women, students, and retirees were excluded from the analyses (n = 483).

Outcome Measure

Back pain was analyzed as a binary outcome of this study and categorized as “always” or “sometimes” vs. “rarely” or “never” in response to the question “How often to you experience back pain?” Information on back injury and pain severity was not asked in the health assessment, and was not available for these analyses.

Covariates

All covariates were based on self-reported responses to the health assessment questionnaire. Covariates were classified as *non-modifiable* (e.g., demographics, job type) and *modifiable* (e.g., occupational sitting time, physical inactivity, health risk behaviors). *Non-modifiable* covariates include age, gender, race, education, and job type. Age was categorized by 10-year increments from 20 to 60 years and 5-year increments after age 60 to represent the near-retirement (60 – 64 years) and retirement-aged employees ($\geq$ 65 years) because these older age groups may be of particular interest to employers as retirement age approaches. Race was categorized as "White," "non-White" and "unknown" because of the high prevalence of White employees. Although information on ethnicity was collected in the questionnaire (e.g., Hispanic or not), it was not included as a covariate in these analyses because the prevalence of employees reporting Hispanic ethnicity was very low (e.g., less than 2 %). Education was categorized into those with and without a 4-year degree because of the high prevalence of workers reporting a 4-year degree. Employees self-selected into one of the following job classifications: labor or production, administrative, professional/management, sales, service, skilled craft, technician, other. These responses were further classified into one of four categories: administrative, professional/management, labor or production, and other.

Modifiable covariates are defined in Table 5 and include: physical inactivity, low energy expenditure, total weekly sitting time, prolonged sitting time at work, body mass index (BMI), and tobacco use. With the exception of BMI, all covariates were analyzed as binary (yes/no). BMI was calculated based on self-reported height in feet and weight in pounds then converted to kg/m^2 and divided into five categories: healthy (18.5 – 24.9), overweight (25.0 – 29.9), obese (30.0 – 44.9), severely obese ($\geq$ 45.0), and underweight (< 18.5). BMI categories were adapted from the Centers for Disease Control and Prevention criteria for adults over age 20. (131) Because no standard measure for sitting time exists, responses to questions on sitting time were dichotomized by the median value. Psychosomatic indicators, such as feeling stressed or depressed and poor job satisfaction, can be both risk factors and consequences of low back pain, (114) however it is our assumption that such indicators are "upstream" from the exposures and covariates included in the conceptual model and Directed Acyclic Graph (DAG), and therefore were not included in the statistical model as potential confounders.

An additional exposure we evaluated was employees' readiness to manage back pain by levels of a covariate (e.g., BMI) on the outcome of back pain. Identifying employees' readiness to change in employees with comorbid overweight or obesity could help employers target programs to those most at risk and tailor programs based on stage of change. (137) The Transtheoretical Model (TTM) stages of change were determined by the employee responses to the question "How ready are you to make changes to manage *back pain*?" Five answer options ranged from precontemplation (i.e., "Changes are not necessary") to Maintenance (i.e., "I have made changes and maintained changes for six or more months") as modeled by TTM Categories of readiness were created based on employee responses: 1) ready to manage back pain and 2) not ready to manage back pain. This allowed comparisons of readiness to manage back pain by levels of a covariate (e.g., BMI) on the outcome of back pain.

Data Analysis

Each covariate was analyzed within an individual logistic model that varied based on potential confounders and assumptions about causality on the outcome of back pain. Causal assumptions informed the statistical model and were identified by drawing directed acyclic graphs (DAGs) (132, 133) for each covariate. The purpose of using DAGs in observational studies (including cross-sectional studies) is to ensure the logistic regression models address the aims of this study by understanding the directionality of relationships. DAGs visually display the underlying assumptions of the relationships between the exposure of interest, covariates, and the outcome of interest. As an example, Figure C. 11 in Appendix C displays the DAG for prolonged sitting time on the outcome of back pain (yes/no), which informed the logistic regression models for each covariate. All analyses were performed using Stata® version 11.

Results

Table 7 presents descriptive information of the study sample by individual and workplace characteristics. At the time of the survey, 40 percent of the sample reported experiencing back pain “sometimes or “always.” The study sample was a highly educated, predominantly female, White sample of workers, on average 47.6 years of age (SD: 10.7 years), who worked an average of 35.8 hours per week (SD: 13.6 hours per week). Relatively few (10%) employees used tobacco, but employees were generally overweight with an average BMI of 28.0 kg/m^2 (SD: 5.9 kg/m^2) and sat an average of 33.9 total hours per week (SD: 23.3 hours per week). Employees reported an average of 1.7 hours (SD: 1.3 hours) of uninterrupted sitting while on the job in a usual workday.

Non-modifiable Factors

Table 8 presents prevalence odds ratios and 95% confidence intervals for non-modifiable factors related to back pain**.** All age categories were at higher risk compared to the youngest workers. Risk of back pain increased with increasing age category up to age 64 with 20% more risk for those aged 30-39 (OR = 1.2), 32% more risk for those aged 40-49 (OR = 1.32), 33% more risk for those aged 50-59 (OR = 1.33), and 42% more risk for those aged 60-64 (OR = 1.42). The relationship of age on back pain was not as pronounced in the 759 employees aged 65 years and older (OR = 1.17). Female workers were at higher risk for back pain compared to male workers (OR = 1.11). Non-White and Unknown race was associated with a lower risk of back pain relative to Whites, although the association was only statistically significant for the unknown race group (OR = 0.83) in contrast to Non-White employees (OR = 0.93). High educational attainment also had a negative association with back pain, with workers having a four-year degree showing 25% less risk for back pain compared to workers without a 4-year degree (OR = 0.75). Compared to administrative workers, workers with physical labor jobs had the highest risk (OR = 1.18), followed by professional/management (OR = 1.13). Employees who classified their jobs as “other” showed an increased risk, however the relationship was not statistically significant (OR = 1.04).

Modifiable Factors

Table 9 presents prevalence odds ratios and confidence intervals for modifiable factors related to sedentary behaviors in the workplace. Of the sedentary measures, employees in the severe obesity category had the highest risk for back pain (OR 1.88), followed by obese (OR = 1.48), overweight (OR = 1.23), employees reporting expending less than or equal to 800 Kcal/week in physical activity (OR = 1.76), not meeting physical activity guidelines (OR = 1.53), prolonged sitting for 1.0 or more hours (OR = 1.21), and total sitting time (e.g., combined hours during leisure, commuting, and at work) for 30 hours or more per week (OR = 1.17). The underweight category was negatively associated with risk for back pain, however it was not statistically significant (OR = 1.02). Employees reporting using any form of tobacco use had higher risk for back pain compared to those who reported no tobacco use (OR = 1.55).

Readiness to Manage Back Pain

Among the 13,901 employees reporting back pain, 23% were in precontemplation, 7.0% were in contemplation, 21% were in preparation, 31% were in action, and 18% were in the maintenance stage of readiness to change related to their back pain. Post-hoc analyses further categorized employees as ready to manage back pain (e.g., 7,212 employees in preparation or action) or not ready to manage back pain (e.g., 4,150 employees in precontemplation or contemplation) and they were compared within each BMI category. BMI was selected because of the high prevalence of high BMI in the sample, its amenability to change and its association with comorbidities in addition to back pain (e.g., cardiovascular disease and diabetes). Knowing the relationship between BMI and readiness to manage back pain allows employers to tailor programs accordingly, possibly addressing additional health problems with one program. Table 10 shows that compared to employees in the healthy BMI category, being ready to manage back pain was most likely among severely obese workers (OR = 1.96) followed by overweight (OR = 1.43) and overweight workers (OR = 1.18).

Discussion

The purpose of this study was to evaluate the impact of sitting on back pain prevalence in a sample of services sector workers. All modifiable risk factors displayed a positive association with risk for back pain. Severe obesity had the most prominent relationship with back pain, followed by sedentary category, not meeting physical activity guidelines, obese, overweight, and prolonged sitting time at work. Results indicate an increase in readiness to manage back pain with an increase in BMI. When interpreting these results, employers should consider both numbers of employees *and* risk ratios when informing workplace health promotion programs, as one may be more appropriate based on the employer population.

Limitations relate to the study design, sample selection, and analysis. Because of the cross-sectional study design, associations, not causality, can be determined between the exposures of sitting time and physical inactivity on the outcome of back pain from these analyses. Furthermore, although the questions in the health assessment were not asked to indicate temporality of the exposures to back pain, the temporal relationships between sedentary behaviors, physical activity and back pain have been described in various settings. (24, 26, 42, 45, 145) Furthermore, employees may overestimate their positive behaviors (e.g., physical activity levels) and/or underestimate their negative behaviors (e.g., sedentary behaviors), and therefore misclassification of the exposure is likely and the true value of the association with back pain may be over-or underestimated. (40, 146, 147) Similar questions related to physical activity and sitting have been determined to be moderately valid and reliable for sedentary lifestyle (e.g. measured as not meeting guidelines), and intense leisure-time physical activity (41, 44, 127) and the questions on physical activity have been shown to accurately classify groups of adults into the levels of recommended for vigorous activity. (41, 44, 128)

The large sample size in this study provided exceptional statistical power to explore the issue of sedentary behaviors and back pain, however the absence of up to 30% of the study population from the sample dataset and the reliance on self-reported outcomes may have influenced the results. The direction of these biases is not known. Additionally the sample was largely non-Hispanic White limiting generalizability. Although the statistical model adjusted for several covariates, the risks for back pain may be higher in certain job classifications due to unmeasured covariates related to job type, such as exposure to whole body vibration or awkward lifting postures (25, 142, 148, 149). To gain a more complete understanding of total worker exposures, it also is important to evaluate exposures to prolonged sitting outside of the workplace such as from television watching. Additionally, readiness to change an outcome, such as back pain, does not necessarily reflect an employee's readiness to change the behaviors, such as those that lead to overweight/ obesity. The TTM is a theoretical framework based on one's perceived ability to change and access to resources to help them change, and the stage an employee is in can fluctuate over time.

Despite these limitations, results of this study are translatable to large employers, particularly those employing workers with similar demographics and exposures to the study population. However, even in industries that are commonly known for physically laborious work, such as construction, occupations within that industry may be prone to the exposure of prolonged sitting(105) and therefore results on industry-level data may not be generalizable to occupations within that industry. These data are the first to show that back pain may occur after only one hour of sitting in a working population. The results address the gap in the literature on a clinically relevant exposure of prolonged sitting as it pertains to negative health consequences in the workplace, as currently a definition is nonexistent and the concept of sitting as a specific type of sedentary behavior studies remains vague and inconsistent. (22, 109, 110, 115)

Results of this study are consistent with the current evidence on the non-modifiable risk factors of age (150-153) and gender, (7, 95, 150, 154) and consistent with the protective effect of education. (2, 5, 35, 91, 96, 143, 155) Employees in the job classifications "labor" and professional/management were at increased risk for back pain compared to those classified as administrative. However, the *number* of employees in administrative jobs reporting back pain was higher than all other job classes combined. Research on the association between race and back pain is minimal (156-158) and because of the relatively small proportion of non-Whites working for this employer and lack of information on them, we do not know whether the association in our results is valid or not. Results on the risk for back pain and BMI are consistent with previous research that suggests obesity may increase risk for injury, (159, 160) and losing weight can ameliorate some of the manifestations of musculoskeletal conditions and improve function among obese individuals because of the reduction of excess load endured by the muscles and joints. (161, 162) Piechota et. al (2005) suggest the leading cause of disability in overweight and obese people is caused by impairment of the musculoskeletal system (e.g., chronic back pain) from excessive weight and suggest a circular relationship between overweight/obesity and back pain as people with pain may become more sedentary for fear of causing more pain, which contributes further to overweight/obesity. (163)

This research supports the Total Worker Health™ movement as put forth by the National Institutes for Occupational Health and Safety, which aims to integrate occupational safety and health protection with health promotion. (15, 16) The circular relationship between overweight/obesity and back pain highlights the importance of integrating health promotion with health protection (e.g., safety) within the workplace because programs to help workers lose weight may have multiple benefits when paired with back-pain reducing ergonomic interventions aimed at reducing static postures from sitting. Further research is needed to explore the interactive effects of physical inactivity outside the workplace and sitting time within the workplace to gain a more in-depth understanding of total worker exposures to sedentary behaviors. Employer-based programs that promote physical activity, ambulation, and/or periodic standing are particularly valuable because they improve employee productivity and reduce short-term disability leave, employee turnover, absenteeism, and healthcare costs. (10-13) Future research on the impact of sedentary behaviors on productivity loss, particularly among those experiencing back pain, is needed.

Chapter 6. Paper 2

The Interactive Effect of Prolonged Sitting and Physical Inactivity and Associated Productivity Loss in a Sample of Services Sector Workers with Back Pain

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Introduction

Physical inactivity and too much sitting have been shown to be independently hazardous to human health in terms of morbidity and mortality (12, 30, 38, 50, 61, 62) and are associated with the most prevalent and costly chronic health outcomes such as back problems, heart disease, and diabetes. (13, 19, 44, 46) Due to technological advances, job tasks are becoming increasingly sedentary, causing prolonged periods of sitting and low levels of occupational physical activity, which predisposes employees to musculoskeletal problems. (59) The occurrence (and recurrence) of back problems is likely to due to interactive effects of multiple factors. (139) Although it is accepted that individuals can be both physically inactive and sedentary, workers may be physically active during leisure time, but experience prolonged sitting while at work because of sedentary job duties or vice versa. (44) This is known as the "active couch (or 'desk') potato phenomenon" which can be prevented by periodic standing or ambulating to avoid prolonged sitting. (12, 13, 44)

Results from research on the relationship between physical inactivity, sitting and back pain, particularly in the workplace, is minimal and inconclusive (53, 66) and therefore, the objective of this study was to evaluate the effects of exposures to sitting (e.g., prolonged sitting) and physical inactivity (e.g., not meeting guidelines) among employees with and without back pain. The secondary objective was to estimate the impact of sedentary behaviors on health-related productivity loss among employees with and without back pain. We hypothesized that sitting would have an interactive effect with physical inactivity ("inactivity") on the outcome of back pain after controlling for age, gender, race, education, job type, body mass index (BMI), tobacco use, total sitting time and perceived access to safety resources. Second, we hypothesized that productivity loss, as a product of health-related absenteeism and forgone labor, would increase with increasing sedentary risk, as measured by varied levels of physical inactivity and prolonged sitting after controlling for age, gender, race, education, job type, body mass index (BMI), tobacco use, and perceived access to safety resources. These hypotheses were formulated based on existing knowledge of the preventative and inverse relationships between physical activity and back pain, (10, 26, 59, 124) and the established inverse associations between back pain and productivity. (8, 9, 92) Definitions of selected variables are listed in Table 4.

Methods

Data Collection and Sample

Health assessment surveys are an efficient way for employers to gain information on the overall and group-specific prevalence of particular health events in their employees. Data gained from health assessments can be used to guide decision-making processes, such as when deciding between investing in, for example, an ergonomic intervention (i.e., adjustable workstations) or programs that promote physical activity (i.e., gym membership subsidy). (63) In November 2010, 51,366 public administration employees of one Midwestern employer were invited to take a self-administered health assessment survey as part of a comprehensive health and wellness program. The incentive structure for participating included a $5 copayment reduction with survey completion and agreement to receive one phone call from a health coach.

Survey questions used in this study were adapted from existing questionnaires including the Behavior Risk Factor Surveillance System (125) (BRFSS) questionnaire and the Work Productivity and Activity Impairment (WPAI) questionnaire. (126) Because no current validated questionnaire existed to measure workplace sitting, personal communication with experts in assessing sitting time were utilized for questions specific to sitting time, which have since been validated and published in the scientific literature for non-occupational settings. (41, 44) Starting with a sample based on a 70% response rate, pregnant women, students, and retirees were excluded from the analyses, (n = 483) as were employees with missing data (n = 2,032). This resulted in a sample of 32,959 services sector employees with complete responses to questions on sitting, physical activity, back pain, productivity loss, and covariates. To protect the privacy of the employees, a contractual agreement with the employer allowed access to only a de-identified dataset of survey responses, and therefore, responses from the survey data served as the sole data source for this study.

Outcome Measures

Back pain was analyzed as a binary outcome; a value of one was given to a response of “always” or “sometimes” and a value of zero was given to a response of “rarely” or “never” to the question “How often to you experience back pain?” This was the sole question assessing back pain during in this survey. The questions and scoring algorithm were adapted from the Work Productivity and Activity Impairment General Health (WPAI-GH) questionnaire to assess health-related productivity loss ("productivity loss"). (126) Employees were asked "During the past 7 days (not including today), how many hours did you miss from work because of your health problems? Include hours you missed on sick days, times you went in late, left early, etc., because of your health problems." Employees were also asked to report total hours worked and time away from work for non-health reasons in the past week. In this study, we used responses from these questions to capture health-related absenteeism ("absenteeism") as a direct indicator of productivity loss.

Absenteeism was defined as the number of hours absent from work due to health problems out of the sum of total number of hours worked and hours missed for all reasons. Absenteeism was represented by a percent of time lost from work due to health problems with the total possible time as the denominator. Absenteeism was then converted into the opportunity cost to the employer defined as the cost of labor forgone due to health-related absenteeism, which is a term used in other occupational studies assessing absence-related productivity loss attributable to sedentary behaviors. (72, 74) Equations for absenteeism and opportunity cost are shown below.

$$Absenteeism = \left(\left(\frac{hrs\ missed\ due\ to\ health}{hrs\ worked + hrs\ missed}\right) \times 100\right)$$

$$\text{Opportunity cost} = (\text{Absenteeism} \times \$52{,}000)\ /\text{person} \ /\ \text{year}$$

Exposures

The 2x2 table in Figure 5 displays the “sedentary risk categories” defined by combining sitting time (S) and physical inactivity (I) as sedentary life (S+I+), sedentary job, or “desk potato” (S+I-), sedentary leisure, or “couch potato” (S-I+), and active life (S-I-). The equation in Figure 5 showcases the probability assumptions of the relationship between sitting exposures and physical inactivity on the outcome of back pain. While all potential values in the quadrant represent the interaction of sitting time and physical inactivity, we hypothesize that “Sedentary life” represents the “worst case” interaction term for inactivity and prolonged sitting and it was expected to have the highest probability of back pain compared to all other groups. Physical inactivity (“inactivity”) was defined as not meeting 2008 United States physical activity guidelines, which are commonly used in workplace health programs. (130) The sitting exposure in this study was uninterrupted sitting time at work (e.g., prolonged sitting at work). The distribution of sitting time among all employees was right-skewed as nearly 70% of workers sat for 1.0 consecutive hour or less on a usual workday. Because no standard for prolonged sitting exists, and because of the skewed distribution, the median value of uninterrupted sitting time at work was used the cut point value for prolonged sitting time.

Covariates

Covariates included age, gender, race, education, job classification, tobacco use, body mass index (BMI), and perceived access to safety resources. Age was categorized by 10-year increments from 20 to 60 years and 5-year increments after age 60 to represent the near-retirement (60 – 64 years) and retirement aged employees (> 65 years) as separate entities because these age groups may be of particular interest to employers. Because of the high prevalence of Caucasian employees, race was categorized combined into "White," "non-White" (e.g., American Indian or Alaskan Native, Asian or Pacific Islander, or Black or African American") and "unknown" (e.g., "other race," "choose not to answer," or "unknown"). Education was dichotomized from seven categories into two categories: those with and without a 4-year degree. Employees self-selected into one of the following job classifications: labor or production, administrative, professional/management, sales, service, skilled craft, technician, and other. These responses were further classified into one of four categories: administrative, professional/ management, labor or production, and other. We know these were public administration employees within the services sector (defined in Appendix A), but neither job titles nor job duties were available for analysis, and therefore, job classification and sitting time were utilized to conceptualize employees' work environments.

Study Design and Analysis

Assumptions of the relationships between sedentary risks (e.g., physical inactivity and prolonged sitting) and back pain and productivity are displayed in the directed acyclic graph (DAG) in Figure C. 1 in Appendix C, respectively. DAGs were drawn prior to the analysis to identify potential confounders based on assumptions of causality between sitting and physical inactivity on back pain and productivity loss. The purpose of using DAGs in observational studies is to ensure the statistical models address the aims of the study by understanding causal concepts. (132-136) DAGs visually display the underlying assumptions of the relationships between the exposure of interest, covariates, and the outcome of interest. The DAGs were the conceptual framework to inform logistic models that produced odds ratios and 95% confidence intervals and quantified the independent and interaction relationships between each sedentary risk category and back pain based on the aforementioned 2 x 2 table. Resulting odds ratios represented a comparison of sedentary risk categories relative to the theoretical best-case scenario, "active life," as it was assumed the most active employees would have the lowest risk for back pain. To further explore the relationship between the exposure of prolonged sitting and inactivity, and because a target group for intervention is hypothesized to be employees who sit for prolonged periods of time, the results were also presented using sedentary job ("desk potato") as the referent group. We created additional 2x2 tables representing sedentary risk categories for employees with and without back pain and calculated absenteeism percentages for each cell of the 2x2 table, and within each stratum of back pain. This allowed the comparisons between employees with and without back pain, and among sedentary risk categories.

A cross-sectional study design was utilized to assess the independent and interactive effects of sitting exposures and not meeting physical activity guidelines on the outcome of back pain and to assess the impact of back pain and sedentary risk on productivity loss. Multivariate logistic regression was utilized to estimate the independent effects and interactions of inactivity and prolonged sitting on the outcome of back pain. To calculate opportunity cost, employees' average annual salary was multiplied by the percent of health-related absenteeism and results were stratified by back pain status sedentary risk category. Because the dataset did not include any employee identifiers, the study was exempted from continuing review by the Institutional Review Boards of the HealthPartners® Institute for Education and Research and the University of Minnesota. All analyses were performed using Stata® version 11.

Results

Table 11 presents descriptive characteristics of the study population by demographic, behavioral, and productivity measures by back pain status. Overall, the sample was highly educated (61% earned an undergraduate or graduate degree), middle aged (64% aged 40-59), mostly White (91%), non-Hispanic (98%), and female (55%). Relatively few (10%) employees used tobacco, but a majority of the employees (65%) had a higher than healthy BMI, averaging 28.0 kg/m2 (SD: 5.9 kg/m2). More than half (57%) classified themselves as administrative and reported an average of 1.7 hours (SD: 1.3 hours) of uninterrupted sitting while on the job per day. Employees worked an average of 37.4 hours in the past week (SD: 11.6 hours per week) and reported 0.61 hours of work missed in the past week due to health reasons. Median uninterrupted sitting time was 1.0 hour per usual workday. Average annual salary, as provided by the employer, was $52,000.

Sedentary Risk

Table 12 displays the prevalence odds and 95% confidence intervals for back pain by sedentary risk category, displaying associations of independent effects and interactions after controlling for covariates. Relative to employees with no exposure to inactivity or sitting (e.g., active life), all sedentary risk groups were at a statistically significant higher risk for back pain. Employees with exposure to both inactivity and prolonged sitting (e.g., sedentary life category) were at highest risk for back pain relative to the most active employees (OR = 1.76, CI: 1.65 – 1.88). The next highest risk category were those in the couch potato group, followed by desk potatoes (OR = 1.51, CI: 1.40 – 1.62 vs. OR = 1.16 CI: 1.10 – 1.23 respectively). When the referent group was changed to desk potato, results showed that couch potatoes had 33% higher odds of risk for back pain compared to desk potatoes (OR = 1. 33, CI: 1.23 – 1.42).

Productivity Loss

Figure 6 presents health-related absenteeism by back pain and sedentary risk category. Employees in all four sedentary risk categories, including those with neither exposure, had a higher percentage of time lost due to health problems in employees with back pain compared to employees without back pain, and overall missed work due to health problems 2.6 percent more often than employees without back pain. Regardless of back pain status, the highest percentages of time away from work due to health reasons were employees exposed to both inactivity and prolonged sitting, or those in the sedentary life category, followed by couch potato, desk potato, and active life. This finding was consistent with our expectations.

Higher percentages of absenteeism translated to higher opportunity costs to the employer (Figure 7); employees in all sedentary categories cost more in terms of lost labor compared to employees without back pain. The most prominent *difference* in comparing those with back pain to those without back pain was in the couch potatoes, followed by desk potatoes, sedentary life, and active life with differences in opportunities cost of $475, $356, $306, and $254 per person per year of excess costs associated with back pain, respectively (Figure 8). Health-related absenteeism was higher among workers with back pain compared to workers without back pain, and increased with increasing levels of sedentary risk These results are consistent with previous research that back pain leads to disability and productivity loss (8, 9, 75, 164-169) and contribute to the literature on the effect of sedentary behaviors on worker productivity. (11, 57, 167, 170, 171)

Discussion

The objective of this study was to compare the independent and interactive effects of physical inactivity (e.g., not meeting guidelines) and prolonged sitting at work, and the impact on productivity loss among employees with and without back pain. This study's findings are the first reported attempt at using health assessment data to quantify the relationship between prolonged sitting, physical inactivity, and back pain, and calculate the associated productivity loss associated with sedentary risk in an employee population. Results contribute to the research on sitting time and risk for back pain and to the impact of sedentary behaviors on productivity loss, and indicate not meeting physical activity guidelines and prolonged sitting time have statistically significant independent and interactive effects on the outcome of back pain compared to those who met guidelines or those who sat less, respectively. Furthermore, the highest risk categories were those that had exposure to inactivity (e.g., categories couch potato and sedentary life); however removing sitting exposure among active employees decreased risk for back pain by 15 percent (i.e., going from desk potato to active life as shown in Table 12.

Limitations of this study relate to the study design, sample selection, and data source. Because of the cross-sectional study design, associations, not causality, can be determined between the exposures of sitting time and physical inactivity on the outcome of back pain and productivity loss from these analyses, but the large sample size increases the statistical power of observed associations and reduces the likelihood of the associations being due to chance alone. Furthermore, temporal relationships between sedentary behavior, physical activity and back pain have been described in various settings, which mitigate the study design limitation. (24, 26, 38, 42, 45, 47, 67, 124) Studies are needed that utilize longitudinal analyses of health assessment data to compare results over time in relation to health program participation rates. An estimated 30% of employees in this study were missing due to nonresponse. The direction of biases resulting from nonresponse on our results is unknown, and therefore generalizing the results to all employees should be done with caution. Although 70% is a relatively high response rate, employers should consider integrating both extrinsic (e.g., financial) and intrinsic (e.g., based on personality type or emotions) incentives as means to encourage employee participation in health assessments as well as health promotion programs. (172-174)

Moreover, due to the nature of this secondary data analysis, we are limited to the available data, which, although extensive, lacked information on history of back injury, job tenure, and genetic predispositions which would have been helpful additions to the statistical model in terms of conceptualizing the relationship between sedentary exposures and back pain in the workplace. “Psychosomatic indicators,” such as feeling stressed or depressed and poor job satisfaction, can be both risk factors and consequences of low back pain, (114) however, although these were assessed in the questionnaire, it was our assumption that such indicators were “upstream” from the exposures and covariates included in the conceptual model and DAGs, and therefore were not included in the statistical model as potential confounders. Nonetheless, future studies should include more complex statistical models that account for psychosomatic indicators when assessing the effect of chronic health problems on health-related absenteeism and presenteeism.

Additionally, back pain-specific absenteeism data were not available within the health assessment data—only health-related absenteeism. However, back pain is known to be the most costly health condition to employers nationally, if not globally, and the negative relationship between back pain and productivity loss has been established (9, 55, 56, 121, 175), which justifies using health-related absenteeism and opportunity costs as proxies. Health-related presenteeism, which captures decreased performance while at work due to health reasons, was not included as a productivity outcome in this study. Although presenteeism can be an informative measure of productivity loss, it has a complex relationship with back pain, and due to the limitations of the data, assessing presenteeism was beyond the scope of this study.(54, 80)

Despite the limitations, exploring the relationship of prolonged sitting, as opposed to total sitting time, is meaningful because total sitting time may be a more comprehensive measure of total worker exposure to sitting, although it does not account for the effect of static posture, which is known to be associated with back pain. (112, 140-144) Further research is needed to look at cumulative exposures of sitting on back pain, such as those during leisure, commuting and during work as high overall sitting time may have an independent and interactive effect with prolonged sitting and/or physical inactivity. (20, 39, 176) Furthermore, tying a dollar amount to the impact of prolonged sitting is extremely useful to employers because demonstrating the financial impact of risk behaviors and health conditions is critical for developing budgetary priorities, including the amounts allocated for employee benefits such as health insurance, health promotion programs, and disease management interventions.(56)

Few authors (57, 71, 72) have quantified the economic costs of sedentary behavior in a workplace setting. Oldridge, et. al's (2008) study reported the proportions of direct health costs due to physical inactivity ranged 1.5% to 3%. (73) Cadilhac, et. al (2011) predicted cost savings associated with reductions in sedentary lifestyles and showed a savings of 2% in associated health care costs, absenteeism, and household productivity when sedentary lifestyle was reduced by 10% nationally, especially in government workers. (74) Pronk, et. al (2012) evaluated a sit-stand desk on measures of employee performance and found that use of sit-stand desks and reductions in sitting time were correlated with improved outcomes for upper back and neck pain as well as various mood states, including happiness and productivity., but cost was not measured. (22) Research on sedentary behavior and back pain on productivity thus far has focused on the cost of general and specific health outcomes (e.g., mortality, cardiovascular disease, diabetes, stroke, and back pain) as a function of sedentary behavior, not costs specifically attributable to sedentary behavior as the exposure. (1, 2, 48, 73)

Evidence is growing that environmental interventions, such as contemporary workstations that require intermittent standing or very slow walking, doubled energy expenditure throughout the day and that employees enjoyed using them, supported their use, and wished they had the option to sit less at work. (88, 89) A paradigm shift in how physical activity is promoted within the workplace is underway, and this study provides data on the potential value of the scientific innovation of a “move more, sit less” approach to reducing the burden of injury and illness of workers experiencing back pain. (13, 43, 44, 46)

Findings from this study are meaningful to U.S. employers conducting health assessments who currently use physical activity guidelines to identify sedentary employees, as current guidelines do not include measures of sitting time, particularly in the workplace. Sedentary lifestyle is a known risk factor for back pain in the general working population, yet currently no definitive recommendations exist on how long people should sit or how often people should break up their sitting time. (39, 49) Therefore, the study findings suggest the need to adapt guidelines to include sitting exposures if the findings are replicated in other populations. This contribution can support employers' decision-making regarding resource investments for worker health and well-being programs. The results also support the National Institutes of Occupational Safety and Health's Total Worker Health™ strategy by informing the direction of future research aimed at utilizing health risk assessment screening tools for occupational back pain and informing future research on interventions that extend healthy lives of workers and reduce the burdens of illness and disability. (16)

Chapter 7. Discussion

This study utilized employee health assessment data to examine the impact of sitting time and physical inactivity on back pain and productivity in a sample of services sector workers. The gaps in the literature, which this study addresses, include those related to the etiology of occupational back pain, the distinction between physical inactivity, which can be addressed with increasing physical activity levels, and sitting time, which can be addressed by sitting less, and impacts of sedentary behavior on productivity in the workplace. Results are consistent with the inactivity physiology paradigm that proposes sedentary behaviors, including sitting too much, are independent of the type of physical activity delineated for health in the Physical Activity Guidelines for Americans. (38) These data address the gap in the literature on a clinically relevant exposure of prolonged sitting as it pertains to negative health consequences in the workplace, as currently a definition is nonexistent and the concept of sitting as a specific type of sedentary behavior studies remains vague and inconsistent. (22, 109, 110, 115)

Results from paper 1 suggest that both non-modifiable factors, such as age, gender, education, and job classification, and modifiable factors, such as sedentary behaviors, high BMI and tobacco use, are important when designing health promotion programs to prevent and treat back pain in a working population. Results are consistent with the current evidence on the non-modifiable risk factors of age (150-153) and gender, (7, 95, 150, 154) and consistent with the protective effect of education. (2, 5, 35, 91, 96, 143, 155) Previous research has shown that breaks in prolonged sitting time (e.g., periodic standing or ambulating) have been associated with lower health risks and related to waist circumference, BMI, triglyceride levels, and 2-hour plasma glucose levels, (36, 37) but these results are the first to show that back pain may occur after only one hour of sitting in a working population. Results on the risk for back pain and BMI are consistent with previous research that suggests obesity may increase risk for injury, (159, 160) and results provide new information on the association between an increase in being ready to manage back pain with an increase in BMI. The circular relationship between overweight/obesity and back pain highlights the importance of integrating health promotion with health protection (e.g., safety) within the workplace because programs to help workers lose weight may have multiple benefits when paired with back-pain reducing ergonomic interventions aimed at reducing static postures from sitting.

Paper 2 is the first reported attempt at using health assessment data to quantify the interactive relationship between prolonged sitting and physical inactivity with associated productivity loss in an employee population by tying a dollar amount to sedentary risk. Regardless of back pain status, the highest percentages absenteeism, and therefore opportunity costs, were employees exposed to both inactivity and prolonged sitting, or those in the sedentary life category, followed by couch potatoes, desk potatoes, and those in the active life category. Results indicate that risk for back pain is highest when employees do not meet physical activity guidelines and also sit for prolonged periods of time at work, indicating prolonged sitting adds risk to physical inactivity on the outcome of back pain. Few authors (57, 71, 72) have quantified the economic costs of sedentary behavior in a workplace setting. Research thus far has focused on the cost of general and specific health outcomes (e.g., mortality, cardiovascular disease, diabetes, stroke, and back pain) (9, 55, 75, 76) as a function of sedentary behavior, not costs specifically attributable to sedentary behavior as the exposure. Results from paper 2 are consistent with previous research that back pain contributes to disability and productivity loss (8, 9, 75, 164-169) and contribute to the literature on the effect of sedentary behaviors on worker productivity. (11, 57, 167, 170, 171)

Study limitations are related to the design, sample selection, and data analysis. Because of the cross-sectional study design, associations, not causality, can be determined between the exposures of sitting time and physical inactivity on the outcome of back pain and productivity loss from these analyses. However, the temporal relationships between sedentary behaviors, physical activity and back pain have been described in various settings. (24, 26, 42, 45, 145) Furthermore, employees may overestimate their positive behaviors (e.g., physical activity levels) and/or underestimate their negative behaviors (e.g., sedentary behaviors), and therefore misclassification of the exposure is likely and the true value of the association with back pain may be over-or underestimated. (40, 146, 147) However, similar questions related to physical activity and sitting have been determined to be moderately valid and reliable for sedentary lifestyle (e.g. measured as not meeting guidelines), and intense leisure-time physical activity (41, 44, 127) and the questions on physical activity have been shown to accurately classify groups of adults into the levels of recommended for vigorous activity. (41, 44, 128)

The absence of up to 30% of the study population from the sample dataset and the reliance on self-reported outcomes may have influenced the results but the direction of these biases is not known. Additionally, the sample was largely non-Hispanic and White, limiting generalizability. Non-White race and Hispanic ethnicity have been associated with poorer access to care and outcomes for pain-related conditions, (157, 177) however research on the association between race and back pain is minimal (156-158) and because of the relatively small proportion of non-Whites working for this employer and lack of information on them, we do not know whether the association in our results is valid or not. Further research within the services sector with more diverse employee populations with respect to age, race, ethnicity and occupations and within non-services sector industries is warranted to get a better representation of exposures to sedentary behavior and its relationship with back pain. It is also important to note that even in industries that are commonly known for physically laborious work, such as construction, occupations within that industry may be prone to the exposure of prolonged sitting (105) and therefore results on industry-level data may not be generalizable to occupations within that industry. Similarly, these results may be generalizable to occupations in industries other than in the services sector.

Although the statistical model adjusted for several covariates, the risks for back pain may be higher in certain job classifications due to unmeasured covariates related to job type, such as exposure to whole body vibration or awkward lifting postures (25, 142, 148, 149). To gain a more complete understanding of total worker exposures, it also is important to evaluate exposures to prolonged sitting outside of the workplace, such as television watching. The measurement of back pain was incomplete, as it did not assess pain severity, intensity, or measures taken to address back pain. Additionally, readiness to change an *outcome*, such as back pain, does not necessarily reflect an employee's readiness to change the *behaviors*, such as those that lead to overweight or obesity. Furthermore, back pain-specific absenteeism data were not available within the health assessment data—only health-related absenteeism. However, back pain is known to be the most costly health condition to employers nationally, if not globally, and the negative relationship between back pain and productivity loss has been established (9, 55, 56, 121, 175), which justifies using health-related absenteeism and opportunity costs as proxies. Future research should include a more comprehensive measure of productivity loss attributable to sedentary behavior that includes both direct and indirect measures such as absenteeism, presenteeism and health claims data.

The strengths of this research counter the limitations. The sample was a very large employee dataset with extensive measures allowing us to control for potential confounders in the statistical model. Similarly, the odds ratios produced narrow confidence intervals reducing the likelihood of the associations being due to chance. Furthermore, although 30% of the employees did not respond to the survey, a response rate of 70% was relatively high given the low financial incentive of $5 copayment reduction to participate. Results of this research are not only translatable directly to the employer providing the data, but also are generalizable to other large employers within other sectors and industries, particularly of those employing services sector workers with similar demographics of the study population.

This research is particularly valuable because it contributes to the literature on sitting time and back pain. Exploring the relationship of prolonged sitting, as opposed to total sitting time, is meaningful because, although total sitting time may be a more comprehensive measure of total worker exposure to sitting, it does not account for the effect of static posture, which is known to be associated with back pain. (112, 140-144) Likewise, when designing worksite health programs, employers should utilize health assessment data to integrate health promotion and health protection while targeting specific occupational groups and assess employees' readiness to change pertaining to both amenable harmful exposures and outcomes. These results suggest a need for environmental and/or policy-level interventions that aim to reduce sedentary behaviors in the workplace, such as workstation design, in addition to those that focus on individual behavior change such as physical activity programs.

Physical activity benefits workers regardless of sitting exposure at work (i.e., job classification); however the *types* of physical activities that are beneficial are conceptually different depending on typical work tasks. For example, among sedentary workers, interventions should focus more on reducing sedentary time (e.g., sitting) or incorporating short bursts of activity to interrupt sitting time, rather than on structured physical activity or meeting guidelines. (22, 107, 108, 110) Employees with physically demanding jobs might benefit more from "regular" or structured physical activities during leisure time, rather than at work. (79, 105, 106, 109, 111, 114, 116, 117, 122) Employer-based programs that promote a combination of physical activity, ambulation, and/or periodic standing may be particularly valuable because they have the potential to improve employee productivity and reduce short-term disability leave, employee turnover, absenteeism, and healthcare costs. (10-13) When interpreting these results for worksite health programs and policies, employers should consider both numbers of employees *and* risk ratios when informing workplace health promotion programs, as one may be more appropriate based on the employer population. Future research is needed to assess longitudinal exposures to sedentary risk on outcomes of back pain and productivity loss over time.

Tables.

Table 1. PICOTS eligibility criteria (117)

Population (Types of participants)
Eligible studies included employees 18 years of age or older and employed at a company anywhere in the world. Potential covariates were employee demographics (age, gender, race, income, education, occupation), other employee characteristics (BMI, tobacco use, job tenure, psychosocial characteristics (e.g., motivation to change)), and workplace characteristics (workstation ergonomics, accessibility of health programs)
Interventions, Comparators (Types of exposures/ interventions)
Intervention and exposure topics were related to reducing sedentary behaviors such as sitting or physical (in)activity. The comparator group included non-sedentary occupations or employees and interventions that aimed to address sedentary behavior. Interventions were compared to other types of interventions if they included a comparison, however a comparison was not required for eligibility.
Outcome (Types of outcome measures)
The primary outcomes assessed were back pain (any definition). Secondary outcomes were changes in sitting behavior and employee performance.
Timing and Setting
The timing for this review was not limited. Year of publication and data collection, and time of follow up and/or recall were recorded. The setting was any occupational setting in the world. The country of study location, industry, and company were tracked where available.

Table 2. Characteristics of studies[1]

Years	Countries	Study Design[2]	Sample Size	Data Source[3]	Results[4]
1989 – 2013 median: 2009 mode: 2012	4 Australia 4 Finland 3 United States 1 France 1 Hong Kong 1 Japan 1 Spain 1 India 1 Poland 1 Switzerland	8 Pre/Post 4 RCT 3 CX 1 LT 1 CC 1 CS	8 (< 50) 4 (50 – 100) 2 (101 – 300) 4 (>300) mean: 284 median: 68	5 Q only 3 Q + log 7 Q + PE 1 Q + AM 1 Q + PE+MRI 1 Q + PE+EMR	11 sit (+) 1 sit (o) 4 paL (+) 7 pa (+)

1 Counts of articles are presented within each category.
2 Study designs: RCT (randomized clinical trial), LT (longitudinal), CX (cross-sectional), CC (case control), CS (case study).
3 Sources of data: Q (questionnaire/s), PE (physical exam), MRI (magnetic resonance imaging) EMR (employee medical record), AM (activity monitor).
4 Exposure/Interventions: sit (sitting), paL (physically active labor), pa (physical activity), (+) and (o) signs indicate authors' regards of the results as favorable (+) and null (o) on the outcome of back pain. Unfavorable results (-) were not reported.

Table 3. Quality assessment

Citation	Study			Intervention			
	Design[5]	Methods[6]	Quality[7]	Access[8]	Mode[9]	Quality[10]	Overall Quality[11]
Riihimaki et al, 1989	1	1	1	na	na	na	1
Leino, 1993	2	2	2	na	na	na	2
Arokoski, et al, 2002	2	1	1.5	1	0	1	2.5
Robertson & O'Neill, 2003	1	2	1.5	1	1	2	3.5
Dainoff, et al 2005	2	2	2	1	1	2	4
Konarska, et al, 2005	2	2	2	1	1	2	4
O'Sullivan, et al, 2006	1	2	1.5	na	na	na	1.5
Schenk, et al, 2007	2	2	2	na	na	na	2
Szeto & Lam, 2007	1	1	1	na	na	na	1
Nassif, et al, 2011	2	2	2	1	0	1	3
Alkhajah, et al, 2012	2	1	1.5	1	2	3	4.5
Pandey, et al, 2012	1	1	1	na	na	na	1
Pronk, et. al, 2012	1	2	1.5	1	2	3	4.5
Rantonen, et. al, 2012	3	3	3	0	0	na	3
Sakuma, et. al, 2012	2	1	1.5	0	0	0	1.5
Cooley & Pedersen, 2013	2	2	2	1	0	1	3
del Pozo-Cruz et al, 2013	3	3	3	1	0	1	4
Pedersen, et al, 2013	2	2	2	1	0	1	3
Overall Quality of the Literature			**1.8**			**1.6**	**2.7**

5 Design: Respective scores based study design low, moderate, high (0, 1, 2).
6 Methods: Respective scores based likelihood of bias scores of based on very low, low, moderate, high (0, 1, 2, 3).
7 Study Design Quality: Score based on average of Design and Methods scores (possible range: 0 – 3.0).
8 Accessibility: Respective scores based on onsite, off site, or onsite/offsite combo, not applicable (0, 1, 2, na).
9 Mode of delivery: Respective scores based on active, passive, active/passive combo, not applicable (0, 1, 2, na).
10 Intervention Quality: Score based on the sum scores of accessibility and mode (possible range: 0 - 4).
11 Overall quality: sum of scores for study design and intervention quality (possible range: 0 – 7.0).

Table 4. Study terminology and definitions

Construct	*Variable*	Definition
Sedentary Behavior	*Sedentary behavior*	Sitting or reclining in the energy-expenditure range of some 1.0 to 1.5 METs (multiples of the basal metabolic rate). (5, 41)
Sitting Time	*Prolonged sitting*	Uninterrupted sitting time while at work.
	Total Sitting Time	Total hours of sitting time in a usual week including time spent at home, commuting, and at work.
Physical Activity	*Physical activity guidelines*	Weekly accumulation of an equivalent of at least 150 min of moderate physical activity, sustained in bouts lasting 10 minutes or longer.(1)
	Physically inactive	Not meeting the physical activity guidelines in a usual week.
Back Pain	*Back pain*	A response of "sometimes" or "always" to the question "How often do you have back pain?"
Risk Factors	*Worker risk factors*	Demographics factors such as age, gender, education, and race; and lifestyle factors such as physical inactivity, total sitting time, high body mass index tobacco use, perceived job safety.
	Workplace risk factors	Those risks that are directly related to the workplace, such as job classification and prolonged sitting time.
Perceived Job Safety	*Perceived Access to Safety Resources*	A response of "Always" or "Usually" (vs. "Sometimes," "Rarely," or "Never") to the question " How often do you have the knowledge, tools and resources you need to perform your job safely and without injury?"
Productivity losses	*Absenteeism*	Percent of time missed from work due to health reasons.
	Opportunity cost	Cost to the employer, in dollars, of labor forgone due to health-related absenteeism.

Table 5. Modifiable covariates

1.	*Physical inactivity* (yes/no) was based on not meeting the 2008 Surgeon General guidelines and Healthy People 2010 goals of 150 minutes of moderate or physical activity per usual week in bouts of 10 minutes or more. (130)
2.	*Low energy expenditure (Active vs. Sedentary)* was determined based on the cut point of 800 kilocalories (Kcal) per week calories expended after adjusting for body weight (pounds converted to kilograms). Kcals were calculated from self-reported "vigorous" and "moderate" physical activity adapted from the 2008 Surgeon General guidelines questionnaire, which asks specifically about leisure time activities. (130) The resulting activity categories were classified as sedentary or active, and are a function of type of activity (e.g., leisurely, moderate, vigorous physical activities) and body weight.
3.	*High (vs. low) weekly sitting time* was created by taking the median cut-off value of all responses to the question: "For this question, think about the time you spend sitting—at work, at home, while driving your car, during leisure time, etc. In a usual week, how much total time do you spend sitting?"
4.	*Prolonged sitting time at work* (yes/no) was created by using median sitting time from all responses to the question "In a usual day, what is the longest period of time that you sit at work without getting up to move?"
5.	*Body mass index (BMI)* was calculated using height in feet and weight in pounds then converted to kg/m^2 and divided into five categories based on the Centers for Disease Control and Prevention criteria for adults over age 20: healthy (18.5 – 24.9), overweight (25.0 – 29.9), obese (30.0 – 44.9), severely obese ($\geq$ 45.0), and underweight (< 18.5).
6.	*Current tobacco* use was determined by a response of "yes" to the question "Do you use any kind of tobacco, including cigarettes, cigars, a pipe, snuff, or chewing tobacco?"

Table 6. Transtheoretical Model of Behavior Change (TTM) [12]

TTM Stage of Change	Employee Response
1. Precontemplation	❍ I do not think changes are necessary
2. Contemplation	❍ I have been thinking about making some changes
3. Preparation	❍ I am seriously thinking about making some changes
4. Action	❍ I am currently making changes or have made changes within the past 6 months
5. Maintenance	❍ I have made and maintained changes for more than 6 months

12 The Transtheoretical Model (TTM) Stages of Change were determined by the employee responses to the question "How ready are you to make changes to manage back pain?"

Table 7. Paper 1 descriptive statistics

Characteristic	Back pain **No** n = 21,090	 **Yes** n = 13,901
Individual		
Age category		
20-29	7.4%	5.8%
40-49	26.6%	27.3%
50-59	35.5%	36.7%
60-64	10.5%	11.6%
65+	2.3%	2.1%
Female	54.2%	56.7%
White	93.2%	93.8%
4yr degree	63.5%	56.3%
BMI (kg/m^2) (mean, SD)	27.5 (5.6)	28.8 (6.3)
Use tobacco	8.25%	12.80%
Inactive (Do not meet guidelines)	24.05%	34.55%
Total sitting time $\geq$ 30 hrs/wk	33.0 (22.7)	35.3 (24.1)
Work - related		
Hrs worked per week	35.9 (13.3)	35.6 (14.0)
Prolonged sitting (hrs @ work)	1.7 (1.3)	1.8 (1.3)
Job classification (%)		
Administrative	58.4%	52.7%
Professional/Management	13.4%	16.2%
Labor	16.8%	19.9%
Other	10.9%	10.9%
Low perceived access to safety resources	2.60%	4.30%

Table 8. Non-modifiable factors and employees' risk for back pain[13]

Non-modifiable Factor	OR (95% CI)
Age category	
20-29	1.00
30-39	1.20 (1.09, 1.33)
40-49	1.32 (1.20, 1.45)
50-59	1.33 (1.22 1.46)
60-64	1.42 (1.28, 1.58)
65+	1.17 (0.99, 1.39)
Gender	
Male	1.00
Female	1.11 (1.06, 1.16)
Race	
White	1.00
non-White	0.93 (0.85, 1.01)
unknown	0.83 (0.73, 0.94)
Education (4-yr degree) [14]	
no	1.00
yes	0.75 (0.72, 0.79)
Job type[15]	
Administrative	1.00
Professional/Management	1.13 (1.05, 1.21)
Labor	1.18 (1.11, 1.26)
Other	1.04 (0.97, 1.12)

13 Odds ratios (OR) and 95% confidence intervals (CI) of back pain (sometimes or always) by non-modifiable factors for n = 21,090 without back pain and 13,901 with back pain.

14 Controlled for age, gender, and race.

15 Controlled for age, gender, race, education, and BMI.

Table 9.[16] Modifiable factors and employees' risk for back pain

Modifiable factors	OR (95% CI)
BMI category (kg/m^2) [17]	
healthy (18.5-24.9)	1.00
overweight (25-29)	1.23 (1.16, 1.30)
obese (29.1-45)	1.48 (1.39, 1.56)
severely obese (>45)	1.88 (1.56, 2.27)
underweight (< 18.5)	1.02 (0.76, 1.37)
Current tobacco use [18]	
No	1.00
Yes	1.55 (1.44, 1.66)
Physical inactivity[19]	
Meets guidelines	1.00
Does not meet guidelines	1.53 (1.46, 1.61)
Low energy expenditure[20]	
Active (> 800 Kcal/wk)	1.00
Sedentary (≤ 800 Kcal/wk)	1.76 (1.67, 1.86)
Total sitting time [21]	
low (< 30 h/wk)	1.00
high (≥ 30 h/wk)	1.17 (1.12, 1.22)
Prolonged sitting time at work[22]	
no (<1.0 h/day)	1.00
yes (≥1.0 h/day)	1.21 (1.16, 1.27)

16 Odds ratios (OR) and 95% confidence intervals (CI) of back pain (sometimes or always) by modifiable factors. n = 21,090 without back pain and 13,901 with back pain

17 Controlled for age, gender, race, education, tobacco use, prolonged sitting time, physical inactivity, and perceived access to safety resources

18 Controlled for age, gender, race, education, job class, and perceived access to safety resources

19 Controlled for age, gender, race, education, job class, BMI, tobacco use, prolonged sitting time, total sitting, and perceived access to safety resources

20 Controlled for age, gender, race, education, job class, tobacco use, and perceived access to safety resources

21 Controlled for age, gender, race, education, job class, BMI, tobacco use, prolonged sitting time, and perceived access to safety resources

22 Controlled for age, gender, race, education, job class, BMI, tobacco use, perceived access to safety resources

Table 10. Readiness to manage back pain by BMI category[23]

BMI category (kg/m^2)[24]	Ready to Manage Back Pain[25] OR (95% CI)
Overweight (25 - 29)	1.18 (1.07 – 1.31)
Obese (29.1 - 45)	1.43 (1.29 – 1.58)
Severely obese (>45)	1.96 (1.45 – 2.65)

23 Readiness to make changes to address back pain by BMI category among 13,901 employees reporting back pain.
24 Compared to those with a BMI of 18.5 – 24.9 kg/m^2; controlled for age, gender, race, education, job class, perceived access to safety resources.
25 Preparation or action back pain stages of change, compared to precontemplation or contemplation

Table 11. Paper 2 descriptive statistics[26]

	Frequent Back Pain	
Demographics	No (n = 19,925)	Yes (n = 13,034)
Age	47.2 (10.8)	47.9 (10.4)
Female	54.4%	57.1%
White	90.3%	91.1%
Education (4 – year degree)	63.8%	57.0%
Job classification		
Administrative	59.4%	54.1%
Professional/Management	13.7%	16.6%
Labor	15.9%	18.5%
Other	11.0%	10.8%
Behavioral		
BMI (kg/m^2)	27.5 (5.6)	28.7 (6.3)
Use tobacco	8.2%	12.7%
Sedentary Risks		
Inactive (Do not meet guidelines)	24.2%	34.7%
Sitting hours per usual week (work + leisure)	33.3 (22.7)	35.6 (25.1)
Uninterrupted sitting per usual day at work	1.7 (1.3)	1.8 (1.3)
Health-Related Productivity Loss (past 7 days)		
Hours worked	37.5 (11.3)	37.3 (12.0)
Hours missed (health - related)	0.48 (2.8)	0.81 (3.5)
Hours missed (other)	4.76 (8.1)	5.14 (8.3)

26 Continuous variables are expressed as means (standard deviation) and categorical variables are expressed as percentages.

Table 12. Interaction between inactive (I) and prolonged sitting time (S) [27]

Risk for Back Pain by Sedentary Risk Category

I	S	Sedentary Risk Category	n	OR[28]	95% CI
-	-	active life (ref)	13,255	--	--
-	+	desk potato	10,364	1.16	1.10 - 1.23
+	-	couch potato	4,085	1.51	1.40 - 1.62
+	+	sedentary life	5,255	1.76	1.65 - 1.88
-	+	desk potato (ref)	10,364	--	--
-	-	active life	13,255	0.85	0.80 - 0.90
+	-	couch potato	4,085	1.33	1.23 - 1.42
+	+	sedentary life	5,255	1.45	1.36 - 1.56

27 Controlled for age, gender, race, education, job class, BMI, tobacco use, perceived access to safety resources.

28 Odds of sedentary risk for employees reporting back pain (n = 19,925) compared to those not reporting back pain (n = 13,034),

Figures.

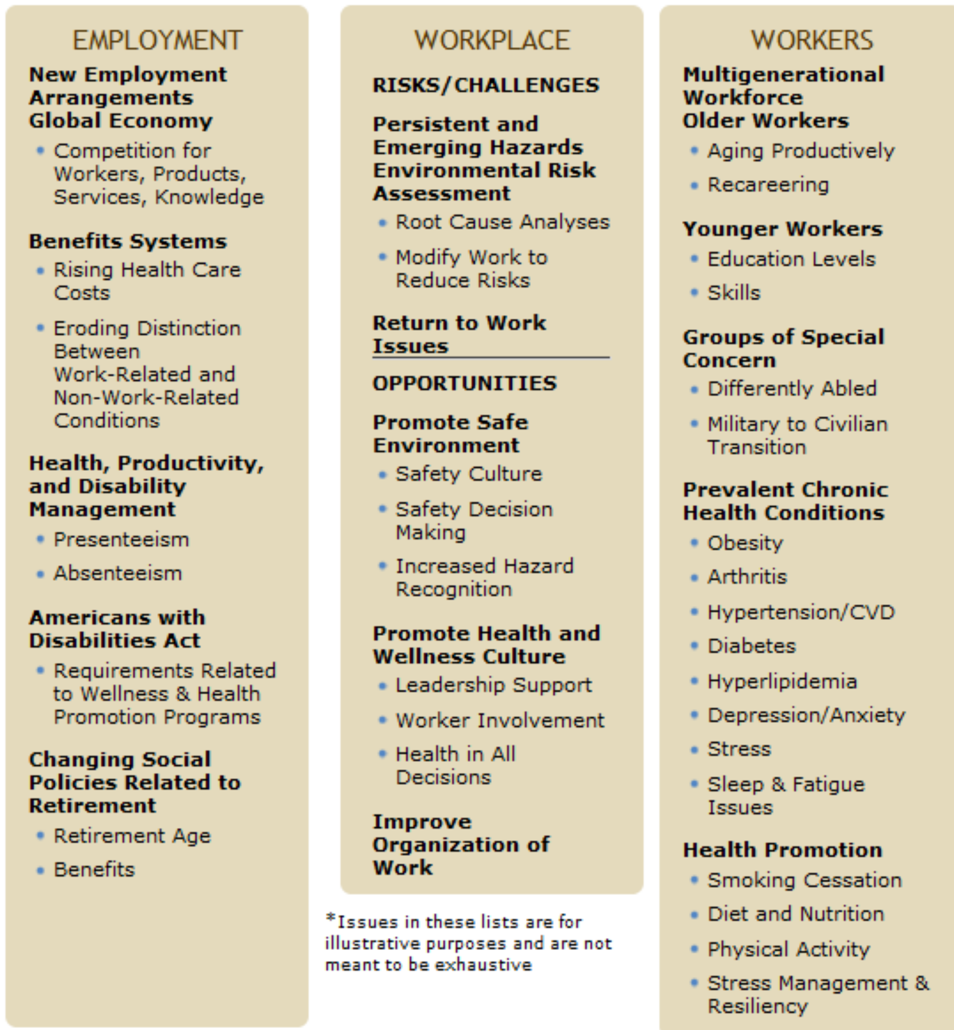

Figure 1. Issues related to NIOSH Total Worker Health™

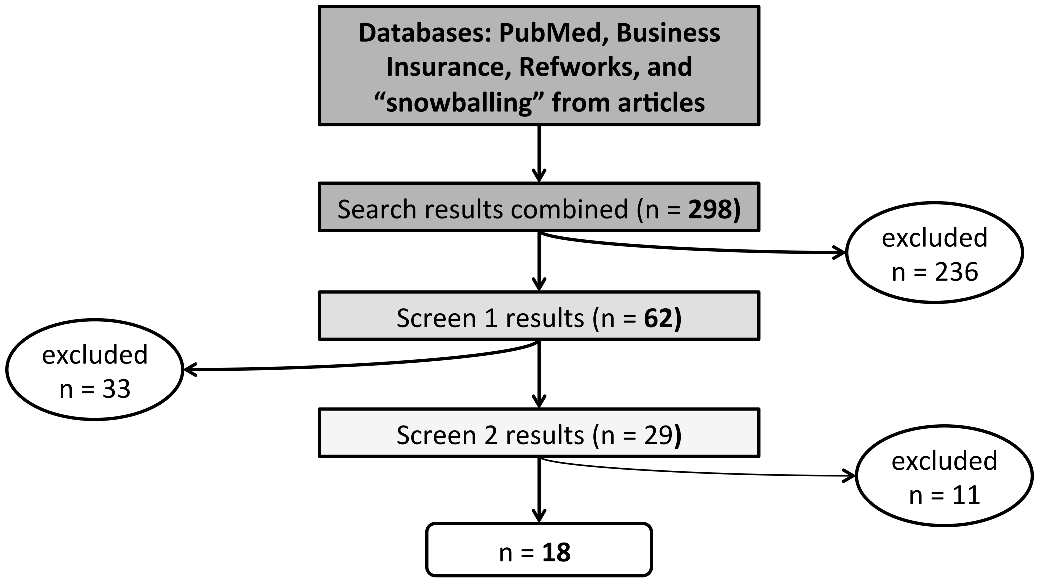

Figure 2. Literature search flow chart

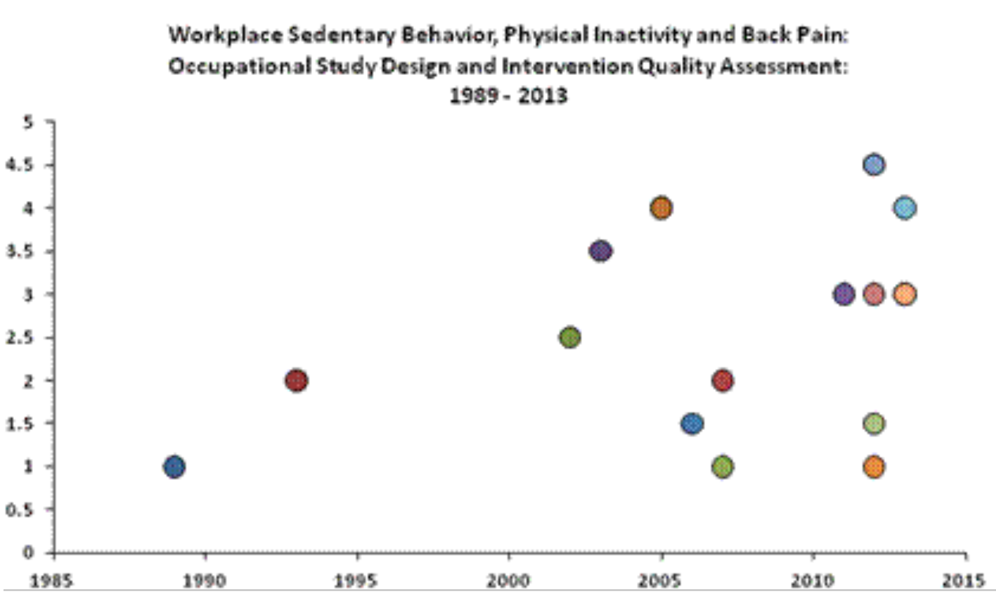

Figure 3. Study quality over time[29]

29 Workplace Studies on sedentary behaviors and back pain were evaluated for quality (n = 18). Studies ranged from 1989(106) to 2013(107, 110, 117) and include intervention studies.

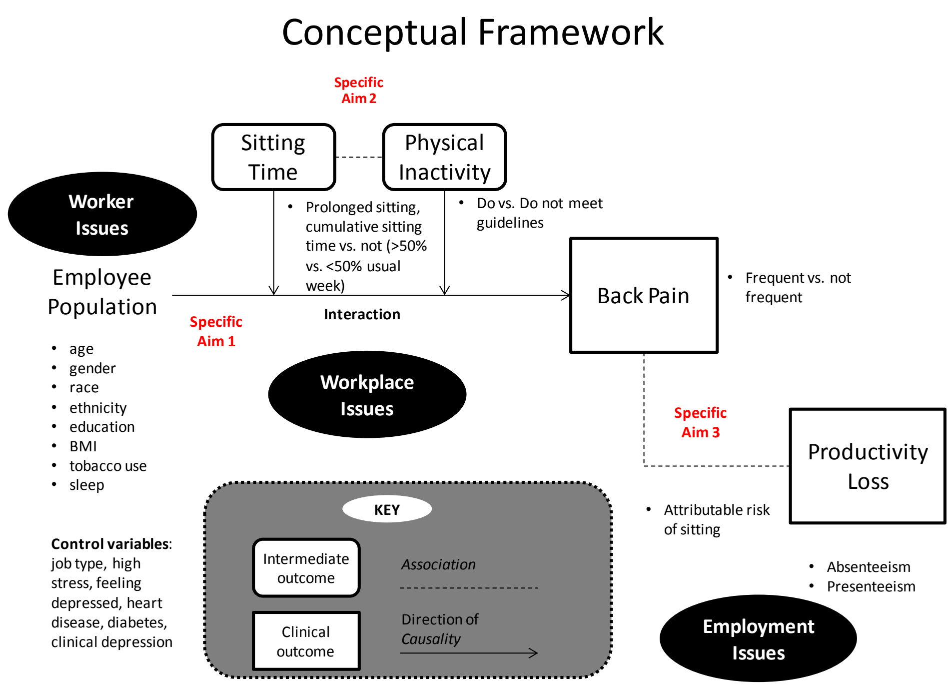

Figure 4. Research conceptual framework for “An Evaluation of Prolonged Sitting and Physical Inactivity on Back Pain and Productivity Loss Among Services"

		Inactive	
Sitting Time		**Yes (+)**	**No (-)**
	Yes (+)	**S+I+** Sedentary Life	**S+I-** Sedentary Job ("desk potato")
	No (-)	**S-I+** Sedentary Leisure ("couch potato")	**S-I-** Active Life

$$P(BP|sed\ life) > P(BP|sed\ leisure) > P(BP|sed\ job) > (BP|active\ life) > 0$$

Figure 5. 2x2 table and probability equation[30] [31]

30 Physical inactivity and prolonged sitting are dichotomous variables calculated by not meeting guidelines and prolonged sitting for 1.0 hour or more during the work day, respectively.

31 Sedentary Life (S+I+) represents the interactive relationship between prolonged sitting (S+) and physical inactivity (I+).

Back Pain = No

Prolonged Sitting	Inactive: Yes (+)	Inactive: No (-)	Total
Yes (+)	sed life 1.7%	desk potato 1.0%	2.7%
No (-)	couch potato 1.3%	active life 0.8%	2.1%
Total	3.0%	1.7%	**4.8%**

Back Pain = Yes

Prolonged Sitting	Inactive: Yes (+)	Inactive: No (-)	Total
Yes (+)	sed life 2.3%	desk potato 1.7%	4.0%
No (-)	couch potato 2.2%	active life 1.3%	3.5%
Total	4.5%	2.9%	**7.4%**

Figure 6. Health-related absenteeism[32]

32 Absenteeism is an indicator of productivity loss and is represented by a percentage of time lost due to health problems. The percent was calculated by taking the number of hours missed due to health problems divided by the total number of hours worked and missed per person in the past 7 days.

Back Pain = No

Prolonged Sitting	*Inactive* Yes (+)	No (-)	Total
Yes (+)	sed life $894.45	desk potato $503.82	$ 1,398.27
No (-)	couch potato $680.95	active life $403.99	$ 1,084.94
Total	$1,575.40	$907.81	**$2,483.21**

Back Pain = Yes

Prolonged Sitting	*Inactive* Yes (+)	No (-)	Total
Yes (+)	sed life $1,200.52	desk potato $859.49	$ 2,060.01
No (-)	couch potato $1,155.53	active life $657.59	$ 1,813.12
Total	$2,356.05	$1,517.08	**$3,873.13**

Figure 7. Opportunity cost[33]

33 Opportunity cost is calculated by multiplying the percent of absenteeism by the average employee salary $52,000 per year and represents forgone labor person per year.

Back Pain (yes - no)

Prolonged Sitting	*Inactive* Yes (+)	No (-)	Total
Yes (+)	sed life $306.07	desk potato $355.67	$ 661.74
No (-)	couch potato $474.58	active life $253.60	$ 728.18
Total	$780.65	$609.27	**$1,389.92**

Figure 8. Excess costs attributable to back pain[34]

34 Opportunity costs were calculated based on employee salary and percent missed time from work due to health reasons (absenteeism). This table compares the difference between employees with back pain compared to employees without back pain per person per year by sedentary category.

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Appendices

Appendix A. NORA Services Sector

The NORA Services Sector grouping covers over 66 million workers in North American Industry Classification System (NAICS) industries 51 – 56, 61, 71, 72, 81 and 92. The Table lists the major industry groups in the NORA Services Sector grouping for the 2012 Current Population Survey. The sample used in this study represnts the Public Administration Industry, or NAICS industry 92 which covers just over 4.0 million workers nationally.

NAICS	NAICS Industry Title	Industries within NAICS Group	Number of Workers
51	Information	Libraries, Publishing, Sound and Movie Recording, Wired and Wireless Communications	2,971,000
52	Finance and Insurance	Depository and Non-depository Credit, Insurance, Brokerages	6,786,000
53	Real Estate, Rental, Leasing	Real Estate Brokerages, Facility Leasing and Rental, Real Estate Management, Consumer Products and Equipment Rental	2,804,000
54	Professional, Scientific and Technical	Drafting and Design, Law Offices, Accounting, Direct Mail, Marketing and Public Relations, Survey and Mapping, Engineering, Laboratories, Consulting	9,913,000
55	Management of Corporations and Entities	Corporate, Subsidiary, and Regional Offices; Bank Holding Companies	187,000
56	Administrative Support and Waste Management	Office, Business and Facility Support; Building Services; Travel Reservations; Investigation; Waste Collection, Treatment and Disposal; Employment Services	6,439,000
61	Education	Primary and Secondary Schools, Technical and other Colleges, Universities, Professional Schools, Educational Support	12,945,000
71	Arts, Entertainment and Recreations	Performing Arts, Spectator Sports, Museums, Zoos, Botanical Gardens, Amusement Parks, Gambling Industries, Historic Sites, and Nature Sites	3,022,000
72	Accommodations and Food Services	Hotels and Motels, RV Parks, Boarding Houses, Restaurants, Catering, Drinking Establishments	10,171,000
81	Other Services	Automobile and Machine Servicing and Repair; Giving Organizations; Religious Organizations; Social Clubs; Business, Professional, Labor, Political and Trade Organizations; Personal Care; Laundries; Private Households	7,168,000
92	Public Administration	Local, State, and Federal Governments excluding Members of the Military (Public safety workers have been included in a separate NORA sector grouping.)	4,027,000

Appendix B. JourneyWell™ Health Assessment Questions

I. Demographics

The following demographic information helps to accurately assess your health risks

2.	What is your gender?	❍ Male ❍ Female
3.	How tall are you?	__________ feet, __________ inches (round to the nearest inch)
4.	An accurate body weight is an important measure of health. How much do you weigh?	__________ pounds
5.	What is your race?	❍ American Indian or Alaska Native ❍ Asian or Pacific Islander ❍ Black or African American ❍ White ❍ Some other race ❍ Unknown ❍ Choose not to answer
7.	What is the highest level of education that you have completed?	❍ 8^{th} grade or less ❍ Some high school ❍ High school diploma or GED ❍ Technical training or Associate degree ❍ Some college ❍ College degree ❍ Graduate studies

8.	What is your job type?	❍ Administrative support ❍ Labor or production ❍ Professional/management ❍ Retired ❍ Sales ❍ Service ❍ Skilled craft ❍ Student ❍ Technician ❍ Other

Work and Health

The following questions are about your work and its relationship to your health.

P2.	Are you currently employed (working for pay)?	❍ Yes ❍ No → **SKIP to question 9**
P3.	During the past seven days (not including today), how many hours did you miss from work because of your health problems? *Include hours you missed on sick days, times you went in late, left early, etc., because of your health problems.*	__________ Hours (whole hours only; round to the nearest hour)
P4.	During the past seven days (not including today), how many hours did you miss from work because of any other reason, such as vacation, holidays, or time off?	__________ Hours
P5.	During the past 7 days (not including today), how many hours did you work?	__________ Hours

II. Personal Health

The following questions are about your health status.

31.	How often do you have back pain?	❍ Always ❍ Sometimes ❍ Rarely ❍ Never
45.	Are you pregnant?	❍ Yes ❍ No

IV. Health Choices — Physical Activity

The choices you make every day are important to your health.

S1.	In a usual day, what is the longest period of time that you sit at work without getting up to move?	☐ Hours each day *response parameters: 0 through 24 hours*
S3.	For this question, think about the time you spend sitting—at work, at home, while driving your car, during leisure time, etc. In a usual week, how much **total** time do you spend sitting?	☐ Hours each week *response parameters: 0 through 168 hours*

83.	How many ***days*** in a usual week do you do ***vigorous activities*** for at least 10 minutes at a time, such as running, aerobics, heavy yard work, or anything else that causes a large increase in your breathing or heart rate?	❍ 0 ❍ 4 ❍ 1 ❍ 5 ❍ 2 ❍ 6 ❍ 3 ❍ 7
84.	On days when you do vigorous activities for at least 10 minutes at a time, how much total time (minutes) each day do you spend doing these activities?	❍ 10-14 ❍ 50-54 ❍ 90-94 ❍ 15-19 ❍ 55-59 ❍ 95-99 ❍ 20-24 ❍ 60-64 ❍ 100-104 ❍ 25-29 ❍ 65-69 ❍ 105-109 ❍ 30-34 ❍ 70-74 ❍ 110-114 ❍ 35-39 ❍ 75-79 ❍ 115-119 ❍ 40-44 ❍ 80-84 ❍ 120 or more ❍ 45-49 ❍ 85-89 ❍ I do not do vigorous activities for at least 10 minutes at a time
85.	How many ***days*** in a usual week do you do ***moderate activities*** for at least 10 minutes at a time, such as brisk walking, bicycling, vacuuming, gardening, or anything else that causes a small increase in your breathing or heart rate?	❍ 0 ❍ 4 ❍ 1 ❍ 5 ❍ 2 ❍ 6 ❍ 3 ❍ 7

86.	On days when you do ***moderate activities*** for at least 10 minutes at a time, how much ***total time (minutes)*** each day do you spend doing these activities?	❍ 10-14 ❍ 15-19 ❍ 20-24 ❍ 25-29 ❍ 30-34 ❍ 35-39 ❍ 40-44 ❍ 45-49	❍ 50-54 ❍ 55-59 ❍ 60-64 ❍ 65-69 ❍ 70-74 ❍ 75-79 ❍ 80-84 ❍ 85-89	❍ 90-94 ❍ 95-99 ❍ 100-104 ❍ 105-109 ❍ 110-114 ❍ 115-119 ❍ 120 or more
		❍ I do not do moderate activities for at least 10 minutes at a time		
87.	How many ***days*** in a usual week do you do ***muscle strengthening*** exercises or activities such as calisthenics, heavy lifting, free weights, or other activities like these?	❍ 0 ❍ 1 ❍ 2 ❍ 3	❍ 4 ❍ 5 ❍ 6 ❍ 7	
88.	How many ***days*** in a usual week do you do ***flexibility*** exercises or activities such as bending, stretching or twisting?	❍ 0 ❍ 1 ❍ 2 ❍ 3	❍ 4 ❍ 5 ❍ 6 ❍ 7	

V. Health Choices —Tobacco

The choices you make every day are important to your health.

101.	Do you use any kind of tobacco, including cigarettes, cigars, a pipe, snuff, or chewing tobacco?	❍ Yes ❍ No, I quit less than 6 months ago ❍ No, I quit at least 6 months ago ❍ No, I have never used tobacco

102.	Do you smoke cigarettes?	❍ Yes ❍ No
103.	Do you smoke cigars?	❍ Yes ❍ No
104.	Do you smoke a pipe?	❍ Yes ❍ No
105.	Do you use chew or snuff?	❍ Yes ❍ No

VI. Opportunities for Worksite Wellness
The following questions ask about worksite health and wellness.

S4.	How often do you have the knowledge, tools and resources you need to perform your job safely and without injury?	❍ Always ❍ Usually ❍ Sometimes ❍ Rarely ❍ Never

Appendix C. Directed Acyclic Graphs (DAGs).

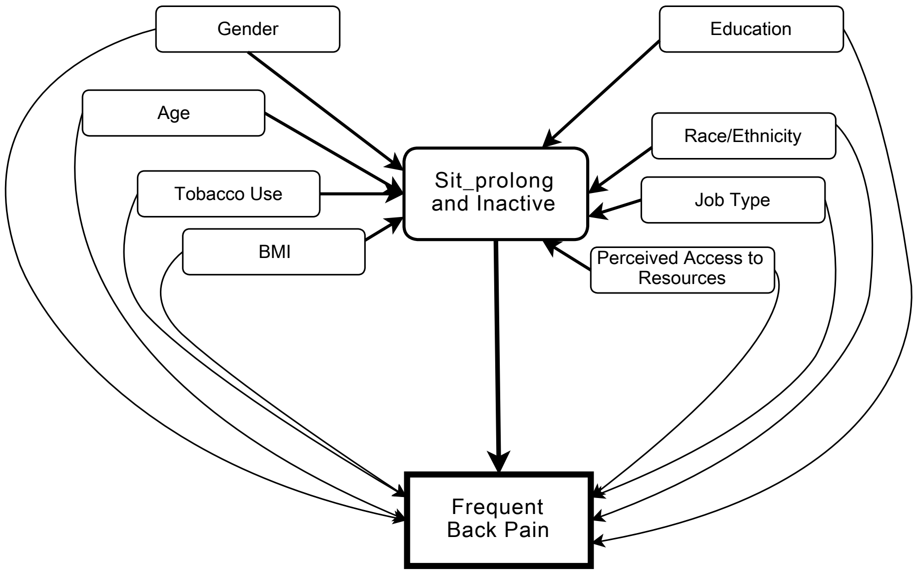

Figure C. 1 Prolonged sitting and Physical inactivity and back pain.

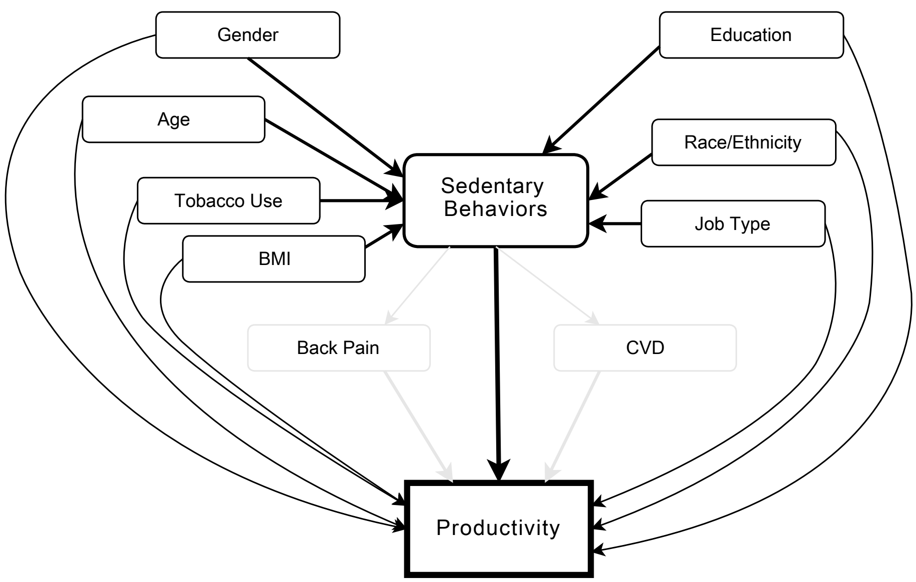

Figure C. 2 Sedentary behaviors on productivity loss[35]

35 Sedentary behaviors include prolonged sitting at work and physical inactivity.

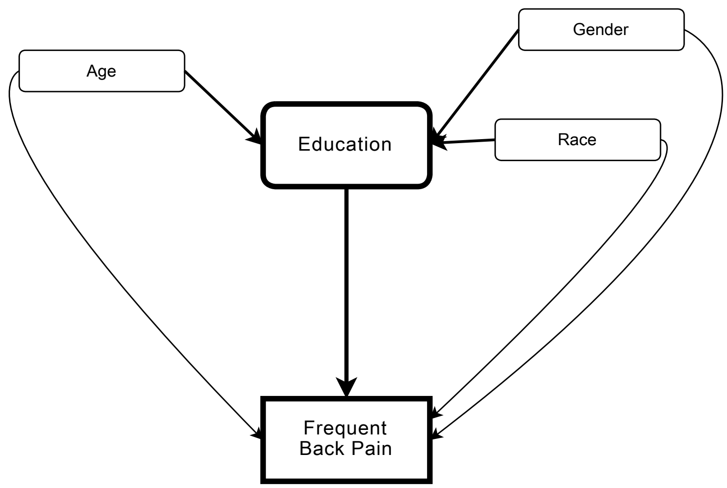

Figure C. 3. Education

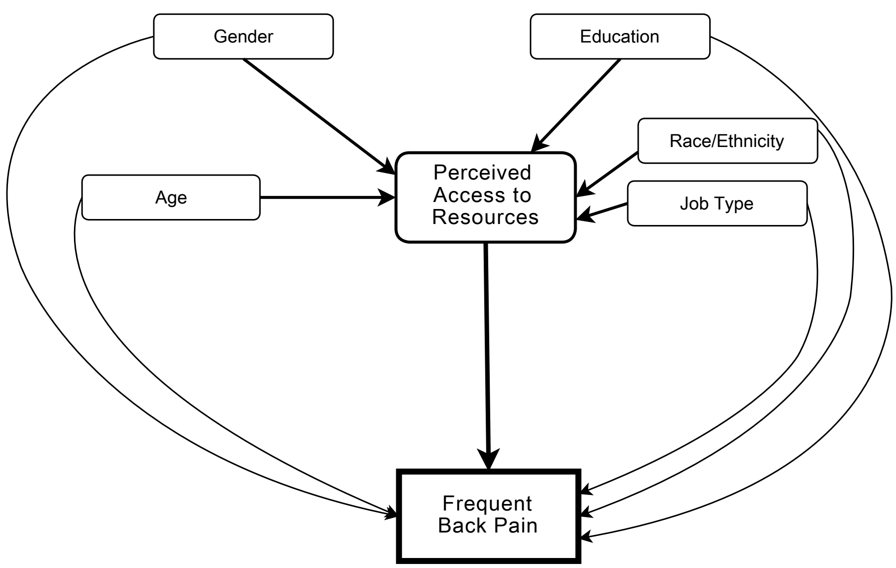

Figure C. 4 Perceived Access to Safety Resources

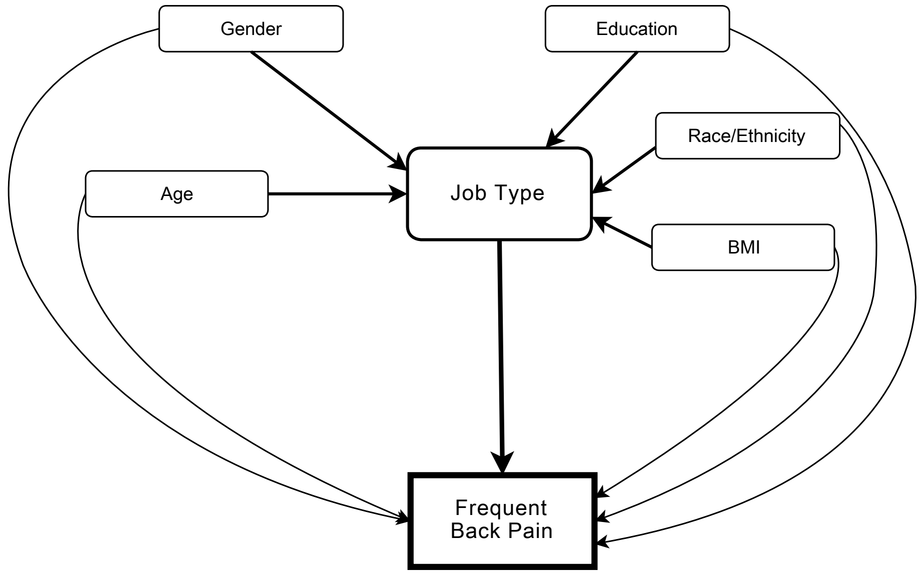

Figure C. 5 Job Classification

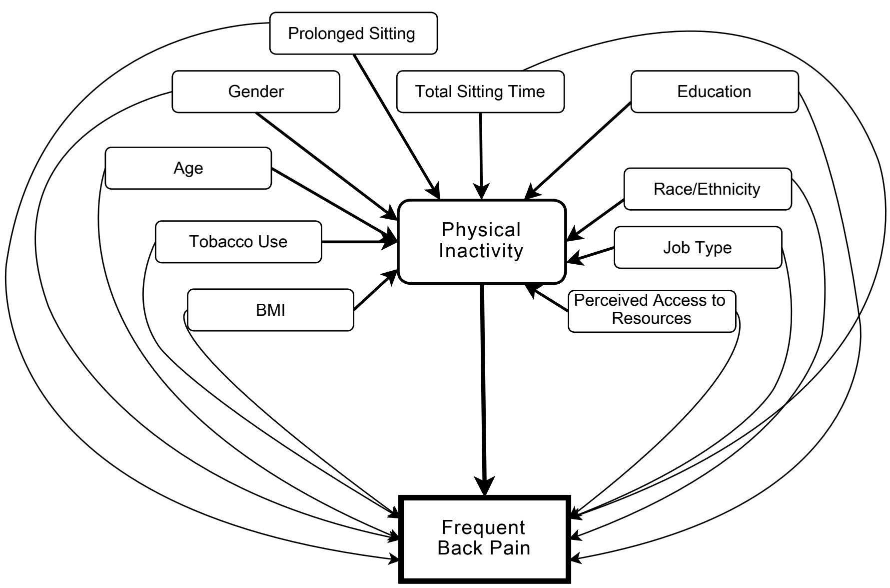

Figure C. 6 Physical Inactivity

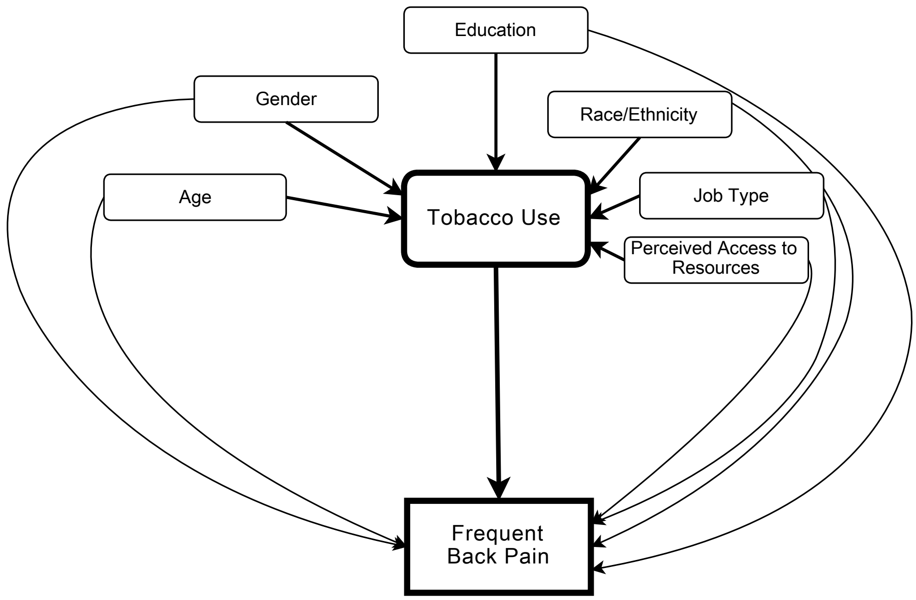

Figure C. 7 Tobacco Use

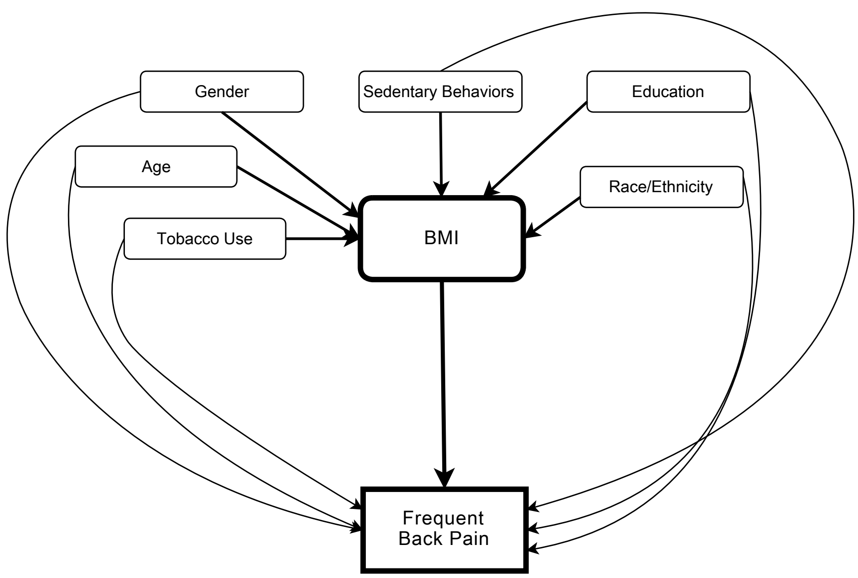

Figure C. 8 Body Mass Index

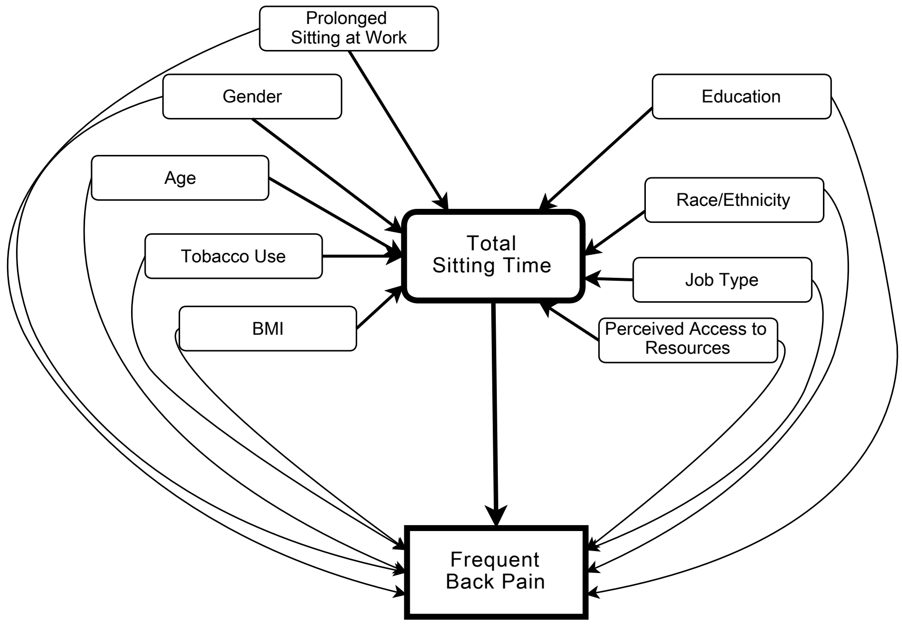

Figure C. 9 Total Sitting Time

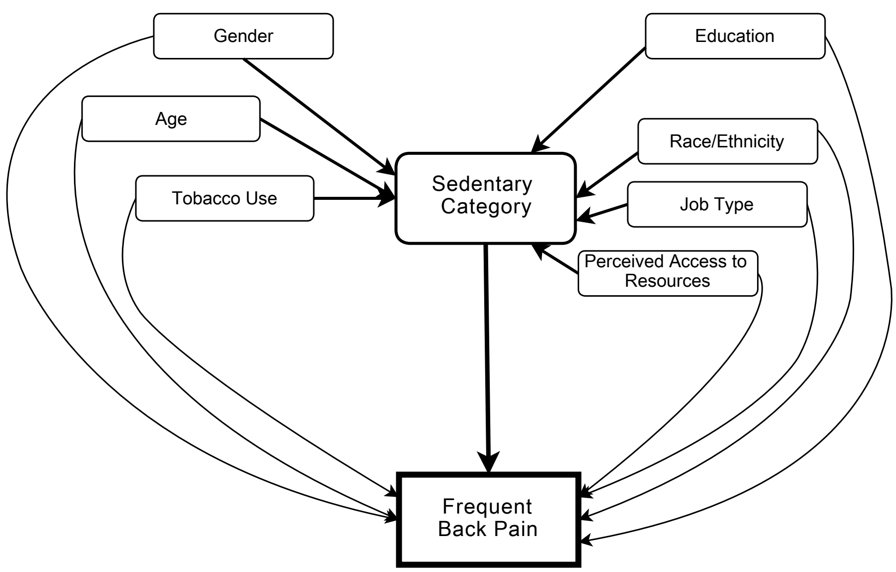

Figure C. 10 Sedentary Category

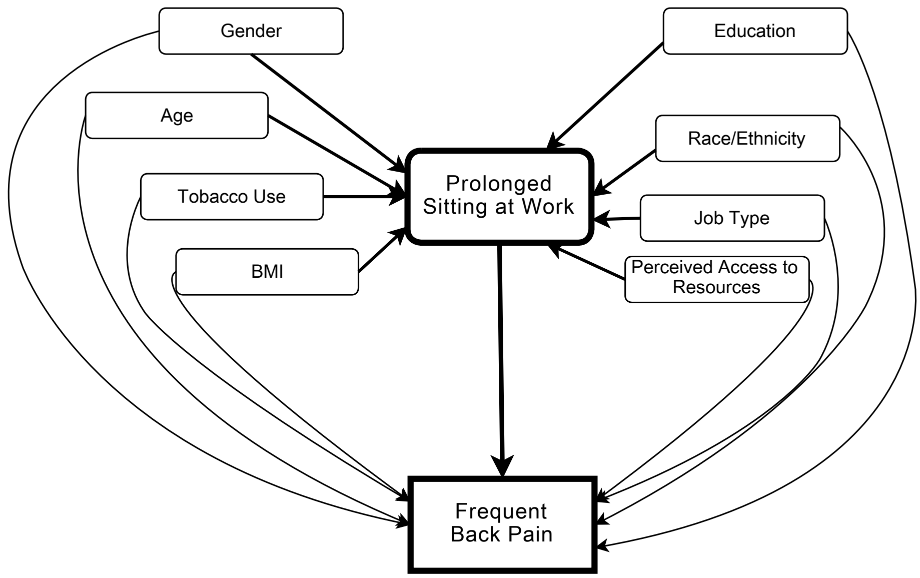

Figure C. 11 Prolonged Sitting Time at Work

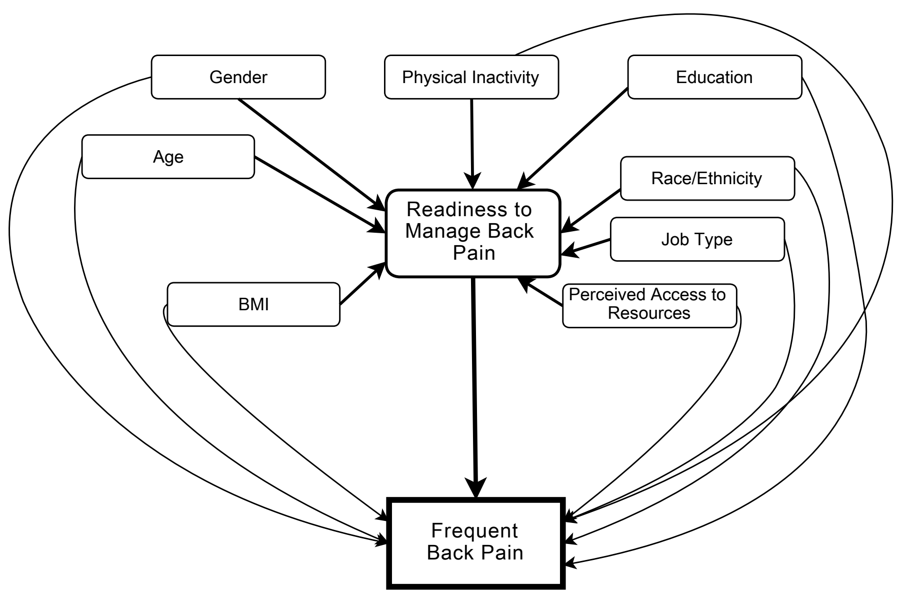

Figure C. 12 Readiness to Manage Back Pain

Appendix D. Stata® Output

Aim 1. Sedentary Risk Profile

```
. logistic bp_freq i.age_cat, or allbaselevels

Logistic regression                               Number of obs   =      34991
                                                  LR chi2(5)      =      57.49
                                                  Prob > chi2     =     0.0000
Log likelihood =  -23481.38                       Pseudo R2       =     0.0012
```

bp_freq	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
age_cat						
1	(base)					
2	1.202736	.0611085	3.63	0.000	1.088735	1.328673
3	1.320973	.0636938	5.77	0.000	1.201853	1.4519
4	1.33335	.0627133	6.12	0.000	1.215929	1.462109
5	1.423777	.0774496	6.50	0.000	1.27979	1.583963
6	1.174828	.101751	1.86	0.063	.9914082	1.392183

```
. logistic bp_freq i.white, or allbaselevels

Logistic regression                               Number of obs   =      34991
                                                  LR chi2(2)      =      11.15
                                                  Prob > chi2     =     0.0038
Log likelihood = -23504.553                       Pseudo R2       =     0.0002
```

bp_freq	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
white						
1	(base)					
2	.9275258	.0419804	-1.66	0.096	.8487896	1.013566
3	.8296038	.0526189	-2.95	0.003	.7326253	.9394194

```
. logistic bp_freq i.race, or allbaselevels

Logistic regression                               Number of obs   =      34991
                                                  LR chi2(6)      =      24.94
                                                  Prob > chi2     =     0.0003
Log likelihood = -23497.655                       Pseudo R2       =     0.0005
```

bp_freq	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
race						
1	(base)					
2	.759761	.0554423	-3.77	0.000	.6585094	.8765809
3	1.045632	.0746164	0.63	0.532	.9091531	1.202599
4	1.161501	.150838	1.15	0.249	.900489	1.498168
5	.9643977	.1205543	-0.29	0.772	.7548347	1.232141
6	.8284636	.0535851	-2.91	0.004	.7298231	.940436
7	.8578199	.2690136	-0.49	0.625	.463936	1.586113

```
. logistic bp_freq educ_col age_cat female, or allbaselevels

Logistic regression                               Number of obs   =      34991
                                                  LR chi2(3)      =     219.32
                                                  Prob > chi2     =     0.0000
Log likelihood =  -23400.47                       Pseudo R2       =     0.0047

------------------------------------------------------------------------------
     bp_freq | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    educ_col |   .7522109    .016858   -12.71   0.000      .719885    .7859883
     age_cat |   1.048387    .010066     4.92   0.000     1.028843    1.068303
      female |   1.097923   .0242712     4.23   0.000     1.051368    1.146539
------------------------------------------------------------------------------

.

. logistic bp_freq ib6.educ age_cat, or allbaselevels

Logistic regression                               Number of obs   =      34991
                                                  LR chi2(7)      =     237.25
                                                  Prob > chi2     =     0.0000
Log likelihood = -23391.501                       Pseudo R2       =     0.0050

------------------------------------------------------------------------------
     bp_freq | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        educ |
          1  |   2.081056   .9189503     1.66   0.097     .8758129    4.944887
          2  |   1.484032   .3293942     1.78   0.075     .9605308    2.292847
          3  |   1.265346   .0545881     5.46   0.000     1.162754    1.376991
          4  |   1.267123   .0423107     7.09   0.000     1.186851    1.352824
          5  |   1.185336   .0405822     4.97   0.000     1.108407    1.267605
          6  |  (base)
          7  |   .8538474   .0245776    -5.49   0.000     .8070097    .9034034
             |
     age_cat |   1.053469   .0102059     5.38   0.000     1.033654    1.073663
------------------------------------------------------------------------------
```

```
. logistic bp_freq i.job_niosh age_cat female educ_col white ovrwt, or allbasel
> evels

Logistic regression                               Number of obs   =      34980
                                                  LR chi2(8)      =     529.78
                                                  Prob > chi2     =     0.0000
Log likelihood = -23238.418                       Pseudo R2       =     0.0113

------------------------------------------------------------------------------
     bp_freq | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   job_niosh |
          1  |  (base)
          2  |   1.129099   .0408841     3.35   0.001     1.051745    1.212142
          3  |   1.179541    .038294     5.09   0.000     1.106824    1.257035
          4  |   1.041001   .0398378     1.05   0.294     .9657766    1.122084
             |
     age_cat |   1.040155   .0101605     4.03   0.000     1.020431    1.060261
      female |    1.13867   .0269861     5.48   0.000     1.086987    1.192809
    educ_col |   .8401002   .0220308    -6.64   0.000     .7980115    .8844087
       white |   .9321102   .0249567    -2.63   0.009     .8844573    .9823306
       ovrwt |   1.243317     .01655    16.36   0.000     1.211299    1.276182
------------------------------------------------------------------------------
```

```
. logistic bp_freq i.ovrwt age_cat female white educ_col tobacco_use sit_prolon
> g1 pa_guidelines perc_safety, or allbaselevels
```

```
Logistic regression                             Number of obs   =      34968
                                                LR chi2(12)     =    1083.56
                                                Prob > chi2     =     0.0000
Log likelihood = -22952.115                     Pseudo R2       =     0.0231
```

bp_freq	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ovrwt						
0	(base)					
1	1.227023	.0339976	7.38	0.000	1.162166	1.295499
2	1.475225	.0439074	13.06	0.000	1.39163	1.563841
3	1.88242	.1781668	6.68	0.000	1.563696	2.266109
4	1.015643	.1534474	0.10	0.918	.7553327	1.365665
age_cat	1.048291	.0102822	4.81	0.000	1.028331	1.068638
female	1.112079	.0256465	4.61	0.000	1.062932	1.163499
white	.9070818	.0246112	-3.59	0.000	.8601049	.9566244
educ_col	.8155844	.0190601	-8.72	0.000	.77907	.8538102
tobacco_use	1.510024	.0554644	11.22	0.000	1.405136	1.62274
sit_prolong1	1.152888	.0261542	6.27	0.000	1.102749	1.205306
pa_guideli~s	1.496249	.0372044	16.21	0.000	1.425078	1.570974
perc_safety	.6175256	.0380069	-7.83	0.000	.547351	.696697

```
. logistic bp_freq tobacco_use age_cat female white  educ_col job_niosh perc_sa
> fety, or allbaselevels
```

```
Logistic regression                             Number of obs   =      34979
                                                LR chi2(7)      =     459.74
                                                Prob > chi2     =     0.0000
Log likelihood = -23270.847                     Pseudo R2       =     0.0098
```

bp_freq	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tobacco_use	1.550292	.0563642	12.06	0.000	1.443665	1.664795
age_cat	1.060999	.0103424	6.07	0.000	1.040921	1.081465
female	1.11098	.0248777	4.70	0.000	1.063275	1.160826
white	.9194852	.0246648	-3.13	0.002	.872392	.9691205
educ_col	.8157853	.0203942	-8.14	0.000	.7767769	.8567527
job_niosh	1.0322	.0116998	2.80	0.005	1.009522	1.055388
perc_safety	.5884836	.0358466	-8.70	0.000	.5222574	.6631077

```
. logistic bp_freq i.pa_guidelines age_cat female white  educ_col job_niosh ovr
> wt tobacco_use /*sit_prolong1 sit_tot*/ perc_safety, or allbaselevels

Logistic regression                               Number of obs     =     34968
                                                  LR chi2(9)        =   1024.72
                                                  Prob > chi2       =    0.0000
Log likelihood = -22981.537                       Pseudo R2         =    0.0218

------------------------------------------------------------------------------
     bp_freq | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
pa_guideli~s |
          0  |  (base)
          1  |   1.533776   .0378361    17.34   0.000     1.461383    1.609755
             |
     age_cat |   1.048988   .0103328     4.86   0.000      1.02893    1.069436
      female |   1.123597    .025555     5.12   0.000      1.07461    1.174817
       white |   .9056462   .0245396    -3.66   0.000     .8588043    .9550431
    educ_col |   .8476553   .0214613    -6.53   0.000     .8066186    .8907798
   job_niosh |   1.031803   .0117993     2.74   0.006     1.008934     1.05519
       ovrwt |      1.195   .0162168    13.13   0.000     1.163635    1.227211
 tobacco_use |   1.495779   .0549104    10.97   0.000     1.391937    1.607368
 perc_safety |   .6171879   .0379707    -7.84   0.000     .5470786    .6962819
------------------------------------------------------------------------------


. logistic bp_freq i.sed_cat age_cat female white  educ_col job_niosh tobacco_u
> se /*sit_prolong1 sit_tot*/ perc_safety, or allbaselevels

Logistic regression                               Number of obs     =     34979
                                                  LR chi2(10)       =    948.16
                                                  Prob > chi2       =    0.0000
Log likelihood = -23026.634                       Pseudo R2         =    0.0202

------------------------------------------------------------------------------
     bp_freq | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     sed_cat |
          1  |  (base)
          2  |    .818386   .0490187    -3.35   0.001     .7277362    .9203276
          3  |   .5462482   .0304803   -10.84   0.000     .4896588    .6093777
          4  |   .4427321   .0244617   -14.75   0.000     .3972928    .4933685
             |
     age_cat |   1.056514   .0103737     5.60   0.000     1.036377    1.077043
      female |   1.068172   .0241913     2.91   0.004     1.021794    1.116654
       white |   .8995295   .0243866    -3.91   0.000     .8529803     .948619
    educ_col |   .8251754   .0207834    -7.63   0.000     .7854298    .8669322
   job_niosh |    1.03733   .0118496     3.21   0.001     1.014363    1.060816
 tobacco_use |     1.4954   .0548439    10.97   0.000     1.391681     1.60685
 perc_safety |   .6264884   .0385504    -7.60   0.000     .5553095    .7067909
------------------------------------------------------------------------------
```

```
. logistic bp_freq sedentary age_cat female white  educ_col job_niosh tobacco_u
> se /*sit_prolong1 sit_tot */perc_safety, or allbaselevels

Logistic regression                               Number of obs   =      34979
                                                  LR chi2(8)      =     865.90
                                                  Prob > chi2     =     0.0000
Log likelihood = -23067.766                       Pseudo R2       =     0.0184

------------------------------------------------------------------------------
     bp_freq | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   sedentary |   1.762467   .0495008    20.18   0.000     1.668069    1.862207
     age_cat |   1.058161   .0103749     5.77   0.000     1.038021    1.078692
      female |   1.082775    .024424     3.53   0.000     1.035948     1.13172
       white |   .9038625   .0244481    -3.74   0.000      .857193    .9530729
    educ_col |   .8234818   .0207122    -7.72   0.000      .783871    .8650941
   job_niosh |   1.034704   .0117965     2.99   0.003      1.01184    1.058085
 tobacco_use |   1.503808   .0550856    11.14   0.000     1.399627    1.615744
 perc_safety |   .6193646   .0380392    -7.80   0.000     .5491218    .6985929
------------------------------------------------------------------------------
```

```
. logistic bp_freq sit_prolong1 age_cat female white  educ_col job_niosh ovrwt
> tobacco_use perc_safety, or allbaselevels

Logistic regression                               Number of obs   =      34968
                                                  LR chi2(9)      =     798.33
                                                  Prob > chi2     =     0.0000
Log likelihood = -23094.732                       Pseudo R2       =     0.0170

------------------------------------------------------------------------------
     bp_freq | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
sit_prolong1 |   1.213591   .0275189     8.54   0.000     1.160835    1.268743
     age_cat |   1.058168   .0104216     5.74   0.000     1.037938    1.078792
      female |   1.136303   .0257853     5.63   0.000     1.086872    1.187981
       white |    .911928   .0246324    -3.41   0.001     .8649051    .9615075
    educ_col |   .8393086   .0212044    -6.93   0.000      .798761    .8819145
   job_niosh |   1.041301   .0119742     3.52   0.000     1.018094    1.065036
       ovrwt |   1.233155   .0165008    15.66   0.000     1.201235    1.265924
 tobacco_use |    1.54954     .05661    11.99   0.000     1.442466    1.664562
 perc_safety |   .5989162   .0366984    -8.37   0.000       .53114    .6753411
------------------------------------------------------------------------------
```

```
. logistic bp_freq sit_high age_cat female white  educ_col job_niosh ovrwt toba
> cco_use /*pa_guidelines*/ sit_prolong1 perc_safety, or allbaselevels

Logistic regression                               Number of obs   =      34968
                                                  LR chi2(10)     =     843.50
                                                  Prob > chi2     =     0.0000
Log likelihood = -23072.146                       Pseudo R2       =     0.0180

------------------------------------------------------------------------------
     bp_freq | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    sit_high |   1.167902   .0269759     6.72   0.000     1.116209    1.221989
     age_cat |   1.059265   .0104368     5.84   0.000     1.039005    1.079919
      female |   1.124618   .0255921     5.16   0.000     1.075561    1.175913
       white |   .9208156   .0249107    -3.05   0.002     .8732633    .9709572
    educ_col |   .8331064   .0210841    -7.21   0.000     .7927905    .8754725
   job_niosh |   1.050567   .0121694     4.26   0.000     1.026984    1.074691
       ovrwt |   1.229848   .0164712    15.45   0.000     1.197985    1.262559
 tobacco_use |   1.555861   .0568895    12.09   0.000     1.448261    1.671455
sit_prolong1 |   1.178658   .0272239     7.12   0.000      1.12649    1.233242
 perc_safety |   .5940651   .0364309    -8.49   0.000     .5267862    .6699367
------------------------------------------------------------------------------
```

```
. logistic bp_freq sit_prolong1 age_cat female white  educ_col job_niosh ovrwt
> tobacco_use perc_safety, or allbaselevels

Logistic regression                               Number of obs   =      34968
                                                  LR chi2(9)      =     798.33
                                                  Prob > chi2     =     0.0000
Log likelihood = -23094.732                       Pseudo R2       =     0.0170
```

bp_freq	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sit_prolong1	1.213591	.0275189	8.54	0.000	1.160835	1.268743
age_cat	1.058168	.0104216	5.74	0.000	1.037938	1.078792
female	1.136303	.0257853	5.63	0.000	1.086872	1.187981
white	.911928	.0246324	-3.41	0.001	.8649051	.9615075
educ_col	.8393086	.0212044	-6.93	0.000	.798761	.8819145
job_niosh	1.041301	.0119742	3.52	0.000	1.018094	1.065036
ovrwt	1.233155	.0165008	15.66	0.000	1.201235	1.265924
tobacco_use	1.54954	.05661	11.99	0.000	1.442466	1.664562
perc_safety	.5989162	.0366984	-8.37	0.000	.53114	.6753411

```
. logistic bp_freq i.health_rtc job_niosh  diab_dx hd_dx diab_risk hd_risk bmi_cat stre
> ss_gen_score tobacco_use sleep_bad pa_guidelines , or allbaselevels

Logistic regression                               Number of obs   =      34978
                                                  LR chi2(14)     =    1631.57
                                                  Prob > chi2     =     0.0000
Log likelihood = -22684.425                       Pseudo R2       =     0.0347
```

bp_freq	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
health_rtc						
1	(base)					
2	1.409339	.0689023	7.02	0.000	1.280562	1.551067
3	1.516512	.0629498	10.03	0.000	1.398018	1.645049
4	1.320165	.0507376	7.23	0.000	1.224374	1.42345
5	1.001879	.0424131	0.04	0.965	.9221066	1.088554
job_niosh	1.066873	.0112133	6.16	0.000	1.04512	1.089079
diab_dx	1.02561	.0574345	0.45	0.652	.9189983	1.14459
hd_dx	1.421428	.0981207	5.09	0.000	1.241557	1.627357
diab_risk	.8490229	.0245387	-5.66	0.000	.8022648	.8985062
hd_risk	.8239583	.0283007	-5.64	0.000	.7703158	.8813362
bmi_cat	1.020319	.0027937	7.35	0.000	1.014858	1.025809
stress_gen~e	1.250796	.0197196	14.19	0.000	1.212737	1.290049
tobacco_use	1.332362	.0520666	7.34	0.000	1.234124	1.43842
sleep_bad	1.343454	.0340251	11.66	0.000	1.278394	1.411825
pa_guideli~s	1.309631	.0340652	10.37	0.000	1.244538	1.378129

Aim 2. Main effects and interaction between prolonged sitting (categorical) and physical inactivity.

```
. tab inactive
```

inactive	Freq.	Percent	Cum.
meets guidelines	23,619	71.66	71.66
does not meet guidelines	9,340	28.34	100.00
Total	32,959	100.00	

```
.
. logistic bp_freq inactive age_cat female white  educ_col job_niosh ovrwt tobacco_use perc_safety, or allbaselevels

Logistic regression                               Number of obs   =      32959
                                                  LR chi2(9)      =     928.25
                                                  Prob > chi2     =     0.0000
Log likelihood = -21655.592                       Pseudo R2       =     0.0210
```

bp_freq	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
inactive	1.537033	.0390019	16.94	0.000	1.462461	1.615408
age_cat	1.043846	.0106265	4.22	0.000	1.023225	1.064883
female	1.12829	.0264287	5.15	0.000	1.077662	1.181297
white	.9122224	.0255761	-3.28	0.001	.8634465	.9637536
educ_col	.8510111	.0222871	-6.16	0.000	.8084314	.8958335
job_niosh	1.02457	.0121753	2.04	0.041	1.000983	1.048713
ovrwt	1.187883	.0165823	12.33	0.000	1.155823	1.220832
tobacco_use	1.491092	.0565697	10.53	0.000	1.384239	1.606193
perc_safety	.6267903	.0404294	-7.24	0.000	.5523543	.7112573

```
.
. logistic bp_freq sit_prolong1 age_cat female white  educ_col job_niosh ovrwt tobacco_use
>  perc_safety, or allbaselevels

Logistic regression                               Number of obs   =      32959
                                                  LR chi2(9)      =     708.13
                                                  Prob > chi2     =     0.0000
Log likelihood =  -21765.65                       Pseudo R2       =     0.0160
```

bp_freq	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sit_prolong1	1.20785	.0281809	8.09	0.000	1.15386	1.264365
age_cat	1.053214	.0107168	5.10	0.000	1.032418	1.074429
female	1.139779	.0266425	5.60	0.000	1.088738	1.193212
white	.9185221	.0256692	-3.04	0.002	.8695644	.9702362
educ_col	.8421412	.0220033	-6.58	0.000	.8001012	.8863902
job_niosh	1.034113	.0123515	2.81	0.005	1.010185	1.058607
ovrwt	1.227069	.0168798	14.88	0.000	1.194427	1.260603
tobacco_use	1.542545	.0582397	11.48	0.000	1.432518	1.661022
perc_safety	.6083002	.039078	-7.74	0.000	.5363345	.6899223

```
. logistic bp_freq i.potato_pro   age_cat female white  educ_col job_niosh ovrwt tobacco_use perc_safety, or allbaseleve
> ls

Logistic regression                               Number of obs   =      32959
                                                  LR chi2(11)     =     969.30
                                                  Prob > chi2     =     0.0000
Log likelihood = -21635.068                       Pseudo R2       =     0.0219
```

bp_freq	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
potato_pro						
0	(base)					
1	1.507594	.0555558	11.14	0.000	1.402546	1.62051
2	1.160965	.0324171	5.35	0.000	1.099136	1.226272
3	1.759362	.0600015	16.57	0.000	1.645605	1.880982
age_cat	1.049138	.0107187	4.70	0.000	1.028339	1.070358
female	1.115928	.026224	4.67	0.000	1.065696	1.168528
white	.9083401	.0255089	-3.42	0.001	.8596945	.9597382
educ_col	.8436702	.0221376	-6.48	0.000	.8013781	.8881942
job_niosh	1.034999	.0124139	2.87	0.004	1.010951	1.059618
ovrwt	1.183242	.0165412	12.04	0.000	1.151262	1.21611
tobacco_use	1.496706	.0568244	10.62	0.000	1.389375	1.612329
perc_safety	.6322717	.0408167	-7.10	0.000	.5571266	.7175525

Aim 3. Productivity and cost of back pain and sedentary

```
. by bp_freq, sort: tab2 sit_prolong1 inactive, sum (absent_cost)

-> bp_freq = no

-> tabulation of sit_prolong1 by inactive
```

Means, Standard Deviations and Frequencies of absent_cost

prolonged sitting at work (1.0+ hours)	inactive meets gui	does not	Total
no	403.99247	680.95419	459.70257
	2435.8692	3345.9223	2646.3621
	8634	2174	10808
yes	503.82333	894.45417	616.98074
	2605.9504	3570.8378	2923.6325
	6476	2641	9117
Total	446.77901	798.05771	531.66769
	2510.5774	3472.3624	2777.7042
	15110	4815	19925

```
-> bp_freq = yes

-> tabulation of sit_prolong1 by inactive
```

Means, Standard Deviations and Frequencies of absent_cost

prolonged sitting at work (1.0+ hours)	inactive meets gui	does not	Total
no	657.59374	1155.5338	803.27094
	3206.633	3972.9892	3455.6267
	4621	1911	6532
yes	859.49024	1200.5213	996.59502
	3410.9159	4205.2132	3753.9358
	3888	2614	6502
Total	749.84589	1181.5222	899.71049
	3302.8799	4108.3555	3608.6792
	8509	4525	13034

.

potato risk: prolonged sitting	Summary of percent of time absent due to health reasons Mean	Std. Dev.	Freq.
active li	.00776909	.04684364	8634
sed leisu	.01309527	.06434466	2174
sed job (	.00968891	.05011443	6476
sedentary	.01720104	.06866996	2641
Total	.01022438	.05341739	19925

-> bp_freq = yes

potato risk: prolonged sitting	Summary of percent of time absent due to health reasons Mean	Std. Dev.	Freq.
active li	.01264603	.06166602	4621
sed leisu	.0222218	.07640364	1911
sed job (	.01652866	.06559454	3888
sedentary	.02308695	.08086948	2614
Total	.01730212	.06939768	13034

. by bp_freq, sort: sum worktime_7d absent_hr absenteeism absent_cost

-> bp_freq = no

Variable	Obs	Mean	Std. Dev.	Min	Max
worktime_7d	19925	37.4671	11.25361	1	120
absent_hr	19925	.4792974	2.808149	0	80
absenteeism	19925	.0102244	.0534174	0	.8333333
absent_cost	19925	531.6677	2777.704	0	43333.33

-> bp_freq = yes

Variable	Obs	Mean	Std. Dev.	Min	Max
worktime_7d	13034	37.26239	12.00161	1	120
absent_hr	13034	.8071198	3.496083	0	72
absenteeism	13034	.0173021	.0693977	0	.8260869
absent_cost	13034	899.7105	3608.679	0	42956.52

```
. by potato_pro, sort: tab potato_pro, sum (absenteeism )

-----------------------------------------------------------------
-> potato_pro = active life

     potato |
      risk: |
  prolonged |       Summary of absenteeism
    sitting |        Mean   Std. Dev.       Freq.
------------+------------------------------------
  active li |   .0094693    .0525376       13255
------------+------------------------------------
      Total |   .0094693    .0525376       13255

-----------------------------------------------------------------
-> potato_pro = sed leisure (couch pot)

     potato |
      risk: |
  prolonged |       Summary of absenteeism
    sitting |        Mean   Std. Dev.       Freq.
------------+------------------------------------
  sed leisu |  .01736475   .07038285        4085
------------+------------------------------------
      Total |  .01736475   .07038285        4085

-----------------------------------------------------------------
-> potato_pro = sed job (desk pot)

     potato |
      risk: |
  prolonged |       Summary of absenteeism
    sitting |        Mean   Std. Dev.       Freq.
------------+------------------------------------
  sed job ( |  .01225481   .05651573       10364
------------+------------------------------------
      Total |  .01225481   .05651573       10364

-----------------------------------------------------------------
-> potato_pro = sedentary life

     potato |
      risk: |
  prolonged |       Summary of absenteeism
    sitting |        Mean   Std. Dev.       Freq.
------------+------------------------------------
  sedentary |  .02012887   .07503747        5255
------------+------------------------------------
      Total |  .02012887   .07503747        5255

.
```

Appendix E. Stata® Code

```
**********AIM 1
*drop variables not needed***********
drop SVY_Y2004 SVY_Y2005 SVY_Y2006 SVY_Y2007 SVY_Y2008 SVY_Y2009
drop SVY_Y2011 SVY_Y2012 FX_AVAIL_FLAG BUYER_ID SERVICE_ENTITY
AUTH_CODE AUTH_DESC
drop AUTH_END_DT AUTH_START_DT RESP_ID EXTERNAL_PERSON_ID
PERSON_NO BIRTH_DT SVY_COVERAGE_GROUP_ID SVY_CONTRACT_NO
drop SVY_CONTRACT_REL SURVEY_COPY_DT SVY_LANGUAGE
OPT_OUT_FLAG CUSTOMER_ID CUSTOMER_NAME
drop q2 q9 q10 q11 q12 q13 q14 q15 q16 q18 q21 q24 q25 q29 q30 q34 q35 q36
drop  q40 q41 q42  q44 q45  q47 q48 q50 q51 q52 q53 q54  q56
drop q57 q60 q61 q62 q63 q64 q65  q83 q84 q85 q86
drop q89 q91 q92 q93 q99 q100 q102 q11* q12* q13* q140 q141 q142 q143 q144 q145
drop q146 q147 q148 q150 q151 q152 q153 q154 q155
drop q20* q210 q210 q212 q213 q214 q215 q216 q217 q218 q219 q230 q231 q233 q234
q236
drop q238 q239 q241 q242 q244 q246 q247 q249 q250 q26* q27* q28* q29* q30* q310
q311 q312 q313 q314 q317
drop q319 q321 q322 q323 q324 q326 q327 q328 q329 q331 q334 q340 q341 q342 q343
q344 q346 q347  q349 q350
drop q516 q35* q36* q37* q38* q39* q40* q491 q492 q493 q494 q495 q498 q499 q503
q504 q505 q506 q510 q511
drop q518 q519 q520 q521 q524 q525 q527 q528 q529 q530 q531 q604  q613 q614 q615
q616 q617
drop q619 q620 q621 q622 q623 q625 q626 q630 q631 q632 q633 q634 q657 q658
drop q71* q722 q723 q724 q726 q730 q731 q732 q734 q737 q81*
drop q829 q835 q863 q865 q885 q886 q899 q905 q908 q909 q910 q911 q913 q914 q916
q917 q918 q919 q920
drop q921 q922 q923 q924 q926 q927 q928 q931 q937 q938 q939 q940 q941 q943 q944
q946 q948 q951 q952
drop q953 q954 q955 q961 q962 q963 q964 q965 q966 q967 q968
drop  q235 q575 q576 q577 q578 q579 q580 q186 q184 q435 q436 q437 q438 q439 q440
q441 q442 q443 q444 q445 q446
/*these are the algorithm variables*/
drop  q541 q542 q551 q552 q553 q554 q555 q556 q569  q165
drop q167 q166  q180 q181 q182
drop q183  q185
drop GENDER_CHAR SVY_MEMBER~N  q243 q245 q248 q232 q237 q240 q345 q325
q330 q315 q316 q318 q320
*********************************************
*label variables
label var ID            "unique identifyer"
label var AGE           "age"
label var SURVEY_DT "survey completion date"
label var BMI           "BMI"
```

```
label var DM_SCORE   "diabetes score"
label var HEART_SCORE "heart disease score"
label var VERSION_NUMBER "version number"
label var SVY_Y2010 "survey year 2010"
label var q17     "primary care"
label var q3      "gender (0/1)"
label var q4      "height"
label var q5      "weight"
label var q6      "race"
label var q7      "education level"
label var q8      "job classification"
label var q17     "primary provider"
label var q19     "number of prescriptions"
label var q31     "dx depression"
label var q32     "dx diabetes"
label var q33     "dx heart disease"
label var q49     "pregnant status"
label var q58     "past 12 mo physician/clinic"
label var q68     "moderate PA-number of days"
label var q69     "moderate PA-daily time"
label var q72     "vigorous PA daily time"
label var q73     "muscle strengthening-past 7 days"
label var q74     "flexibility-past 7 days"
label var q79     "any tobacco use"
label var q88     "readiness to make healthy changes"
label var q90     "readiness to improve physical activity"
label var q95     "readiness to manage stress"
label var q96     "readiness to manage back pain"
label var q101    "ethnicity"
label var q104    "phone triage liklihood"
label var q105    "stress rating"
label var q106    "effectively deal with stress"
label var q108    "feel depressed frequency"
label var q109    "back pain frequency"
label var q149    "usual hours of sleep"
label var q170    "confidence in initiating within 6 mo"
label var q171    "confidence in maintaining for 2 years"
label var q175    "uninterrupted sitting hours at work"
label var q177    "total sitting in a time usual week"
label var q220    "currently employed"
label var q221    "work hours missed due to health"
label var q222    "work hours missed due to other reasons"
label var q223    "hours worked - past 7 days"
label var q224    "HR productivity loss work"
label var q225    "HR productivity loss activity"
```

```
label var q226   "job satisfaction"
label var q227   "job fulfillment"
label var q228   "feel valued for work"
label var q332   "have the knowledge, tools and resources = safety"
label var q333   "likely to call LifeMatters"
label var q490   "playground_bmi_message"
label var q501   "heart disease risk score"
label var q502   "diabetes risk score"
label var q507   "BMI category/comorbidities"
label var q509   "alcohol risk score"
label var q512   "phys activity risk report"
label var q513   "tobacco risk report"
label var q522   "alcohol risk report"
label var q523   "quality of life report"
label var q526   "heart disease active or risks"
label var q601   "actual BMI score"
label var q603   "vigorous activity risk"*/
label var q605   "age"
label var q610   "APA phys activity score"
label var q611   "APA phys activity score by weight"
label var q612   "depression risk"
label var q618   "risk for diabetes"
label var q624   "risk for heart disease"
label var q656   "BMI category"
label var q659   "stress score adjusted for gender"
label var q701   "at risk for physical activity, per SURGEON GENERAL"
label var q728   "stress risk"
label var q729   "depression"
label var q735   "alcohol risk points"
label var q736   "healthy weight section"
label var q738   "pregnancy and gender correction"
label var q801   "cigarette use"
label var q802   "cigar use"
label var q803   "pipe use"
label var q804   "smokeless tobacco"
label var q809   "back pain score"
label var q873   "muscle strength score"
label var q874   "flexibility/stretching score"
label var q879   "tobacco use score"
label var q900   "final score"
label var q901   "potential score"
label var q902   "non-modifiable risks"
label var q903   "modifiable risks"
label var q904   "potential score for modifiable questions"
label var q912   "phys activity sum of points"
```

```
label var q915   "general well being sum of points"
label var q932   "readiness to change category phys activity"
label var q933   "readiness to change category: strength"
label var q934   "readiness to change category: flexibility"
label var q936   "readiness to change category: stress"
label var q942   "sum of all personal health hx questions"
label var q945   "no personal hx of any disease"
label var q950   "back pain and RTC back pain"

*********************rename variables****
rename q49 preg
recode preg (1 =1) (2=0)
rename q605 age
rename q3 gender
rename  q6 race
rename q101 ethn
rename q7 educ
rename q79 tob_any
rename q149 sleep
rename q8 job_class
rename q728 stress_risk
rename q108 feel_dep
rename q226 job_sat
rename q33 hd_dx
rename q526 hd_dx_risk
rename q109 bp
rename q610 pa_score
rename q175 sit_pr_work
rename q177 sit_tot
rename q105 stress_rate
rename q106 stress_deal
rename q31 depress_dx
rename q32 diab_dx
rename q4 height
rename q5 weight
rename q501 hd_score
rename q509 alcohol_score
rename q512 pa_risk
rename q513 tob_risk
rename q522 alco_risk
rename q523 qol
rename pa_score pa_apa
rename q601 bmi_score
rename q611 sed_cat
rename q612 depress_risk
```

```
rename q618 diab_risk
rename q624 hd_risk
rename q656 bmi_cat
rename q659 stress_gen_score
rename q68      pa_mod_numdays
rename q69      pa_mod_daily
rename q701 pa_guidelines
rename q72      pa_vig_daily
rename q73      muscle_stren
rename q74      flexibility
rename q809 bp_score
rename q873 muscle_stren_score
rename q874 flexibility_score
rename q88      health_rtc
rename q900 final_score
rename q901 potential_score
rename q902 nonmod_sum
rename q903 mod_sum
rename q912 pa_points_sum
rename q915 wellbeing_sum
rename q932 pa_rtc
rename q933 stren_rtc
rename q934 flex_rtc
rename q936 stress_rtc
rename q942 health_hx_sum
rename q945 no_hx
rename q950 bp_and_bp_rtc
rename q801 cig_use
rename q802 cigar_use
rename q803 pipe_use
rename q804 slt_use
rename q95 stress_rtm /*readiness to manage stress*/
rename q96 bp_rtm
rename q90 pa_rt_improve /*readiness to improve physical act*/
rename q58 visit_clinic /*How many times have you visited a
                                    physician or clinic in the previous 12 months?*/
rename q170 conf_init_6mo
rename q171 conf__maintain_2yr
rename q220 employed
rename q221 worktime_loss_health /*absenteeism from work*/
rename q222 worktime_loss_other /*absenteeism from non-work*/
rename q223 worktime_7d
rename q224 hrpl_work /*presenteeism at work*/
rename q225 hrpl_leisure /*presenteeism at non-work*/
```

```
notes: exclude pregnant women (n=338), students, and retired individuals (n = 95)

rename q738 preg_gender
recode preg_gender  (2=0) (1 = 1)
label var preg_gender "gender corrected for pregnant status"
label var preg_gender "gender 0/1
label define preg_genderlabel 0"male" 1"female" 3"pregnant"
label values preg_gender preg_genderlabel

drop if (preg_gender == 3)
drop if (job_class == 4) | (job_class==8)
*drop if (worktime_7d > 80)

**************************DEMOGRAPHICS
recode gender  (1=0)(2=1)
label var gender "gender 0/1"
label define genderlabel 0"male" 1"female"
label values gender genderlabel
gen female=gender

**AGE
gen age_cat=.
replace age_cat =0 if (age>=18) & (age<=29)
replace age_cat =1 if (age>=30) & (age <=39)
replace age_cat =2 if (age>=40) & (age <=49)
replace age_cat =3 if (age>=50)& (age <= 59)
replace age_cat =4 if (age>= 60) & (age <= 64)
replace age_cat =5 if (age>=65) & (age <=87)

label define age_catlabel  0"20-29" 1"30-39" 2"40-49" 3"50-59"  4"60-64" 5"65+"
label values age_cat age_catlabel
label var age_cat "age category 0/5"

**RACE
recode race (4=1) (1=4)(2=2) (3=3) (5=5) (6=6) (7=7)/*makes white the default reference
category by coding it to 1*/
label define racelabel 1"White" 2"Asian or Pacific Islander" 3"Black or African American"
4"American Indian or Alaskan Native" 5"Some other race" 6"Choose not to answer"
7"Unknown"
label values race racelabel

generate white=.
replace white=1 if (race==1)
replace white=2 if (race==4)|(race==2)|(race==3)|(race==5)
```

```
replace white= 3 if (race==6)|(race==7)
label var white "White race"
label define whitelabel 1"white"  2"non-White" 3"unknown"
label values white whitelabel


**ETHNICITY
recode ethn (2=0)(1=1) (3=.)
label define ethnlabel 0"non-Hisp" 1"Hisp"
label values ethn ethnlabel

** JOB CLASSIFICATION
label define job_classlabel 1 "Administrative" 2 "Labor or production" 3
"Professional/Management" 4 "Retired" 5 "Sales" 6 "Service" 7 "Skilled craft" 8 "Student" 9
"Technical" 10"Other"
label values job_class job_classlabel

notes: (from Abigail Katz on 4/2/13: Nico and I discussed how to collapse the job type
variable as follows.  Administrative (current category)· Professional/management (current
category)· Labor (to include the following current categories: “labor or production”;
“service”; “skilled craft”; & “technical”· All else= other

generate job_niosh = .
replace job_niosh = 1 if (job_class ==1)
replace job_niosh = 2 if (job_class == 3)
replace job_niosh = 3 if (job_class ==2)| (job_class ==6) | (job_class==7)| (job_class==9)
replace job_niosh = 4 if (job_class ==4) |(job_class ==5)|(job_class ==8)|(job_class ==10)
label var job_niosh "niosh job buckets"

label define job_nioshlabel 1"Administrative" 2 "Professional/management" 3"Labor"
4"other"
label values job_niosh job_nioshlabel

**EDUCATION
label define educlabel 1"8th grade or less" 2"Some high school" 3"High school diploma or
GED" 4"Technical training or Associate degree" 5"Some college" 6"College degree"
7"Graduate studies"
label values educ educlabel

gen educ_col = .
replace educ_col = 0 if (educ <=5)
replace educ_col = 1 if (educ >5) & (educ <8)
label var educ_col "4 year college degree or more"
label define educ_collabel 0"no college degree" 1"college degree"
label values educ_col educ_collabel
```

```
**************************OVERWEIGHT CATEGORY
generate ovrwt = .
replace ovrwt = 0 if (bmi_score >=18.5) & (bmi_score <=24.9)
replace ovrwt = 1 if (bmi_score >=25) & (bmi_score <= 29.9)
replace ovrwt = 2 if (bmi_score >=30.0) & (bmi_score <45.0)
replace ovrwt = 3 if (bmi_score >45)
replace ovrwt = 4 if (bmi_score <18.5)
label define ovrwtlabel 0"healthy" 1"overweight" 2"obese" 3"severely obese"
4"underweight"
label values ovrwt ovrwtlabel
label var ovrwt "overweight category 0/4"

***************************SEDENTARY

recode  pa_guidelines (2=0)(1=1)           /* At risk per Surg. General guidelines*/
label define  pa_guidelineslabel  0"not at risk per guidelines" 1"at risk per guidelines"
label values  pa_guidelines pa_guidelineslabel

/*based on Kcal per week expended (physical activity level, and weight)*/
notes:The APA acronym stands for "Algorithm for Physical Activity" We take reported
weight and activity levels and calculate Kcal per week expended by physical activity. 610 is
the raw score we get from that calculation; 611 puts the scores into activity level "buckets"
as defined below.


label define sed_catlabel  1 "sedentary" 2"low activity" 3"moderately active" 4"very active"
label values sed_cat sed_catlabel

notes:We take reported weight and activity levels and calculate Kcal per week expended by
physical activity. scores are put into activity level "buckets"

gen activity_score= sed_cat
label values activity_score sed_catlabel

gen sedentary = .
replace sedentary = 1 if sed_cat <=2
replace sedentary = 0 if (sed_cat >2) & (sed_cat <5)
label define sedentarylabel 1 "sedentary (<=800Kcal)" 0"active(>800Kcal)"
label values sedentary sedentarylabel
label var sedentary "sedentary classified by Kcal/wk"
gen sit_high = .
replace sit_high = 0 if (sit_tot <=30)
replace sit_high = 1 if (sit_tot >30)&(sit_tot <169)
label var sit_high "sitting 30+ hrs/wk"
```

```
label define sit_highlabel 0"no" 1" yes"
label values sit_high sit_highlabel
gen sit_prolong = .
replace sit_prolong = 0 if (sit_pr_work <=1.5)
replace sit_prolong = 1 if (sit_pr_work >=1.6)& (sit_pr_work <25)
label var sit_prolong "prolonged sitting at work (1.5+ hours)"
label define sit_prolonglabel 0"no" 1"yes"
label values sit_prolong sit_prolonglabel

gen sit_prolong1 = .
replace sit_prolong1 = 0 if (sit_pr_work <=1.0)
replace sit_prolong1 = 1 if (sit_pr_work >=1.1)& (sit_pr_work <25)
label var sit_prolong1 "prolonged sitting at work (1.0+ hours)"
label values sit_prolong1 sit_prolonglabel

recode bp_and_bp_rtc (1=1) (2=0)
rename bp_and_bp_rtc bp_risk
label define bp_risklabel 1"Back pain and ready to change = thinking, doing or done (2-5)"
0"No back pain or not ready to change"
label values bp_risk bp_risklabel

label define bp_rtmlabel 1"Precontemplation" 2"Contemplation" 3"Preparation" 4"Action"
5"Maintenance"
label values bp_rtm bp_rtmlabel

gen bp_risk_no =.
replace bp_risk_no = 1 if (bp_rtm ==.)

replace bp_ready = 1 if (bp_rtm ==3)| (bp_rtm ==4)
replace bp_ready = 0 if (bp_rtm ==1)| (bp_rtm==2)
label define bp_readylabel 1"ready to manage back pain" 0"not ready to manaage back pain"
label values bp_ready bp_readylabel
label var bp_ready "ready to manage back pain"

generate perc_safety = .
replace perc_safety = 0 if (q332 ==3)| (q332 == 4) |(q332 == 5)
replace perc_safety = 1 if (q332 <= 2)
label define perc_safetylabel  0"Sometimes, Rarely or Never" 1"Always or Usually"
label values perc_safety perc_safetylabel


label var perc_safety "knowl, tools, resources to work safely"
generate low_perc_safety = .
replace low_perc_safety = 0 if (q332 <= 2)
replace low_perc_safety = 1 if (q332 ==3)| (q332 == 4) |(q332 == 5)
```

```
label var low_perc_safety "lacks knowledge, tools, recources to work safely without injury"
label define low_perc_safetylabel 0"yes" 1"no"
label values low_perc_safety low_perc_safetylabel

gen safe_job = perc_safety

************************UNHEALTHY BEHAVIORS
/*TOBACCO USE*/
generate tobacco_use = .
replace tobacco_use = 1 if (tob_any == 1)
replace tobacco_use = 0 if (tob_any >=2) & (tob_any<5)
label define tobacco_uselabel  0 "none" 1 "any"
label values tobacco_use tobacco_uselabel
label var tobacco_use "current use of any tobacco"

/*SUBOPTIMAL SLEEP*/
generate sleep_bad =.
replace sleep_bad = 1 if (sleep == 1)|(sleep ==3) | (sleep==4)
replace sleep_bad = 0 if (sleep==2)
label define sleep_badlabel 0" optimal sleep" 1"suboptimal sleep"
label values sleep_bad sleep_badlabel
label var sleep_bad "suboptimal sleep"

**BACK PAIN
label define bp_scorelabel 1 "frequent bp" 2 "not frequent & male" 3 "not frequent &
female"
label values bp_score bp_scorelabel
decode bp_score, generate (bp_freq)
gen bp_freq2=1 if bp_score ==1
replace bp_freq2 = 0 if bp_score >1

drop bp_freq
rename bp_freq2 bp_freq
label var bp_freq "back pain"
label define bp_freqlabel 1 "yes" 0 "no"
label values bp_freq bp_freqlabel

generate salary = .
replace salary = 52000
label var salary "average annual salary ($)"

*revised code*/

logistic bp_freq age_cat, or allbaselevels
logistic bp_freq female, or allbaselevels
```

```
logistic bp_freq i.white, or allbaselevels
logistic bp_freq i.race, or allbaselevels
logistic bp_freq educ_col age_cat white female, or allbaselevels
logistic bp_freq ib6.educ age_cat white female, or allbaselevels
logistic bp_freq job_niosh age_cat female educ_col white ovrwt, or allbaselevels

logistic bp_freq i.ovrwt age_cat female white educ_col tobacco_use sit_prolong1
pa_guidelines perc_safety, or allbaselevels
logistic bp_freq tobacco_use age_cat female white  educ_col job_niosh perc_safety, or
allbaselevels
logistic bp_freq i.pa_guidelines age_cat female white  educ_col job_niosh ovrwt
tobacco_use /*sit_prolong1 sit_tot*/ perc_safety, or allbaselevels
logistic bp_freq i.sed_cat age_cat female white  educ_col job_niosh tobacco_use
/*sit_prolong1 sit_tot*/ perc_safety, or allbaselevels
logistic bp_freq sedentary age_cat female white  educ_col job_niosh tobacco_use
/*sit_prolong1 sit_tot */perc_safety, or allbaselevels
logistic bp_freq sit_high age_cat female white  educ_col job_niosh ovrwt tobacco_use
/*pa_guidelines*/ sit_prolong1 perc_safety, or allbaselevels
logistic bp_freq sit_prolong1 age_cat female white  educ_col job_niosh ovrwt tobacco_use
perc_safety, or allbaselevels
logistic bp_freq perc_safety age_cat female white  educ_col job_niosh, or allbaselevels

*association overweight category on readiness to manage back pain among those reporting
back pain*
 logistic bp_ready i.ovrwt age_cat female white  educ_col job_niosh  perc_safety, or
allbaselevels
 logistic bp_ready i.ovrwt  age_cat female white  educ_col job_niosh  perc_safety if ovrwt
>0

**********AIM 2******************************

sort ID, stable

drop if hrpl_work ==. | hrpl_leisure == . | worktime_loss_health == . | worktime_loss_other
==. | worktime_7d ==. | employed==.
drop if tobacco_use ==.
drop if ovrwt ==.
gen absent_hr = worktime_loss_health
label var absent_hr "work health-rel absenteeism hours"

gen absent_l = worktime_loss_other
label var absent_l "non-health rel absenteeism"

****
gen meets_guidelines = .
```

```
replace meets_guidelines =1 if (pa_guidelines ==0)
replace meets_guidelines =0 if (pa_guidelines ==1)
/*recode meets_guidelines (1=1) (2=0) from at risk (meets guidelines) no = 1; to meets
guidelines no = 0 at risk.*/
label define meets_guideines 0"no" 1"yes"
label values  meets_guidelines meets_guidelineslabel

/*based on Kcal per week expended (physical activity level, and weight)*/
notes:The APA acronym stands for "Algorithm for Physical Activity" We take reported
weight and activity levels and calculate Kcal per week expended by physical activity. 610 is
the raw score we get from that calculation; 611 puts the scores into activity level "buckets"
as defined below.

gen inactive = .
replace inactive =1 if (meets_guidelines ==0)
replace inactive =0 if (meets_guidelines ==1)
label define inactivelabel 0"meets guidelines" 1"does not meet guidelines"
label values inactive inactivelabel
drop if inactive ==.

**prolonged sitting
generate potato_pro = ./*potato_pro indicates risk of potato and prolonged sitting time at
work*/
replace potato_pro = 0 if (sit_prolong1==0) &(meets_guidelines==1) /*active*/
replace potato_pro = 1 if (sit_prolong1==0)& (meets_guidelines==0) /*couch potato*/
replace potato_pro = 2 if (sit_prolong1==1)& (meets_guidelines==1) /*desk potato*/
replace potato_pro = 3 if (sit_prolong1==1)& (meets_guidelines==0) /*sedentary*/
label var potato_pro "potato risk: prolonged sitting" /*based on prolonged sitting and
physical inactivity*/

label define potato_prolabel 0 "active life"  1 "sed leisure (couch pot)" 2"sed job (desk pot)"
3 "sedentary life"
label values potato_pro potato_prolabel
drop if potato_pro ==.

***INTERACTION
logistic bp_freq i.potato_pro   age_cat female white  educ_col job_niosh ovrwt tobacco_use
perc_safety, or allbaselevels
logistic bp_freq ib3.potato_pro   age_cat female white  educ_col job_niosh ovrwt
tobacco_use perc_safety, or allbaselevels
logistic bp_freq ib2.potato_pro   age_cat female white  educ_col job_niosh ovrwt
tobacco_use perc_safety, or allbaselevels//*main effects*/
logistic bp_freq inactive age_cat female white  educ_col job_niosh ovrwt tobacco_use
/*sit_prolong1 sit_tot*/ perc_safety, or allbaselevels
```

```
logistic bp_freq sit_prolong1 age_cat female white  educ_col job_niosh ovrwt tobacco_use
perc_safety, or allbaselevels

logistic bp_freq ib1.inactive age_cat female white  educ_col job_niosh ovrwt tobacco_use
perc_safety, or allbaselevels
logistic bp_freq ib1.sedentary age_cat female white  educ_col job_niosh tobacco_use
perc_safety, or allbaselevels
logistic bp_freq ib1.sit_high age_cat female white  educ_col job_niosh ovrwt tobacco_use
sit_prolong1 perc_safety, or allbaselevels
logistic bp_freq ib1.sit_prolong1 age_cat female white  educ_col job_niosh ovrwt
tobacco_use perc_safety, or allbaselevels

by bp_freq, sort: sum age female i.white i.educ_col i.job_niosh bmi_score tobacco_use
inactive  sit_tot  \\
\\\sed_cat  sit_pr_work worktime_7d absent_hr absent_l pres_hr_w pres_hr_leis
/*hrpl_w_tot*/ i.job_sat salary


**********AIM 3***************************************************

***productivity tables
by inactive, sort: sum absent_hr
by sit_prolong1, sort: sum absent_hr
by potato_pro, sort: sum absent_hr
by potato_sit, sort: sum absent_hr

generate absenteeism =((absent_hr)/(worktime_7d + worktime_loss_health +
worktime_loss_other))
generate absent_cost = absenteeism*salary
label var absenteeism "percent of work hours missed due to health reasons"
label var absent_cost "annual dollars lost per employee due to health-related absence"

by bp_freq, sort: sum worktime_7d absent_hr absenteeism absent_cost
by bp_freq, sort: tab2 sit_prolong1 inactive, sum (absent_cost)
by bp_freq, sort: tab potato_pro, sum (absenteeism)
by bp_freq, sort: tab potato_pro, sum (absent_cost)
by potato_pro, sort: tab potato_pro, sum (absenteeism )
by potato_pro, sort: tab potato_pro, sum (absent_cost )
```