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Consequences of Fatigue and Sleep Deficiency in the Workplace: Implications for the Construction Industry

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Abstract

Background: This study was a review of the (1) consequences that fatigue and sleep deficiency have on the human body, personal safety and safety in the workplace with implications for the construction industry; and (2) factors in the workplace that contribute to worker fatigue.

Methods: A systematic search and review of peer-reviewed articles and gray literature was conducted for sources describing common industry policies, standards and/or recommendations addressing sleep related problems in the workplace.

Results: The contributing factors of fatigue include work-related mental exertion, sleep deficiency and work-related physical exertion. Major work-related effects stem from circadian rhythm disruptions due to shift work, extensive overtime and extended work hours.

Recommendations: Sleep issues in the workplace have been studied for years, yet only a few key industries have implemented policies to control the fatigue-related problems workers face. The reoccurring countermeasures identified in this search and review include: workers naps and breaks; work place policies for length of shifts, overtime and work schedules; education to sleep management to improve sleep practices for labor force and management; and fatigue risk management systems.

Keywords: Fatigue risk management, work hours, work schedules, shift work, sleep hygiene, risk factors, costs, circadian rhythms

Consequences of Fatigue and Sleep Deficiency in the Workplace: Implications for the Construction Industry

According to the 2012 guidance statement of the American College of Occupational and Environmental Medicine (ACOEM), *fatigue* is "the body's response to sleep loss or to prolonged physical or mental exertion" (Lerman et al., 2012, p. 231). Sleep loss, also called *sleep deprivation*, is "a sufficient lack of restorative sleep over a cumulative period so as to cause physical or psychiatric symptoms and affect routine performances of tasks" (sleep deprivation, 2012). The National Institutes of Health, National Heart Lung and Blood Institute (NHLBI) describes sleep deprivation as a subtype of the broader concept of *sleep deficiency*. They state that sleep deficiency is a measure of sleep quality:

> It occurs if you have one or more of the following:
>
> - You don't get enough sleep (sleep deprivation)
> - You sleep at the wrong time of day (that is, you're out of sync with your body's natural clock)
> - You don't sleep well or get all of the different types of sleep that your body needs
> - You have a sleep disorder that prevents you from getting enough sleep or causes poor quality sleep (verbatim text from NHLBI, 2017, first paragraph)

Physical and mental exertion can come from any human activity. This study focused on the mental and physical exertions in the workplace. Figure 1 shows the relationship between the variables of interest in the study.

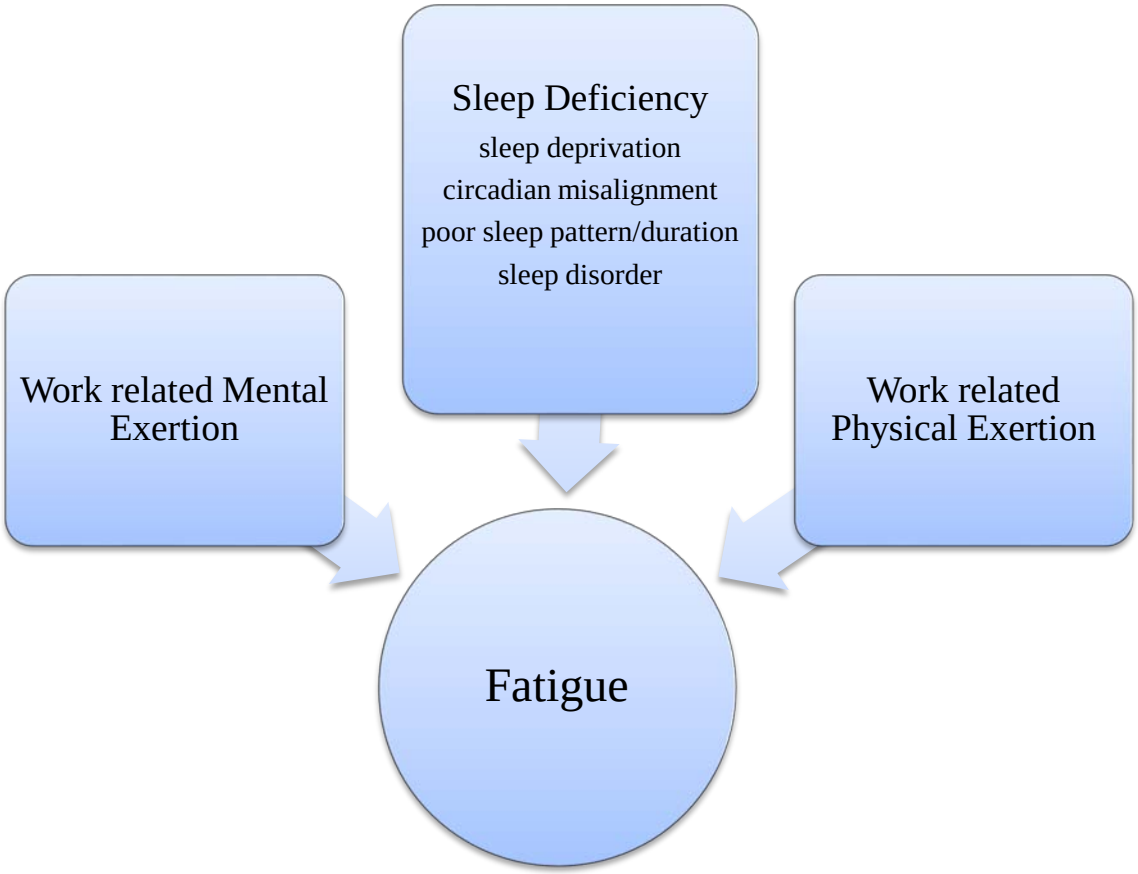

Figure 1. Contributors to human fatigue. By KP, following guidance statement from American College of Occupational and Environmental Medicine (ACOEM) (Lerman et al., 2012).

In the academic and occupational literature, the terms *sleep deprivation*, *sleep deficiency* and *fatigue* are used somewhat interchangeably in studies of human error. This study uses the terms *fatigue* and *sleep deficiency* since they encompass the broadest concepts (Figure 1).

Sleep Deficiency

The 2006 Institute of Medicine (IOM) report *Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem* states somewhere between 50 and 70 million Americans may suffer from a chronic sleep disorder and wakefulness, which negatively affects mortality, quality of life, and daily activities (Colten & Altevogt, 2006). Sleep disorders and sleep deprivation have been linked to a broad array of adverse health issues which include high blood pressure,

diabetes, obesity, depression, heart attack, and stroke (Colten & Altevogt, 2006, p. 55). In this call to action, the IOM report suggested several strategies to lessen the negative consequences sleep deficiency has on public health. A more recent list of recommended approaches to improve upon sleep health of the public includes the following (verbatim text from Perry, Patil, & Presley-Cantrell, 2013, subtitle Call to Action):

- Research on the effectiveness of screening and counseling efforts
- Education of employers on the health effects of long shifts and insufficient sleep
- Delaying school start time for high school students
- Educating the public on the risks of drowsy driving
- Improving surveillance of sleep health, especially among young children

Like proper nutrition and adequate exercise, proper sleep is a necessity for health and well-being. Sleep deficiency has been linked to unfavorable health outcomes including chronic disease, diabetes, high blood pressure, obesity, mental disorders, heart disease, stroke, work-related safety issues and injuries (Centers for Disease Control & Prevention [CDC], 2013; Watson et al., 2015; Liu, Wheaton, Chapman, & Croft, 2013). One of the new objectives added to Healthy People 2020 (HP 2020) was ‘Sleep Health’ (U.S. Department of Human Health Services, Office of Disease Prevention and Health Promotion [DHHS, ODPHP], n.d.). HP 2020 stated that 25 percent of the U.S. adult population (working and non-working) reported getting insufficient amount of sleep 15 days out of every 30. This American issue with sleep deficiency, coupled with the lack of knowledge about poor sleep hygiene, will require a national effort to improve the sleep health of Americans. The HP 2020 goal is to “increase public knowledge of how adequate sleep and treatment of sleep disorders improve health, productivity, wellness,

quality of life, and safety on roads and in the workplace" (DHHS, ODPHP, n.d., Overview: Goal).

The Centers for Disease Control and Prevention (CDC, 2015) proclaimed insufficient sleep an American public health problem. According to the National Sleep Foundation (NSF), adults need a minimum of seven hours of sleep each night (Yong, Li, & Calvert, 2017). An estimated 83.6 million American adults get less than this recommended seven hours or more (Watson et al., 2015). According to the National Health and Nutrition Examination Survey (NHANES) data from 2005-2006 and 2007-2008, approximately 38 percent of American working adults aged 18 years and older reported getting less than seven hours of sleep (Yong et al., 2017). Predictable effects of fatigue and sleep deficiency that impact worker safety and workplace performance include; slowed reaction time, reduced attention to critical details, errors of omission, compromised problem solving, diminished motivation, and decreased accomplished tasks (Page, 2004). Lombardi, Folkard, Willetts, and Smith (2010) reported on the amount of sleep per day U.S. workers get compared to the number of injuries experienced using data from the CDC's National Health Interview Survey (NHIS). They reported that U.S. workers reporting less than five hours of daily sleep have an estimated annual injury incidence rate approximately four times higher than workers who get between seven and eight hours of sleep (the recommended amount or more) (Table 1). The RAND Europe research institute (Hafner, Stepanek, Taylor, Troxel, & van Stolk, 2016) reported an increased risk of mortality up to 13 percent and 1.2 million lost workdays annually are consequences of sleep deficiency in the United States.

Fatigue. Fatigue experienced from sleep deprivation and mental/physical exertion creates an unsafe condition in the American workplace. The 2006 IOM report linked sleep

deprivation as a contributor to industrial disasters, motor vehicle accidents, and occupational errors (Colten & Altevogt, 2006). Sleep fatigue has been associated with work-site/work-related accidents across all industries (Industrial Safety & Hygiene News, 2012; Smith, 2015). IOM's 2006 call to action created a movement for changes, primarily in health care for recommended shift lengths for healthcare workers (e.g., Ulmer, Wolman & Johns, 2009) and policy changes in the transportation industry (e.g., Federal Motor Carrier Safety Administration, 2017).

Fatigue is an occupational exposure risk. This risk is higher for shift work, which includes non-daytime hours (6:00 pm to 7:00 am). Similarly, the risk is higher for employees working overtime (> 40 hours/workweek) and/or working extended hours (> eight hours/workday) (Lerman et al., 2012; Occupational Safety and Health Administration [OSHA], n.d.a). Studies show that workplace accidents occur more frequently during employee overtime hours: accident rates *increase* after nine consecutive hours worked by employees, *double* after 12 consecutive hours worked, and *triple* after 16 consecutive hours worked (Dembe, Erickson, Delbos, & Banks, 2005; Hanecke, Tiedemann, Nachreiner, & Grzeh-Sukalo, 1998; Page, 2004). However, there is currently no Occupational Safety and Health Administration (OSHA) code for fatigue in the workplace (La Duke, 2014). OSHA instead provides suggestions for what employers can do to reduce the risk of worker fatigue in the workplace: examining/adjusting work schedules and the environment (e.g., lighting, noise), providing education and training on hazards of fatigue and implementing a Fatigue Risk Management System (FRMS, detailed on page 35) (OSHA, n.d.b).

The current U.S. economy is exhibiting lower unemployment rates. With this comes fewer available and less qualified workforce to fill employment needs. Fewer available employees can lead to voluntary and mandatory overtime to fulfill work requirements, which

means more time spent at work for employees. Increased number of overtime hours worked comes at the expense of sleep, and contributes to the rise of fatigue and sleep deficiency seen in U.S. workers. Several states (California, Maine, New Jersey, and Oregon) have implemented laws restricting mandatory overtime by employers (Golden & Jorgensen, 2002). Similarly, the American Nurses Association (2011) lists seventeen states have enacted laws or regulations to restrict mandatory overtime for nurses in health care settings. However, further investigation and more sweeping changes need to take place and employers must address fatigue as an occupational exposure risk.

Statement of Purpose

The purpose of this study was to conduct a systematic literature search and review to identify industry policies and standards to reduce safety concerns related to fatigue and sleep deficiency in the workplace. This included: 1) examining the published literature describing the causes and effects of fatigue and sleep deficiency on safety in the American workplace; 2) identifying practices and policies that address workers' fatigue and sleep deficiency; and 3) identifying industries that currently have policies and practices addressing workers' fatigue and sleep deficiency, with a special interest in the construction industry. Results were used to create recommendations that can be used by management in any industry, with specific recommendations for construction.

Background

Sleep deficiency and fatigue are the result of many related and encompassing components: they may result from less than adequate rest, loss of sleep, or from working shift work (Page, 2004). Job-related influences such as workplace pressures, shift work, the number of hours worked (over eight hours) during a shift, and physically challenging work have been

associated with the duration and amount of sleep and quality of sleep experienced (Shockey & Wheaton, 2017; Drake, Roehrs, Richardson, Walsh, & Roth, 2004). The following literature review explains the complex causes, effects, and health and safety outcomes of fatigue and sleep deficiency for individuals, companies and public health. This background is provided to the reader as a context for explaining the extent and complexity of the public health and workplace safety issues of fatigue and sleep deficiency.

Fatigue

Fatigue is a broad concept that is characterized by feeling tired, sleepy, lack of energy and/or physically and mentally spent. Fatigue can be caused by one or a combination of many contributing factors found in the workplace, such as stress and workloads to health conditions, environmental conditions, personal sleep habits, social conditions and lifestyle that negatively impact health and therefore impact performance in the workplace. Use of the term *fatigue* is a good proxy for workplaces to measure the contributing factors identified in Figure 1. Physiological factors of fatigue are loss of sleep and disruption of the natural sleep/wake cycles (Powell & Copping, 2010). Observable workplace effects of fatigue may include slowed reactions, increased error rates, compromised problem solving, reduced motivation, and decreased perceptive capacity (Folkard, Lombardi, & Spencer, 2006; Page, 2004; Techera, Hallowell, Stambaugh, & Littlejohn, 2016). Individual effects of fatigue in humans include costs of lost productivity (tired workers accomplish less) as well as hidden costs such as employee injuries, health issues, and diminished morale (Lerman et al., 2012). Fatigue and sleep deficiency are such common occurrences that people do not recognize them as problems with potentially major consequences (Lerman et al., 2012). The following sections describe many of the interrelated components that can contribute to human fatigue.

Sleep

Normal human sleep pattern. The human body operates on a sleep/wake cycle called the circadian rhythm. This is the process that controls functions such as sleep, digestion, hormone secretion, body temperature, and attentiveness (Powell & Copping, 2010). The circadian rhythm is naturally programed and functions best when sleep occurs during nighttime hours with natural darkness, and less so during daytime hours (Page, 2004; Powell & Copping, 2010). Circadian internal synchronized metabolic processes can be disrupted by a wide range of outside effects or stimuli. (Note: specific stimuli are discussed in the section entitled *Relevant Factors that Contribute to Fatigue and Sleep Deficiency*).

Sleep deficiency. Consecutive nights of inadequate (< 7 hours) sleep, create a *sleep deficiency*. The three main factors that contribute to sleep deficiency are non-biological circadian/sleep cycle disruption, inadequate sleep, and sleep disorders (Lerman et al., 2012).

***Circadian/sleep cycle disruption*.** Changes in circadian rhythm can result in drowsiness and fatigue and can affect sleep, digestion, hormone secretion, body temperature, and attentiveness (CDC, 2015; Lerman et al., 2012; Techera et al., 2016). People with chronic fatigue and sleep deficiency due to disrupted circadian rhythms are more likely to experience increased mortality and chronic disease be less productive in life, experience a decrease in the quality of life, and have increased risk of substance abuse (Colten & Altevogt, 2006; CDC, 2015; Dong, 2005; Shockey & Wheaton, 2017). In the short term or long term these physiological effects can make fatigued or sleep deprived individuals dangerous to themselves and possibly to others (Powell & Copping, 2010).

***Inadequate sleep*.** Inadequate sleep can be defined as not getting enough *quality* sleep, or long enough *duration* of quality sleep (Lerman et al., 2012). Some primary reasons American

adults are getting inadequate sleep include: working shift work; working extended work hours per day and week; too many personal obligations; unawareness of the importance of sleep; poor sleep hygiene; and/or suffering from sleep disorders. Studies have shown that shift workers have more sleep-related problems than the general population, it is harder for to fall asleep, the amount of sleep they get is inadequate and they do not feel well rested upon waking (Akerstedt, Ingre, Broman, & Kecklund 2008; Drake et al., 2004).

Sleep disorders. The IOM (Colten & Altevogt, 2006) reported somewhere between 50 and 70 million American adults may suffer from a chronic sleep disorder. Sleep disorders such as insomnia or obstructive sleep apnea may also be contributing factors to circadian disruption and inadequate sleep issues (CDC, 2015).

Relevant Factors that Contribute to Fatigue and Sleep Deficiency

In data from the National Health and Nutrition Examination Survey (NHANES) (2005-2006 and 2007-2008 cycles) of 6,338 U.S. working adults 37.6 percent reported getting less than seven hours of sleep a night, which represents 54.1 million fatigued U.S. workers (Yong et al., 2017). Due to the current around-the-clock society, more American workers have issues with getting adequate and quality sleep (Givens et al., 2015). In addition, more work is being done on multiple shifts and incidence of extended work hours has increased (Yong et al., 2017). Studies have shown an association between overtime and extended work shifts that contributes to workers' fatigue (association between overtime and extended work shifts that contributes to workers' fatigue (Dembe et al., 2005).

Work schedules. American workers are spending more hours at work than any other industrialized country. Around one-third of the U.S. workforce works more than a 40-hour work week (Golden & Jorgensen, 2002).

OSHA defines a normal work shift to be “a work period of no more than eight consecutive hours during the day, five days a week with at least an eight-hour rest” (OSHA, n.d.a, first paragraph). They define “extended” or “unusual” shifts as those that have “more continuous hours, more consecutive days of work, or work during the evening ” (OSHA, n.d.a, first paragraph).

During the Industrial Revolution (18^{th} −19^{th} century) work hours and harsh work conditions aroused concerns for workers welfare, especially for women and children (History, 2017a). Early1840s labor unions and activists started lobbying for protective legislation in order to regulate work hours (Dembe, 2009). The Adamson Act, a federal law in which the eight-hour workday and 40-hour workweek were established for interstate railroad employees, was passed by the U.S. Congress in 1916 (Wikipedia, 2017). The act became constitutionalized by the Supreme Court in 1917 (Lebowitz, 2015). A five-day, 40-hour workweek was implemented in 1926 by the Ford Motor Company, the first company in America to adopt this type of workweek (History, 2017b). In 1938 the U.S. Congress legally limited the American workweek to 44 hours when it passed the Fair Labor Standard Act (FLSA), and in 1940 amended the Act to specify the 40-hour workweek (Lebowitz, 2015).

Prior to the widespread use of electric light for workplace illumination, work hours were largely limited to daylight. As a result of progressions in illumination and technology, factories and shops could operate 24 hours a day (Lerman et al., 2012). In the 21^{st} century, the characteristic workday no longer follows the traditional daytime shift. Due to globalization supply and demand, work has gone to multiple shifts that may run around the clock. Shift work schedules may start in the afternoon or during the night, or be a ‘swing-shift’ of day shift for one week, evening shift the next week, then night shift the next week (Yong et al., 2017). The result

of technology and the ability to supply on demand, people now live in a 24/7 society (Lerman et al., 2012).

Shift work. While sleep related problems are common for a large number of workers, night-shift workers are the most likely to encounter sleep problems (Yong et al., 2017). In Yong, Li, and Calver's (2017) study of NHANES almost twice as many night shift workers than day-shift workers reported short sleep durations. Employees doing shift work are known to have more sleep-related problems than the rest of the population, such as trouble falling asleep, too little sleep and being sleepy upon waking (Akerstedt et al., 2008; Drake et al., 2004). A number of research studies have illustrated that extended work hours and shift work adversely affect the health and wellbeing of workers (Dembe et al., 2005; Drake et al., 2004; Givens et al., 2015). Shift workers experience circadian rhythm misalignments and sleep time restrictions, which can contribute to increased incidence of obesity (Heath et al., 2012). Through simulation of shiftwork, Heath et al. (2012) found that sleeping and eating at suboptimal circadian phases negatively affected the quantity and quality of food choices made by shift workers.

In order to work shift work, swing shifts or overtime, employees are required to divert from normal human biological rhythms of nighttime and daytime activities (Givens et al., 2015; Lerman et al., 2012). The normal circadian rhythm is set for a routine of being active during daylight hours and sleeping at night. Not working traditional day shift hours and/or working extended shift hours can disrupt or impair the amount and quality of sleep workers achieve (Drake et al., 2004; Page, 2004).

Extended hours/overtime. Long work hours also have effects on worker psychological well-being and mental health and decreased sleep (Dong, 2005). Continuous overtime, week after week, leads to prolonged periods of wakefulness, increased mental and physical fatigue,

disruption of the circadian rhythm, reduced alertness and impaired performance (Patterson et al., 2014). Dembe, Erickson, Delbos, and Banks (2005) reported that working overtime (12 or more hours per day, more than 60 hours per week) increased the probability of workplace injuries by an estimated 61percent.

Relationship between Fatigue and Sleep

Fatigue is considered a workplace hazard for U.S. workers as it interferes with the ability to think clearly and respond appropriately, and is a common contributor to workplace accidents and injuries (Zhang, Murphy, Fang, & Caban-Martinez, 2015). Occupational risk factors positively associated with workplace fatigue include lack of sleep, extended work hours, a heavy workload, greater age of worker, inclement weather and extreme temperatures, high levels of noise and medical conditions (CDC, 2004; Dembe et al., 2005). Some of these occupational risk factors overlap with the relevant stimuli noted in Figure 2. There are numerous circumstances that can negatively affect sleep and fatigue: this review is limited to work shifts and work environments, two factors which employers can control.

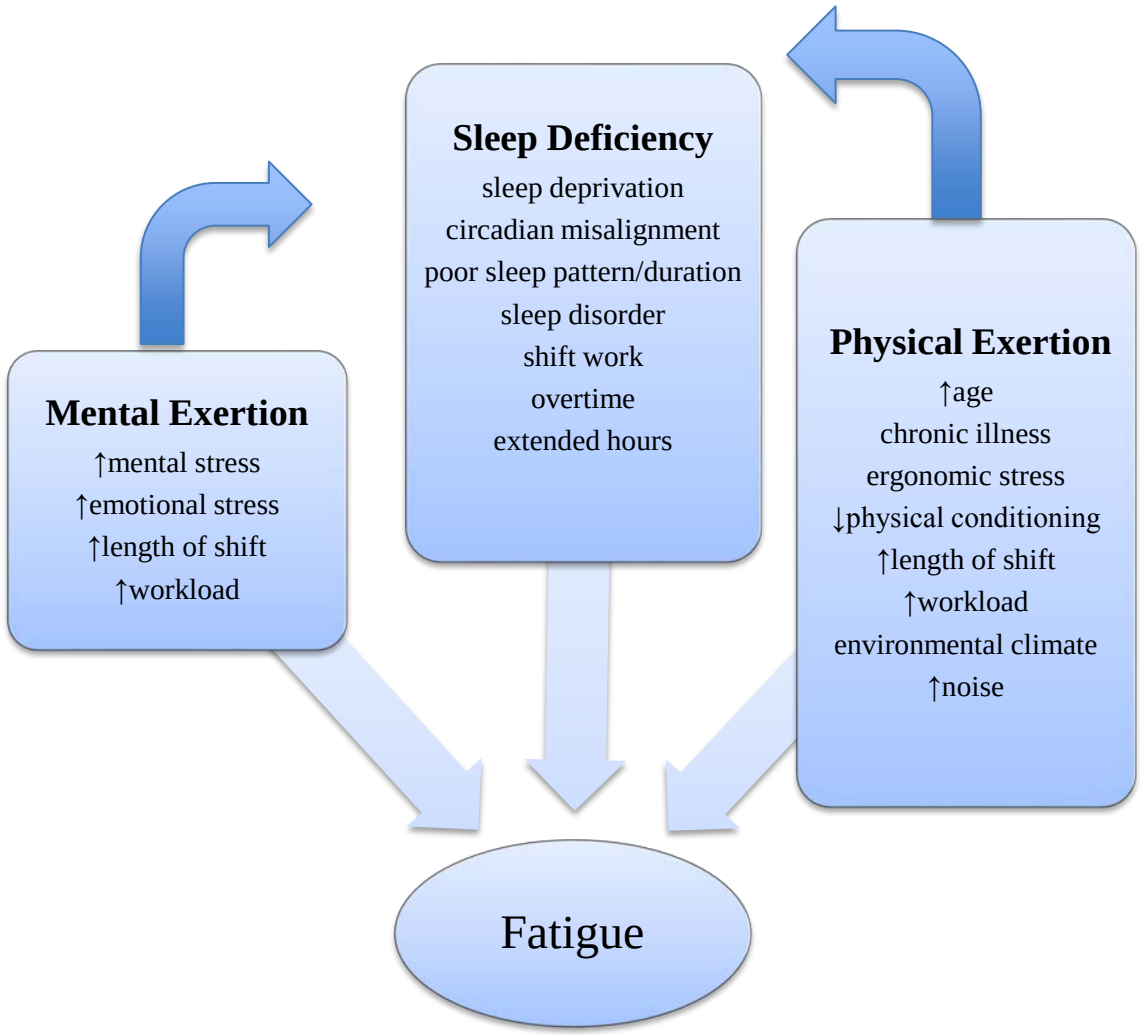

Figure 2. Relevant stimuli contributing to fatigue and sleep deficiency. By KP.

Workplace Safety Studies

Sleep-related problems have been linked with loss of work productivity and adverse safety outcomes (Yong et al., 2017). Occupations with highest risks are those with extended work shifts, overtime on multiple days in a row, and/or where employees are exposed to harsh environmental conditions (Folkard et al., 2006). According to The National Institute of General Medical Sciences (National Safety Council [NSC], 2017a), the disturbance of one's sleep-wake cycle is one of the key risk factors for safety incidents. (An incident is "an *unplanned, undesired*

event that hinders completion of a task and may cause injury, illness, or property damage or some combination of all three in varying degrees from minor to catastrophic" [Ferrante, 2011, third paragraph].) By working nights and sleeping during the day the sleep-wake cycle is misaligned creating a higher risk for safety incidents. Night shifts have a 30 percent higher risk of accidents or incidents than morning shifts (Caruso, Hitchcock, Dick, Russo, & Schmit, 2004).

The relationship of longer work hours, overtime, and shift work has been shown to increase the risk of occupational injuries (Dembe et al., 2005). Studies show that workplace accidents occur more frequently during employee overtime hours: accident rates increase after nine consecutive hours worked by employees, *double* after 12 consecutive hours worked, and *triple* after 16 consecutive hours worked (Hanecke et al., 1998; Page, 2004). According to the CDC (2012), a United States national survey showed that as many as 44 percent of night shift workers reported insufficient sleep (< 7hours/day) compared to 30 percent of employees that work day shift.

There is also an association with the amount of overtime worked and a higher on-the-job injury rate for construction and healthcare workers (Caruso et al., 2004). Over a five-year period (2004−2008) the U.S. National Health Interview Survey (NHIS) gathered sleep data, which identified 129 million at-risk workers (Lombardi et al., 2010). Researchers analyzed the data and identified an incremental increase in injuries as the weekly working hours increased and daily sleep duration decreased, as noted in Table 1 (Lombardi et al., 2010).

Table 1

Annualized Injury Rates (per 100 U.S. Workers)

Work						
Hours per week	≤20	20-30	31-40	41-50	51-60	60+
Injury rates	2.03	3.01	2.45	3.45	3.71	4.34

Sleep							
Hours per week	<5	5-5.9	6-6.9	7-7.9	8-8.9	9-9.9	>10
Injury rates	7.89	5.21	3.62	2.27	2.5	2.22	4.72

Source: Copied verbatim from Liberty Mutual Research Institute for Safety, 2009, p. 9, www.libertymutualgroup.com/researchinstitute.

During a field study of construction workers, Powell and Copping (2010) found that inadequate sleep resulted in decreased performance and greater risk of accidents. Through a survey questionnaire and interviews, Chan (2011) survey respondents compiled the major risk factors for accidents in oil and gas construction. As reflected in the title of their 2011 publication, workers ranked fatigue as the "most critical" risk factor.

Fatigue and sleep deficiency can reduce workers' performance and judgment, putting themselves and their co-workers at higher risk of accidents. Research by Dawson and Reid (1997) correlated the performance of being awake for 17 consecutive hours with having a blood alcohol content (BAC) level of 0.05 %, more than Ohio's legal intoxication level for drivers less than 21 years of age (0.04%) and, all U.S. commercial drivers (0.04%). They argue that fatigue and sleep deficiency contribute to cognitive and motor skill decline, which is similar to that seen in alcohol consumption impairment (Dawson & Reid, 1997). More recently, Hursh, Raslera, Kaye, and Fanzone (2006) developed sleep and performance models that correlate measured

sleep levels with equivalent BAC levels, which show how the lowered performance and mental alertness result in the same risks seen with alcohol impairment.

Cost of worker fatigue and sleep deficiency in the U.S. Fatigue and sleep deficiency have been documented as playing significant roles in major industrial and motor vehicle accidents. Fatigue was identified as a cause or contributing factor in some of the world's worst environmental accidents including the 1984, Union Carbide Corporation plant explosion in Bhopal, India, the 1989, grounding of the Exxon Valdez, the 1986 Chernobyl, and 1979 Three Mile Island nuclear accidents (Hossain & Shapiro, 2002; Powell & Copping, 2010; Techera et al., 2016). The U.S. Chemical Safety and Hazard Investigation Board (2007) cited fatigue due to extreme overtime and uninterrupted shifts as a contributing factor in the 2005 British Petroleum oil refinery disaster (Texas City, Texas, U.S.A.), in which 15 employees were killed and 180 injured.

The negative safety consequences of human fatigue are not surprising, as fatigue reduces human capacity to process and react to new information and respond appropriately. It is estimated that more than 20 percent of the U.S. working population experiences occupational fatigue every day, resulting in an estimated $136 billion in lost productivity, medical costs and other indirect costs to employers (NSC, 2017b; Techera et al., 2016). According to The National Safety Council (NSC, 2017b), the sleep deprived working population most at risk work the night shift, long shifts or irregular shifts.

In September 2017 the NSC (2017c) released the *Fatigue Cost Calculator* (https://forms.nsc.org/real-costs-of-fatigue-calculator/index.aspx) as a tool for employers to estimate what fatigue costs them annually. The latest research is used to predict the prevalence of sleep deficiency and estimates total annual cost of fatigue as well as the costs of absenteeism,

decreased productivity and healthcare based on user choices of location, industry type, number of employees, and any shift workers.

U.S. workers who experience insomnia are involved in higher numbers of occupational accidents, have higher rates of absences and lost work productivity, which costs employers more than $15 billion annually (Kao, Spitzmueller, Cigularov, & Wu, 2016). Estimated costs of insufficient sleep for U.S. economy ranges from $280 to $411 billion due to workplace accidents and lost productivity (Hafner et al., 2016). Costs of absenteeism and turnover due to fatigue are hard to quantify, but is estimated to cost U.S. businesses $150 billion a year (Golden & Jorgensen, 2002). In 2014, on average, absenteeism of an employee working shift work would cost the company approximately $2,660 in excess costs each year (Cooke, 2014).

Rates of absenteeism in industries working extended hours range between three to six times higher than the national average (Lerman et al., 2012). Absent workers either need to be replaced or coworkers must work extra to fulfill the workload, creating further fatigue and stress for those coworkers which leads to further increase in absenteeism. The U.S. loses an equivalent of 1.23 million working days annually due to fatigued employees (Hafner et al., 2016).

The Construction Industry

Construction Industry Fatalities

In 2015, there were 4,836 fatal on-the-job injuries to U.S. workers, 937 of those occurred in the construction industry (see Table 1) (U.S. Bureau of Labor Statistics [BLS], 2016). The fatal injury rate in the private construction industry rose four percent from 2014 to 2015. The total of fatal injuries in 2015 was the highest since 2008. Construction is a very large, dynamic and complex industry with multi-layers of safety issues that are reflected in the number of fatal occupational injuries experienced in 2014 and 2015 (Table 2).

Table 2

U.S. Bureau of Labor Statistics Fatal Occupational Injuries Count and Rates 2014 -2015

	Total Count		Rates %	
	2014	**2015**	**2014**	**2015**
Industry Total	4,821	4,836	3.4	3.4
Agriculture, forestry, fishing and hunting	584	937	9.8	10.1
Mining, quarrying, and oil and gas extraction	183	120	14.2	11.4
Construction	899	937	9.8	10.1

Note: Fatal injury rates are per 100,000 full-time equivalent U.S. workers (FTEs).
Summary of data copied verbatim from Table 4, U. S. Department of Labor, Bureau of Labor Statistics (BLS), 2016.

Fatigue and Sleep Deficiency in Construction

Construction workers are inclined to fatigue due to the physical nature of the work, heavy workloads, awkward working postures, varying weather conditions and extended work hours. Dong (2005) studied the "connection between work hours and safety outcomes among construction workers" (p. 321, Abstract, Objectives) and reported the fatiguing factors of overtime and schedules with irregular hours had an unfavorable outcome on employee safety. The impact of fatigue for workers on construction sites may be more serious where the work environments are always changing due to the number of people on the site from day to day, mandatory overtime due to deadlines, inclement weather, and progress of the work, materials, equipment and vehicles onsite lend to the increase of worker fatigue (Pinto, Nunes, & Ribeiro, 2011). Because construction companies may be regional or interstate entities, construction

workers may have long commute times before and after work depending on the jobsite location that may add to their individual risk.

Methods

This manuscript focused on the consequences of sleep deprivation for individuals in the workplace with a concentration on the construction industry. Through the review the academic literature and the gray literature, consequences and physiological effects of fatigue and sleep deficiency in the occupational setting were evaluated. A systematic search and review for peer-reviewed articles was conducted with the assistance of Wright State University (WSU) librarian Bette Sydelko using available academic literature databases through WSU to search for interventions, policies, standards and/or recommendations to help reduce fatigue in the workplace. All of the databases through *Current Index Nursing and Allied Health Literature (CINAHL) Plus with Full Text* (https://health.ebsco.com/products/the-cinahl-database) were searched. Search terms were chosen based on the author's professional knowledge of occupational safety and health and the review of academic literature conducted for the background section of this project. Search terms that were included using Boolean/Phrase were: (* indicates any derivative of the term)

(Sleep depriv* OR fatigue)
AND (safety)
AND (accident* OR injur*)

Articles collected for the background were also assessed for sleep policies, standards, regulations or recommendations for occupations or employers to handle worker sleep deprivation. Figure 3 illustrates the process of the literature search and selection.

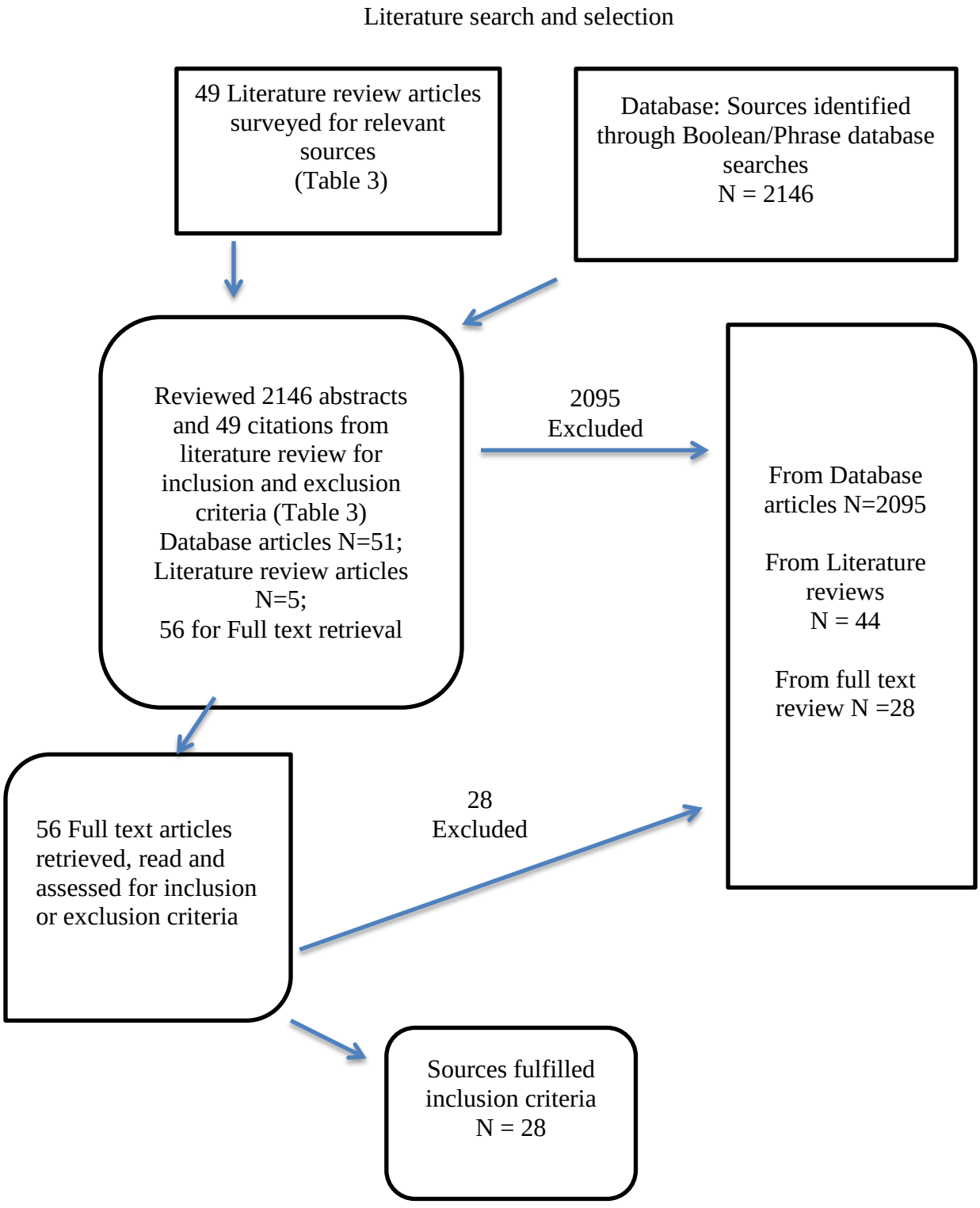

Figure 3. Literature search methods.

Abstract Review

The abstracts for the articles retrieved from the background search were screened for inclusion criteria and exclusion criteria (see Table 3). These criteria narrowed the focus to the issues of fatigue and sleep deprivation in the workplace. If an article met the inclusion criteria, it was marked and stored for download and further review. If an article did not meet the inclusion criteria, it was excluded.

Table 3

Inclusion and Exclusion Criteria for Articles Identified in Systematic Search

Article Inclusion Criteria
• English language • Relevant to overtime and/or extended shifts and/or long work hours and/or shift work • Full text available through Wright State University Library services or Google web search • Contained control interventions for fatigue or sleep deprivation: policy, standards, regulations or recommendations

Article Exclusion Criteria
• Non-English language • Studies or information in the article did not pertain to U.S. workers • Overtime and/or extended shifts and/or long work hours and/or shift work, and fatigue, sleep disorders, sleep deficiencies and/or sleep deprivation were not part of the article content. • Full text was not available through Wright State Library services or Google • Article did not offer any policies, standards, regulations or recommendations to control fatigue or sleep deprivation in the workplace.

Article Review

Articles that met inclusion criteria were marked and downloaded directly from the WSU library website, or requested via the WSU Interlibrary Loan service. Resources used for the background and identified through the database searches were screened for sleep management

content related to policies; and standards, regulations or recommendations for management of workers' sleep problems.

Selection Process Results

The database searches identified 2,146 publications for initial review as noted in Figure 3. A total of 51 articles met the inclusion criteria and were retrieved for further assessment, 2,095 met the exclusion criteria and were excluded. Twenty-three of the 51 inclusion articles met inclusion criteria and were included in this review. Forty-nine literature review articles were also assessed for inclusion and exclusion criteria, five of these articles met the inclusion criteria. Twenty-eight full articles were assessed for policies, regulations, standards or recommendations to reduce workplace fatigue or sleep deficiency. Of the 28 articles assessed, there were only three articles that contained relevant content on construction that gave recommendations on fatigue and sleep management.

Safety and productivity are closely linked to worker health in the workplace. Worker fatigue has been shown to have an impact on health, safety, and productivity. Employees that acquire adequate rest and sleep are more alert, which is significant to maintaining safe and productive operations. The following recommendations were gathered from the 28 articles that met the selection criteria for review. Recommendations that were repeatedly seen in the 28 articles included naps; policy on amount of hours worked, length of hours worked, and shift work; required breaks; fatigue management; and education or training on sleep and fatigue, as shown in Table 4.

Table 4

Articles on Sleep Deprivation in the Workplace and Offered Recommendations

Citation	**Setting**	**Title**	**Literature Type**	**Recommendations, Countermeasures and 'Take home messages'**
Anderson, Grunstein, & Rajaratnam, 2013	Rail Industry	Hours of Work and Rest in the Rail Industry	Original data analysis	Regulatory framework for fatigue, set hours of work and rest, sleep disorder management program, and an FRMS[1]
J. E. Anderson, Goodman, Jensen, Salcedo, & Galante, 2017	Health Care	Restrictions on surgical resident shift length	Literature review	Implementing "Flexible" hours to avoid multiple night shifts in a row or cross-cover of patients
J. R. Anderson, Ogden, Cuningham, & Schubert-Kabban, 2017	Transportation	An Exploratory Study of Hours of Service and its Safety Impact	Literature review	Better enforcement of transportation regulations beyond HOS[4]. Recommend reviewing and mirroring how other occupational fields deal with and handle fatigued workers
Apostolopoulos, Sönmez, Shattell, & Belzer, 2010	Transportation	Worksite Induced Morbidities Among Truck Drivers in the US	Critical literature review	Modify behaviors to increase personal health of truckers, accessible health care and wellness programs at truck terminals, discounts and availability of healthier food choices, education on good sleep hygiene
Chan, 2011	Construction	Fatigue: The Most Critical Accident Risk in Oil and Gas Construction	Original data analysis	Implement FRMS[1]
Darwent, Dawson, & Roach, 2012	General Industry /Shiftwork	Predictive model to monitor shiftworker sleep/rest behaviors in the management of fatigue-related risk in industrial settings	Cohort study	Use of BMMF[2] to predict estimated levels of alertness and potential safety consequences of shiftwork schedules
Dawson, Noy, Härmä, Åkerstedt, & Belenky, 2011	General Industry and Construction	Modeling Fatigue and the Use of Fatigue Models	Literature review	Use of BMMF[2] to predict fatigue and risks quantitatively to correlate with pre-existing global standards in risk management
Dembe, 2009	Health care workers Public Health	Ethical Issues Relating to the Health Effects of Long Working Hours	Literature review	Restrict long hours of work through scheduling guidelines to ensure adequate rest between shifts

Table 4 Cont'd

Articles on Sleep Deprivation in the Workplace and Offered Recommendations

Citation	**Setting**	**Title**	**Literature Type**	**Recommendations, Countermeasures and 'Take home messages'**
Douglass, 2014	Healthcare	Overextended: Fighting the Fatigue of Long Shifts	Literature review	Countermeasures to identify and manage fatigue, rest breaks and naps, work environment lighting and temperatures, teamwork to identify fatigued co-workers
Fang, Zhongming, Zhang, & Wang, 2015	Construction	An Experimental Method to Study the Effects of Fatigue on Construction Workers' Safety	Experimental study	Use FASCW[3] to identify tasks causing fatigue and safety management to manage those tasks
Gander et al., 2011	Transportation	Industry and company organizational factors that can impact fatigue in transportation	Literature review	Implementation of FRMS[1] to minimize safety hazards for the transport sector
Geiger-Brown & Trinkoff, 2010	Health Care	Is It Time to Pull the Plug on 12-Hour Shifts?	Position paper	Provide uninterrupted breaks; schedule more demanding tasks during day shifts; planned on-site naps for night shift workers
Golden & Jorgensen, 2002	All Occupations	Time After Time: Mandatory Overtime in the US Economy	Literature review	Legislation to ban or limit mandatory overtime; cap number of overtime hours per week/two week period, make overtime more voluntary
Hafner, Stepanek, Taylor, Troxel, & van Stolk, 2016	All Occupations	Why sleep matters – the Economic Costs of Insufficient Sleep.	Literature review	Recognition of sleep importance and its promotion by employers through sleep facilities, snooze-friendly policy, brighter workplaces, minimize variability in working hours
James & Vila, 2015	Law Enforcement	Police: Drowsy Driving Predicting Fatigue	Original data analysis	Identify fatigue indicators to establish self-warning signs of degraded driving, designate post-shift napping room, provide rides home for overly drowsy officers, training on fatigue challenges

Table 4 Cont'd

Articles on Sleep Deprivation in the Workplace and Offered Recommendations

Citation	**Setting**	**Title**	**Literature Type**	**Recommendations, Countermeasures and 'Take home messages'**
Kao, Spitzmueller, Cigularov, & Wu, 2016	Industrial Occupations	Linking Insomnia to Workplace Injuries	Original research	Supervisors' influence company culture to reduce negative effects of inadequate sleep and lead the change by implementing company policies on sleep management
Kenny, Groeller, McGinn, & Flouris, 2016	Industrial Occupations (Aging workforce)	Age, Human Performance and Physical Standards Older employees Fatigue faster	Literature review	Work schedules that limit or avoid night shifts for older workers
Kushner & Ruffin, 2015	Nurses	Empowering a Healthy Practice Environment	Case studies	Balance work, home life and personal health with schedules to allow for adequate rest, include sufficient staffing, allow for naps on extended shifts
Lerman et al., 2012	All Occupations	Fatigue Risk Management in the Workplace	Literature review	Employer and employees use FRMS[1] to assuage fatigue risk in shift work and 24/7 operations
Lockley et al., 2007	Health care	Effects of Health Care Provider Work Hours	Literature review	Safe work hours need to be established and enforced
Mansukhani, Kolla, Surani, Varon, & Ramar, 2012	Health care	Sleep Deprivation in Resident Physicians	Literature review	Institute 80 hour per week work limitations, with duty periods no longer than 16hrs.
Mathisen & Bergh, 2016	Oil and Gas industry	Action Errors and Rule Violations at Offshore Oil Rigs: The Role of Engagement, Emotional Exhaustion and Health Complaints.	Original analysis of survey data (N = 653)	Risk management of environmental work factors for fatigued workers
Nelson, 2014	Health care	Can a Nurse be Worked to Death?	Case report and discussion	Education and training on signs of drowsy driving and countermeasures, promotion of safe commuting, provide room for naps
Reed, 2013	Health care	Nursing Fatigue and Staffing Costs: What's the Connection?	Literature review	Employers and employees design schedules and organize work to reduce nurses' fatigue, education on sleep hygiene

Table 4 Cont'd

Articles on Sleep Deprivation in the Workplace and Offered Recommendations

Citation	**Setting**	**Title**	**Literature Type**	**Recommendations, Countermeasures and 'Take home messages'**
Roach, Sargent, Darwent, & Dawson, 2012	Aviation	Early Start Times Restrict the Amount of Sleep	Case study	Implement an FRMS[1] for short-haul pilots required to work early-morning shifts
Trossman, 2015	Health care	More than Just Tired: Nurses, Employers should Work Together to Reduce Fatigue, its effects	Position paper	Employers and nurses address fatigue through scheduling practices, implement educational series to cover fatigue and prevention
Violanti et al., 2012	Law enforcement	Shift Work and the Incidence of Injury Among Police	Original research	Use prediction models to predict times of greatest injury and alter schedules accordingly, establish rotation through high activity areas
Yong, Li, & Calvert, 2017	General Industry	Sleep Related Problems in the US Working Population	Original research	Customized work-based prevention programs and policies to improve the quantity and quality of sleep among employees.

Notes: 1 FRMS - Fatigue Risk Management System; 2 BMMF Bio-Mathematical Models of Fatigue; 3 FASCW - Fatigue Assessment Scale for Construction Workers; 4 HOS - Hours of Service. Critical Review – Literature extensively researched and its quality critically evaluated.

Countermeasure Results

Articles reviewed covered different work settings, topics and interventions. A brief description of the four core countermeasures seen repeatedly in the articles are listed in Table 5.

Table 5

Summary of Four Core Countermeasures for Sleep Deprivation in the Workplace

Study	Countermeasure	Description
J. E. Anderson et al., 2017; Douglass, 2014; Geiger-Brown & Trinkoff, 2010; Hafner et al., 2016; James & Vila, 2015; Kushner & Ruffin, 2015; Lerman et al., 2012; Lockley et al., 2007; Mansukhani et al., 2012; Nelson, 2014; Trossman, 2015; Violanti et al., 2012; Yong et al., 2017	Naps and breaks during long/extended work hours, night shifts or shift work	• Institute nap policies for extended shifts • Provide a space for breaks and/or naps separate from the work area • Policy for uninterrupted breaks and naps during night shifts and extended shifts
Anderson et al., 2013; J. E. Anderson et al., 2017; J. R. Anderson et al.,2017; Apostolopoulos et al., 2010; Dembe, 2009; Douglass, 2014; Geiger-Brown & Trinkoff, 2010; Golden & Jorgensen, 2002; Hafner et al., 2016; Kushner & Ruffin, 2015; Lockley et al., 2007; Mansukhani et al., 2012; Nelson, 2014; Reed, 2013; Trossman, 2015; Violanti et al., 2012	Policy Recommendation for amount of hours worked, length of hours worked, overtime, shift work schedules, night shifts	• Limit amount of overtime hours worked in a week • Limit mandatory overtime or establish stipulations for mandatory overtime • Shift times 12 hours or less
Anderson et al., 2013; J. R. Anderson et al., 2017; Apostolopoulos et al., 2010; Chan, 2011; Darwent et al., 2012; Dawson et al., 2011; Dembe, 2009; Douglass, 2014; Fang et al., 2015; Geiger-Brown & Trinkoff, 2010; Golden & Jorgensen, 2002; Hafner et al., 2016; James & Vila, 2015; Kao et al., 2016; Kenny et al., 2016; Kushner & Ruffin, 2015; Lerman et al., 2012; Mathisen & Bergh, 2016; Nelson, 2014; Roach et al., 2012; Yong et al., 2017	Fatigue Risk Management System (FRMS)	• Employers implement FRM to identify fatigue-causing tasks, establish guidelines for these tasks to reduce fatigue • Employers and employees follow established FRM procedures
Anderson et al., 2013; Apostolopoulos et al., 2010; Fang et al., 2015; Golden & Jorgensen, 2002; Hafner et al., 2016; Kao et al., 2016; Kenny et al., 2016; Kushner & Ruffin, 2015; Lerman et al., 2012; Lockley et al., 2007; Mansukhani et al., 2012; Nelson 2014; Trossman, 2015; Yong et al., 2017	Education on and self-management of fatigue	• Provide training on signs and risks of sleep deprivation and over tiredness • Good sleep hygiene: dark bedrooms, eliminate electronic use before bed, no television or electronic use in bed, dark and quiet bedroom, and set bedtime

Naps and Breaks

A number of authors discussed naps and breaks (Anderson, Goodman, Jensen, Salcedo, & Galante, 2017; Douglass, 2014; Geiger-Brown & Trinkoff, 2010; Hafner et al., 2016; James & Vila, 2015; Kushner & Ruffin, 2015; Lerman et al., 2012; Lockley et al., 2007; Mansukhani, Kolla, Surani, Varon, & Ramar, 2012; Nelson, 2014; Trossman, 2015; Violanti et al., 2012; Yong et al., 2017). The following is a summary of their consensus recommendations.

While many employers offer rest breaks in good practice and through contractual agreement with employees, according to the U.S. Department of Labor, "Federal law does not require lunch or coffee breaks" during an employee work shift (U.S. Department of Labor [DOL], n.d.a, Breaks and Meal Periods, first sentence). The FLSA addresses wages and work hours does not require employers a to provide meal periods or rest breaks for their employees (DOL, n.d.b, FLSA Hours Worked Advisor). Nine states (California, Colorado, Illinois, Kentucky, Minnesota, Nevada, Oregon, Vermont, and Washington) have laws requiring employers to offer employees rest breaks (DOL, 2017). These state laws prevail over the FLSA on this subject. The Occupational Health & Safety Administration also does not have a standard specifically addressing employee breaks (OSHA, 2006).

In the sections below, opinions and suggested recommendations from authors of articles included in Table 5 for the countermeasure *Naps and breaks during long work hours, night shifts or shift work* are summarized for health care providers; law enforcement; and shift work.

Naps and breaks for healthcare providers. Several authors address naps and breaks for healthcare providers (e.g., Dembe, 2009; Douglass, 2014; Geiger-Brown & Trinkoff, 2010; Kushner & Ruffin, 2015; Nelson, 2014). Nurses, medical residents and administrators should work together to establish guidelines to recognize signs of fatigue from working long shifts.

Healthcare employers are encouraged to address employees fatigue while at work by providing rooms for rest breaks and naps during extended work shifts, especially night shifts. Over-tired healthcare providers experience a higher prevalence of medical errors and judgment in patient care, near misses and personal injuries during a long shift or a night shift, as well as when driving home. Developing a policy for scheduled naps and providing a quiet room for rest breaks and naps can be a countermeasure to reduce fatigue, which can benefit workers, patients and the public.

Naps and breaks for law enforcement. In addition to the articles recommending naps and breaks for all occupations and shift workers, James and Vila (2015) specifically focus on law enforcement. Police working extended shifts and/or night shifts experience increased drowsiness, a decrease in driving performance, and their likelihood of automotive collisions increase. State and local law enforcement agencies require training to improve workplace driving safety but hopefully will include drowsy driving in their training. A countermeasure that has been suggested is setting up a post-shift napping room, or providing a ride home for over drowsy officers.

Naps and breaks for shift work. Shift work is a feature of nearly all articles recommending naps and breaks to address fatigue and sleep deprivation. Brief scheduled nap breaks during extended-shifts and night shifts can be an effective countermeasure to sleep deprivation. By implementing structured nap breaks, employee alertness, judgment, and physical performance can be improved, reducing possible mistakes and accidents or injuries. To help address fatigue, companies may encourage employees to take a brief nap if they are demonstrating signs of sleep deprivation. Napping could be helpful to supplement sleep for shift workers, especially on night shifts. Scheduling rest breaks and naps should be done at certain

times to enhance alertness. Staffing must be adequate to cover the operations during times scheduled for naps and rest breaks to ensure employees' breaks are not interrupted. Employers could reduce risk of employee automobile accidents by providing nap opportunities at the end of long shifts.

Policies Limiting Hours Worked and Shift Work Variability

The sections below provide summaries of opinions and recommendations from the systematic search and review articles related to the countermeasure of controlled scheduling, listed in Table 5 as *Policy recommendation for amount of hours worked, length of hours worked, overtime, shift work schedules, night shifts* (Anderson et al., 2013; J. E. Anderson et al., 2017; Anderson, Ogden, Cuningham, & Schubert-Kabban, 2017; Apostolopoulos, Sönmez, Shattell & Belzer, 2010; Dembe, 2009; Douglass, 2014; Geiger-Brown & Trinkoff, 2010; Golden & Jorgenson, 2002; Hafner et al., 2016; Kushner & Ruffin, 2015; Lockley et al., 2007; Mansukhani et al., 2012; Nelson, 2014; Reed, 2013; Trossman, 2015; Violanti et al., 2012). Topics in this section include the number of hours worked and overtime, number of hours worked in a single shift, and shift work, especially alternating shifts and night shifts.

Overtime/Long Shifts. Continuously working overtime over periods of weeks or months can have an unfavorable effect on the worker, their co-workers, their families, and the public. When a worker works overtime, sleep is often neglected instead of family and other outside interests (Golden & Jorgenson, 2002).

Compensation for working overtime is overtime pay or compensatory time (time off at a later date). Under FLSA, eligible employees are entitled to additional pay (overtime pay) of at least 150 percent of the regular rate for the hours worked over 40 in a seven-day workweek (Dembe, 2009). The FLSA imposes no limits on overtime hours for workers aged 16 years and

over (Golden & Jorgenson, 2002; DOL, n.d.c).

Overtime may be voluntary, wanted, or mandatory. The FLSA does not prohibit employers from firing employees that refuse to work established work shifts or mandatory overtime (Golden & Jorgenson, 2002). At this time, employees have no federal recourse protection from employer retaliation if they refuse mandatory overtime.

Legislative initiatives at federal and/or state levels could be created to regulate mandatory overtime and address the public health issue of worker fatigue and sleep deficiency. Updating the provisions of the FLSA could set minimum limits on overtime. The literature recommends that provisions for upper limits of overtime in a week, along with the rights of employees to refuse mandatory overtime without termination by employer should be reviewed.

Transportation. The Federal Motor Carrier Safety & Administration ([FMCSA] 2017) addresses truck driver fatigue by implementing the Hours of Service (HOS) policy that restricts the number of hours that truck drivers can operate their vehicles (driving hours) and be on active duty. The goal of the HOS was to reduce truck driver fatigue while on the road and therefore reduce the number of fatigue-related automobile accidents.

Work-related Accidents. Fatigue-related motor vehicle accidents and medical errors and injuries have a higher occurrence among health care workers working extended hour shifts (12.5 hours or more by nurses and 24 to 30 consecutive hours by residents). By establishing and enforcing safe work hour limits, it is expected that this morbidity and mortality can be reduced or prevented and benefit providers, patients and the public. However, Anderson, Goodman, Jensen, Salcedo, & Galante (2017) reported there was not a consistent association between the longer resident physician shifts and preventable medical errors due to fatigue. Note that more research must be done to fully evaluate the impact of these policies.

Data from an investigation of 12, 686 U.S. construction workers (Dong, 2005) showed that the number of accidents and injuries reported was doubled on a 12-hour shifts compared to workers working eight-hour shifts, and 3.5 times higher for shifts 16 hours and longer (Anderson et al., 2013). Consensus recommendations call for implementing regulatory frameworks to limit the hours of work and ensure rest opportunities, including maximum shift duration, and controlling/limiting the number of successive shifts worked. The literature also notes that employers should respect employees' days off to allow for adequate rest and away time from work.

Changing Shifts. The literature indicates that an intervention that may lead to positive sleep outcomes would be scheduling structures that minimize variability in shift hours (not changing shifts week to week). Additionally, employers are encouraged to offer flexible work schedules to help alleviate stress of employees with conflicts between work and family responsibilities; in turn this could reduce stress-related sleep deficiency.

Fatigue Risk Management System (FRMS)

A workplace where the safety culture is positive and valued by all levels of management can enhance worker health and wellbeing at work and at home. The systematic search and review identified a number of articles that supported the countermeasure of an *FRMS* (Anderson et al., 2013; J. R. Anderson et al., 2017; Apostolopoulos et al., 2010; Chan, 2011; Darwent et al., 2012; Dawson, Noy, Härmä, Åkerstedt, & Belenky, 2011; Dembe, 2009; Douglass, 2014; Fang, Zhongming, Zhang, & Wang, 2015; Geiger-Brown & Trinkoff, 2010; Golden & Jorgensen, 2002; Hafner et al., 2016; James & Vila, 2015; Kao et al., 2016; Kenny, Groeller, McGinn, & Flouris, 2016; Kushner & Ruffin, 2015; Lerman et al., 2012; Mathisen & Bergh, 2016; Nelson, 2014; Roach, Sargent, Darwent, & Dawson, 2012; Yong et al., 2017). The inclusion of an

FRMS in the workplace can benefit the overall health, safety and productivity of the employees. An FRMS is "a system to manage risk associated with fatigue" (Lerman et al., 2012, p. 233). Further, it is:

> …*a data-driven means of continuously monitoring and maintaining fatigue related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness* (International Civil Aviation Organization [ICAO], 2012, p. 1).

An FRMS can be tailored to fit the needs of the company to assist in reducing worker fatigue. It is not as rigid as a blanket policy of required work and rest periods or hours-of-service regulations. Lerman and colleagues (2012) state that FRMS may include:

1. Fatigue management policy;
2. Fatigue risk management, including collecting information on fatigue as a hazard, analyzing its risk, and instigating controls to mitigate that risk;
3. Fatigue reporting system for employees;
4. Fatigue incident investigation;
5. Fatigue management training and education for employees, management (and families);
6. Sleep disorder management; and
7. A process for the internal and external auditing of the FRMS that delivers corrective actions through a continuous improvement process.
   (verbatim from Lerman et al., 2012, p. 234)

Except in select American industries (e.g., the transportation industry), there is inadequate federal and industry leadership support for policies mandating FRMS to protect vulnerable workers, The Federal Railroad Administration ([FRA] 2006), the Federal Aviation Administration ([FAA] 2010), and the National Transportation Safety Board ([NTSB] 2013) all require implementation of an FRMS program. In the U.S., there are OSHA regulatory codes to ensure that employers protect workers' health and safety. However, none of these guidelines or

regulations pertains to worker fatigue or sleep deficiency. Fatigue *can* and *should* be managed like traditionally recognized safety hazards.

Education on Fatigue/Self-management of Fatigue

A general theme shared by the articles identified by the systematic search and review (Anderson et al., 2013; Apostolopoulos et al., 2010; Fang et al., 2015; Golden & Jorgensen, 2002; Hafner et al., 2016; Kao et al., 2016; Kenny et al., 2016; Kushner & Ruffin, 2015; Lerman et al., 2012; Lockley et al., 2007; Mansukhani et al., 2012; Nelson, 2014; Trossman, 2015; Yong et al., 2017) is that employers need to recognize the importance of sleep and their role in promoting good sleep hygiene in their employees. This is reflected in Table 5 as *Education on and self-management of fatigue*. Employers should offer educational programs on the risk factors of fatigue, the impact on the mind and body; strategies to reduce and address fatigue. Good sleep hygiene habits and practices should be included in regular employee-sponsored safety training programs. The CDC's (2017) *Basics about Sleep* lists good sleep habits as those habits that can improve one's sleep. The list is shown in Figure 4.

- Be consistent. Go to bed at the same time each night and get up at the same time each morning, including on the weekends
- Make sure your bedroom is quiet, dark, relaxing, and at a comfortable temperature
- Remove electronic devices, such as TVs, computers, and smart phones, from the bedroom
- Avoid large meals, caffeine, and alcohol before bedtime
- Get some exercise. Being physically active during the day can help you fall asleep more easily at night.

Figure 4. Selected recommendations for better sleep. Listed verbatim from CDC, 2017, https://www.cdc.gov/sleep/about_sleep/sleep_hygiene.html (Tips for better sleep).

Discussion and Recommendations

Considering the growing number of individuals experiencing insufficient sleep and the health impacts and economic costs, it is time to change how fatigue and sleep deficiency are handled in the American workplace. Employers and individuals must take active roles to reduce this public health epidemic.

In current practice, employees involved in workplace accidents are more likely to be screened for substance use than for fatigue or sleep deficiency. For example, The Ohio Revised Code, Title I (State Government) requires drug-free workplace programs for any employers contracted to do public improvement work (Public Improvements Act, Ohio Revised Code §§ 153.03, 2007). There are no federal or state laws or standards that require other employers to implement a Drug Free Safety Program (DFSP) (Substance Abuse and Mental Health Services Administration, 2015).

The National Highway Traffic Safety Administration (NHTSA) (2016) implemented a sleep strategic plan in 2016 to determine the public's attitudes and knowledge in regards to sleep deficiency and drowsy driving. Public education on drowsy driving is essential to support NHTSA's program to reduce traffic accidents caused by drowsy drivers. Most Americans are not aware of this major issue: sleepiness is just accepted as the 'American way'. It therefore comes as no surprise that most American workers currently receive no significant training and education on the importance of sleep, sleep disorders and consequences of sleep deprivation. Employers are in a position to implement policies that promote adequate sleep, provide employee education on sleep and how to avoid fatigue-related safety incidents. The adverse effects of sleep deprivation on both workers' safety and health and the profitability to employers was brought to light in the background research of this study.

Each year, there are more than 4,000 fatal occupational injuries occurring in the U.S. The construction industry had the third highest number of fatal occupational injuries to civilian workers of all major occupation groups in 2015 (BLS, 2016). Construction workers may have longer commutes, work multiple days and long hours to keep completion on schedule, and work in extreme environments, all of which add to their fatigue levels.

Currently there are no federal standards or policies on the amount of time individuals can work (DOL, 2016). Public health professionals must engage industry leaders and help them recognize that sleep-deprived employees are a danger to themselves, their co-workers, the public, and to the job. The FAA, FRA, FMCSA and the NHTSA are some organizations that have already reached this level of recognition. The first step is recognizing− at the professional level− that sleep deprivation is a workplace problem, then determine actionable means to address the problem in the workplaces. To determine the extent of the problem, the literature recommends that employers conduct workplace sleep hygiene screenings through questionnaires to help discover employees with sleep issues. Referrals for individual sleep studies could then be made for those employees experiencing severe sleep issues.

Employers should incorporate sleep deprivation awareness into employee training. Educational awareness on the signs and symptoms of sleep deprivation and steps individuals can take son their own to reduce or eliminate the problem could be a minimal approach to the problem.

Being sleep deprived could be part of the cause for the number of fatalities and injuries experienced by the construction industry (Dong, 2005). Given the standard use of electronic employee work records, a feasible recommendation is to track hours worked by employees, and set limits for employees to work in a 24-hour period and for the workweek. Tracking injuries

and accidents with the number of hours worked can help identify trends and where to focus attention for employee safety in individual workplaces and industries.

Study Strengths and Limitations

This study used the term "deprivation" in regards to all sleep issues that encompass cumulative effects of sleeping less than seven hours a night, including poor quality of sleep due to environment, distractions, and/or time of day sleep takes place; and/or sleep disorders such as sleep apnea that prevent sufficient quality sleep. Based on the NHBLI (2017) definition, sleep deprivation is the lack of enough sleep, whereas deficiency encompasses quality and quantity of sleep. Sleep deficiency is a better term to use since the definition is broader and more encompassing and will incorporate more fatigue related risks and instances.

Fatigue and its negative impact on individuals' health and safety, whether personal life or in the workplace has been under study dating back to the turn of the 20th century, with Edward Thorndike's early studies (Noy et al., 2011). Early studies on the effects of sleep deprivation, sleep-wake cycles, and circadian rhythms were conducted in the early 1920's by Nathaniel Keitman (Noy et al., 2011). From research gathered for this study it was evident that awareness of the problem of fatigue and sleep deficiency has increased over the last 20 to 30 years. There is a better understanding of the physiology of sleep and the circadian cycles as well as the physical and mental effects on individuals. Continued research on technologies to monitor and identify fatigued workers is a promising means for employers to gain control over fatigue risks. In some developing countries (outside the U.S.) fatigue is seen as a hazard, just like other acknowledged workplace safety hazards, under their Occupational Health and Safety legislation organizations/employers are required to develop and implement an FRMS to address the fatigue

issue (Dawson, 2012). Despite the history of studying fatigue and the numerous literature on the topic of its negative affect on safety it remains a concern.

Implications for Construction

The construction industry faces challenges such as multiple worksites; shortage of skilled and general labor; and overworked foremen and superintendents, which can adversely affect the implementation of an FRMS or any type of extra training requirements. Safety and quality should not be sacrificed for the sake of production. All three are important and dependent upon each other.

Summary of Countermeasures

Based on the findings of this research there is a need for increased awareness on the negative effects fatigue and sleep deficiency have on the body and in the workplace. Awareness training on these effects and on good sleep hygiene behaviors is one countermeasure to help reduce Americans' sleep problem. Review of work schedules, work demands and when injuries or accidents occur; reorganization of the shifts, work hours and breaks can be determined for the best productivity and reduced risks of work fatigue and fatigue related accidents. Implementation of policies in regards to maximum hours worked in a week as well as adequate breaks and rest periods may advance the movement to reduce worker fatigue. By incorporating an FRMS employers can manage the issue of fatigue by tailoring a program that best fits the needs of the company and its employees. Implementation of an FRMS would incorporate all of the suggested countermeasures of fatigue cited in this research.

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Appendix A: List of Competencies Met in CE

Wright State Program Public Health Competencies Checklist

Assess and utilize quantitative and qualitative data.
Apply analytical reasoning and methods in data analysis to describe the health of a community.
Describe how policies, systems, and environment affect the health of populations.
Communicate public health information to lay and/or professional audiences with linguistic and cultural sensitivity.
Engage with community members and stakeholders using individual, team, and organizational opportunities.
Make evidence-informed decisions in public health practice.
Evaluate and interpret evidence, including strengths, limitations, and practical implications.
Explain public health as part of a larger inter-related system of organizations that influence the health of populations at local, national, and global levels.

Concentration Specific Competencies Checklist

Emergency Preparedness:
Demonstrate the mastery of the use of principles of crisis and risk management
Demonstrate an understanding of the protection of worker health and safety