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Health effects associated with occupational exposure to hand-arm or whole body vibration

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ABSTRACT

Workers in a number of different occupational sectors are exposed to workplace vibration on a daily basis. This exposure may arise through the use of powered-hand tools or hand-transmitted vibration (HTV). Workers might also be exposed to whole body vibration (WBV) by driving delivery vehicles, earth moving equipment, or through use of tools that generate vibration at low dominant frequencies and high amplitudes, such as jackhammers. Occupational exposure to vibration has been associated with an increased risk of musculoskeletal pain in the back, neck, hands, shoulders, and hips. Occupational exposure may also contribute to the development of peripheral and cardiovascular disorders and gastrointestinal problems. In addition, there are more recent data suggesting that occupational exposure to vibration may enhance the risk of developing certain cancers. The aim of this review is to provide an assessment of the occupations where exposure to vibration is most prevalent, and a description of the adverse health effects associated with occupational exposure to vibration. This review will examine (1) various experimental methods used to measure and describe the characteristics of vibration generated by various tools and vehicles, (2) the etiology of vibration-induced disorders, and (3) how these data were employed to assess and improve intervention strategies and equipment that reduces the transmission of vibration to the body. Finally, there is a discussion of the research gaps that need to be investigated to further reduction in the incidence of vibration-induced illnesses and injuries.

KEYWORDS
Occupational sector; hand-arm vibration syndrome; musculoskeletal

Introduction

Workers may be exposed to occupational vibration through the use of power or pneumatic hand tools or other machinery, or by driving large transportation, construction or agricultural vehicles. Vibration that is generated through the utilization of powered hand tools, and is transmitted from the tool to the hand-arm system is referred to as hand-transmitted vibration [HTV) (Griffin 1996)]. However, several studies also demonstrated that vibration might be transmitted through platforms workers are standing on, and in these situations, the point of contact is the feet (Eger et al. 2014; House et al. 2011; Thompson et al. 2010). Workers might also be exposed to whole body vibration (WBV), which occurs in occupations where workers are driving trucks, large earth moving vehicles, or where hand tools are being employed or in conditions where amplitude of the vibration is sufficient to be transmitted to other portions of the body, such as in workers using jack-hammers (Bovenzi 2010a, 2010b, 2015; Griffin 2004, 2015; Huang and Griffin 2014).

Exposure to WBV is of concern within the workforce because this condition is associated with development of a number of adverse health consequences including back and neck pain (Basri and Griffin 2013; Beard and Griffin 2016; Bovenzi 1996, 2010a, 2010b, 2015; Bovenzi et al. 1991; Charles et al. 2018; Du et al. 2018; Palmer et al. 2012), and potentially, cardiovascular disease (Bovenzi 1990; Hering, Lachowska, and Schlaich 2015), development of various neuropathies (Bovenzi et al. 2004, 2011a; Stoyneva 2016; Stoyneva et al. 2016), digestive problems (Bovenzi 2005, 2006; Ronchese and Bovenzi 2012), headaches, dizziness, motion sickness (Butler and Griffin 2009; Donohew and Griffin 2010; Griffin and Newman 2004; Haward, Lewis, and Griffin 2009; Howarth and Griffin 2003; Joseph and Griffin 2007; Webb and Griffin 2003) and possibly cancer (Jones et al. 2014; Nadalin et al. 2012; Waugh et al. 2016; Young et al. 2009). However,

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workers exposed to WBV are often also subjected to a number of other risk factors that may contribute to the development of these adverse health effects. These risk factors include maintaining a static posture for a long period of time (Antle et al. 2018; Tachi et al. 2004), torque or twisting of the abdomen to view the area around the vehicle (Palmer et al. 2008), and heavy lifting that often occurs when a vehicle is loaded or unloaded (Palmer et al. 2012, 2008). In addition to vibration and physical exposures associated with a job, there may be other co-exposures to chemicals or certain environmental conditions that contribute to the development of disease or injury in workers. Because most workers are exposed to multiple factors that may produce injury or illness, it is difficult to determine which factors pose the greatest risk for inducing injury or illness. Experimental studies examining the effects of each of these factors individually on health outcomes provide additional information that might help determine the contribution of each exposure factor to various health problems.

This review describes the industrial sectors where vibration exposure is most prevalent and the adverse health effects associated with exposure to HTV and WBV. Experimental methods used to measure and characterize vibration generated in various occupational settings are discussed, along with the models that were employed to uncover the etiology of vibration-induced injuries. Although numerous studies have been published on both HTV and WBV, there are new epidemiological studies showing an increased risk of specific cancers associated with exposure to WBV. In addition, there are now more women entering professions where these individuals will be subjected to vibration as part of their employment. Therefore, this review provides data on the number of women working in occupations where they may be exposed to vibration, and there is a discussion of how these situations may affect the health of both males and female working in these sectors.

Occupational exposures to vibration

Transportation, Warehousing And Utilities (TWU)

Workers in the TWU sector make up approximately 3.2% of the workforce. The individuals in this industry transport goods and passengers by air, road, rail, and water. In 2015 approximately 774,900 workers (or 22.3% of all workers in the TWU industry) missed days of work because of injury or illness (Bureau of Labor Statistics (BLS), 2016). Common injuries and illnesses for workers in this sector include back, neck and shoulder pain, headaches and dizziness, motion sickness, and gastrointestinal, cardiovascular and peripheral sensory problems (Bovenzi 1996, 2005; Hulshof et al. 2006; Young et al. 2009; Zeeman et al. 2015). There is also some evidence that WBV may enhance the risk of workers developing specific cancers (Jones et al. 2014; Nadalin et al. 2012; Waugh et al. 2016; Young et al. 2009).

Approximately 24% of employees in this industry are women (BLS, 2016). Women working in the TWU sector primarily work as public transit drivers (37.1%), in air transportation industry (40%), or in water transportation industry (22%). Men working in this sector are primarily employed in ground transportation (i.e., truck driving 56%). Because many workers in the TWU sector are not only exposed to WBV, but also are often performing jobs where they must sit for long periods of time, there may be an elevated risk for developing diabetes, and disorders of organs in the lower abdomen, including reproductive problems (Bovenzi 2005, 2006). As there are data suggesting that WBV may exert systemic effects and increase the risk of developing certain diseases, and as a result of the rise in number of women working in this industry, additional investigations need to be conducted to assess the risk of WBV on development of other disorders such as cancer, cardiovascular and reproductive in this industry.

Agriculture, Forestry, and Fisheries (AgFF)

Approximately 8% of the workforce is employed in the AgFF sector (BLS, 2016). In the agricultural industry, animal husbandry, and crop production and maintenance are the primary occupations (74.1% males, 24.9% females), and in the forestry sector, the majority of the employees are engaged in logging (97.2% males, 2.8% females). Workers performing these jobs are likely to be subjected to both HTV and WBV. The primary exposure to WBV in these industries is through the use of vehicles such as tractors, combines, and bulldozers, and primary exposure to HTV is through utilization of vibrating hand tools (e.g., chainsaws). Approximately 15.3% of employees in these industries incur an injury or occupationally associated illness that results in days of missed work (BLS, 2016). Workers in these industries are most likely to miss work because of physical injuries or as a result of various musculoskeletal disorders (MSDs) due to heavy lifting, maintaining static or awkward postures over an extended period time, and vibration exposure (Bovenzi et al. 1990, 1995, 1998a, 1998b, 2000a; Morgan and Mansfield 2014; Giannini et al. 1999; Heinonen et al. 1987; Yung et al. 2017). However, these individuals were also exposed to other factors such as pesticides and extreme temperatures. These exposures, along with vibration, may increase the risk of developing certain cancers, respiratory problems and neurodegenerative diseases (Anderson et al. 2018; Bencko et al. 2017; Darcey et al. 2018; Kachuri et al. 2017; Manyilizu et al. 2016; Piel et al. 2017; Prado et al. 2017; Prudente et al. 2018; Ramirez-Santana et al. 2018; Suratman, Edwards, and Babina 2015). Additional studies need to be performed to determine how exposure to these vibrations, along with other factors affects the risk of becoming ill.

Workers in the fishing industry are exposed to WBV and HTV vibration generated by the motor and lift equipment on boats, or by the motion of the boat, especially in rough waters. Individuals on fishing vessels in large bodies of water, along with workers who perform water rescues, may be exposed to impact or shock vibration when traveling through rough waters (Howarth and Griffin 2015; Ye et al. 2012; Zhou and Griffin 2017). Exposure to this impact might result in injury to the spine, knees, and hips (Howarth and Griffin 2015). Workers in this industry might also experience fatigue, headaches and motion sickness due to the motion of the vessel generated by the waves (Haward, Lewis, and Griffin 2009; Joseph and Griffin 2007). Although the musculoskeletal disorders usually progress with continued work, employees often note a decline in motion sickness and headaches with continued time working in the industry (Haward, Lewis, and Griffin 2009).

Construction and mining

Approximately 4% of the workers in the United States are in the construction industry and 0.4% in mining. Of these employees 90.9% are male and 9.1% are female within the construction industry and 87.5% are male and 12.5% are female in mining (these data do not include workers in mining administration, only employees involved in the mining process). The % of employees that missed days of work due to a work-related illness or injury was 0.3% and 5.8% for mining and construction, respectively. Workers in these sectors may regularly be exposed to WBV and HTV by driving large earth moving equipment such as bulldozers and dump trucks, or by using hand tools such as drills, jackhammers, and sanders. The combination of vibration exposure and having to maintain awkward or static postures, and lifting heavy loads, contributes to development of injuries and musculoskeletal disorders in employees in these sectors (Eger et al. 2014; Morioka and Griffin 2010; Smets, Eger, and Grenier 2010; Thompson et al. 2010; Yung et al. 2017). In addition, these workers are exposed to inhaled toxicants including various dusts and chemicals including coal dust, diesel, concrete, wood or organic solvents. These mixed exposures may act additively or synergistically with vibration to contribute to the development of many diseases reported in miners and workers in the construction industry (Weissman and Howard 2018).

Manufacturing

Overall, the number of workers employed in manufacturing is 7.9%. Approximately 74% of those individuals are employed in occupations where they may be exposed to vibration, and 29% of those are women. In 2015, 12.5% of the people employed in this sector missed days of work due to illnesses or injury (BLS 2016). The majority of the workers exposed to vibration in this sector are exposed to HTV. Employees in various manufacturing settings use many different types of hand tools, including but not limited to grinders, impact wrenches, sanders, and drills (Bovenzi 1988; Bovenzi et al. 2005; McDowell et al. 2016). Workers in this industry may also be exposed to awkward postures, repetitive motion, and various chemicals that might be inhaled or absorbed through the skin (Bovenzi 1988; Kijko, Jolliet, and Margni 2016; Su et al. 2013), and contribute to the development of injuries or illnesses.

Health effects

Exposure to both segmental and WBV results in an increased risk of developing MSDs, peripheral vascular and sensorineural problems, and other diseases. Repetitive exposure to long-term vibration results in a reduction in tactile sensitivity, loss of manual dexterity and cold-induced vasospasms that induce blanching of fingers and hands (Bovenzi 2010a, 2010b, 2006; Eger et al. 2014; Griffin 1996; House et al. 2011; House, Krajnak, and Jiang 2016; Rui et al. 2008; Thompson et al. 2010; Whitehouse et al. 2006). Taken together these symptoms have been referred to as hand-arm vibration syndrome (HAVS). Workers exposed to tools with a dominant frequency in the range of 60–300 Hz are more likely to develop the symptoms of HAVS (Bovenzi 1998a, 1998b; Bovenzi et al. 1995, 2008) Employees using handtools that emit a lower dominant frequency (i.e., 10–-60 Hz) also might display symptoms of HAVS. However, the tools with a lower dominant frequency are more likely to induce a loss of muscle mass, and joint injuries in the elbow and shoulder (Bovenzi 2005, 2006; Malchaire et al. 1986; Pyykko et al. 1981; Roquelaure et al. 2009; Sekkay et al. 2018).

Data from both human and animal studies suggest that exposure to segmental vibration may also produce systemic effects. For example, repeated exposure to HTV has been associated with hyperactivity of the sympathetic nervous system, hearing loss (independent of noise), and an elevated risk of cardiovascular disease (Harada 1994; Pyykko et al. 1981; Stoyneva et al. 2016; Wong and Figueroa 2018). There is also evidence that segmental vibration is associated with changes in the transcription of genes involved in cell cycle and the development of cancer (Krajnak et al. 2017; Krajnak and Waugh 2018; Waugh et al. 2016). These changes may be due to an increase in systemic inflammation and oxidative activity, or may be the result of alterations in blood flow to various organs (Krajnak and Waugh 2018). These data provide a basis for examining the risk associated with exposure to segmental vibration and development of chronic diseases.

Exposure to WBV has primarily been associated with an increase in lower back, neck and shoulder pain (Bovenzi 1996, 2009; Bovenzi and Betta 1994; Bovenzi and Hulshof 1999; Hulshof et al. 2006). Along with vibration, other exposure factors that may induce musculoskeletal pain in workers include maintaining static positions for a long period of time and twisting or torque while seated (Antle et al. 2018; Stewart, Taneja, and Medow 2007; Tachi et al. 2004). These factors, along with vibration from the truck, and impact from driving on rough roads, may result in compression of the disks and soft tissue strain, which both contribute to back pain (Cann, Salmoni, and Eger 2004; Grenier, Eger, and Dickey 2010; Smets, Eger, and Grenier 2010). WBV has also been associated with fatigue, motion sickness (from vibration and impact that is transmitted to the neck and head), and development of a number of chronic diseases including cardiovascular disease, Type II diabetes and/or metabolic disorder, and prostate cancer (Bovenzi and Hulshof 1999; Harris et al. 2012; Hulshof et al. 2006; Jones et al. 2014; Nadalin et al. 2012; Pollard et al. 2017; Young et al. 2009; Yung et al. 2017). Although other factors such as long work hours, stress, and exposure to toxic chemicals may also contribute to the development of these diseases, animal studies suggest that vibration exposure alone may increase the expression of biomarkers for these diseases (Curry et al. 2002; Govindaraju et al. 2006; Krajnak et al. 2012a, 2010, 2012b; Krajnak and Waugh 2018; Matloub et al. 2005).

Inhalation and WBV

Some of the sensorineural and cardiovascular effects associated with WBV exposure may also be in part due to inhalation of various toxic chemicals. For example, truck drivers and construction workers are often exposed to diesel fumes emitted by the machinery they are driving. Inhalation of diesel fumes is known to be associated with the development of respiratory and cardiovascular problems, asthma, and certain types of cancer (Darcey et al. 2018; Mauderly et al. 2014). At construction sites, workers may also inhale dust during earth moving and wood cutting processes or while mixing concrete. Investigators found that inhalation these different types of dust are associated with an elevation in respiratory, and in some cases cardiovascular disease in workers (Heinonen et al. 1987; Iavicoli et al. 2017). Agricultural workers can be exposed to vibration and various pesticides. Pesticide exposure has been associated with the development of peripheral neuropathies, neurodegenerative disorders, and reproductive problems in workers (Anderson et al. 2018; Iavicoli et al. 2017; Ismail et al. 2018; Kab, Moisan, and Elbaz 2017; Prudente et al. 2018; Ramirez-Santana et al. 2018; Suratman, Edwards, and Babina 2015; Tsai et al. 2018). Understanding how these various exposures may contribute to the development of health problems is important in determining the best actions to take to reduce exposure and incidence of injury and disease.

Models for assessing health effects

Computational modeling

Computational models were developed to examine the effects of various mechanical forces of HTV on the development of back pain and injury in workers exposed to WBV. These models included variables to determine the influence of vibration and mechanical stressors, including load, mass and posture on the hips, spine and intervertebral disks with exposure to WBV (Taskin et al. 2018; Wang et al. 2010; Zhang, Qiu, and Griffin 2015), and grip strength, vibration frequency and amplitude in workers exposed to HTV (Wu et al. 2006, 2008, 2007). The published computational models are consistent with data collected in humans showing that the resonant frequency of the human body is between 5 and 10 Hz (Basri and Griffin 2011; Matsumoto and Griffin 2002; Qiu and Griffin 2010; Zeeman et al. 2015), and that the resonant frequency of the human hand-arm system is between 100 and 300 Hz depending on the location of the measurement (Dong et al. 2004b; Dong, McDowell, and Welcome 2005; Dong, Welcome, and Wu 2005b; Dong et al. 2006; Wu et al. 2007, 2008). These models, along with experimental data collected in human and animal subjects helped predict how various interventions may reduce the transmission of vibration from a vehicle or tool to the body (Krajnak et al. 2015; Hewitt et al. 2015; Md Rezali andGriffin 2016, 2017; Welcome et al. 2016; Basri and Griffin 2014; Qiu andGriffin 2012; Jonsson et al. 2015; Beard andGriffin 2013; Ji, Eger, and Dickey 2017; Du et al. 2018; Johnson et al. 2018). Several studies were performed to examine the physical characteristics of anti-vibration gloves and how different gloves affect transmission of the vibration signal to the body, which have provided information regarding the best type of glove to use depending upon the tools being used (Dong et al. 2014; Krajnak et al. 2015; Welcome et al. 2016; Xu et al. 2011).

Epidemiology

Epidemiological studies demonstrated that there is an increased risk of developing specific musculoskeletal disorders of the lumbar spine, neck, and shoulder attributed to exposure to either HTV or WBV (Bovenzi 1998a, 1998b, 2006, 2015; Charles et al. 2018; Palmer et al. 2008). There is also an elevated incidence of peripheral and cardiovascular disease in employees exposed to vibration (Bovenzi 2006; Stoyneva 2016; Stoyneva et al. 2016), and possibly an increased frequency of prostate cancer (Filon et al. 2013; Jones et al. 2014; Nadalin et al. 2012; Waugh et al. 2016; Young et al. 2009). With more women entering jobs where exposure to either HTV or WBV may occur, it will be important to understand how this exposure affects women's health. There are few studies examining the influence of either HTV or WBV on women in the workforce (Bovenzi et al. 2005). As previously indicated, there are a number of other personal and exposure factors, that depending upon a workers occupation, might add to or alter the effects of vibration, and contribute to the development of vibration-induced injuries and disorders. Multi-variate analyses of some of the most prevalent factors were conducted to determine the potential contribution to development of various musculoskeletal disorders (Charles et al. 2018; Bovenzi et al. 2011b; Bovenzi, Prodi, and Mauro 2016; Bovenzi 2015). Few epidemiological studies were undertaken to examine the relationship between vibration exposure and other diseases such as cancer and cardiovascular diseases (Jones et al. 2014; Kachuri et al. 2017; Nadalin et al. 2012; Schayek et al. 2009; Young et al. 2009)

Experimental studies of HTV in humans and animal models

Experiments examining the effects of single bouts of vibration in humans noted that both physical response and physiological/biological response to vibration are frequency dependent (Dong et al. 2007, 2004b, 2014; Dong, McDowell, and Welcome 2005; Dong, Welcome, and Wu 2005a, 2005b). Frequencies at or near the resonant frequency of the human hand-finger system (i.e., between 100 and 300 Hz) generate an increased biodynamic response of the exposed tissue (Dong et al. 2007, 2004a, 2012; Dong, Welcome, and Wu 2005b). The enhanced responsiveness of the exposed tissues at these frequencies is associated with a greater reduction in blood flow in the exposed tissues (Bovenzi 1998a, 1998b, 2012; Bovenzi et al. 1996, 1995), and employees that use tools that have a dominant frequency in this range exhibit a higher rate of cold-induced finger blanching, or vibration white finger disease (Bovenzi 2008; 2010b; Bovenzi et al. 1995, 1998a, 1998b, 2000a). Exposures at the resonant frequency are more likely to induced pain and diminished tactile sensitivity in the hands and fingers (Bovenzi, Giannini, and Rossi 2000b; Bovenzi et al. 1989; Bovenzi and Zadini 1989; Giannini et al. 1999). Other studies examining the influence of lower frequency vibration (10–60 Hz) found that vibration at these lower frequencies is transmitted to the elbow, shoulder, wrist, and neck (Bovenzi 2006, 2015; Bovenzi et al. 1980b, 1987, 2005). Exposures at these frequencies also results in faster fatigue of the muscles of the upper arm and shoulder (Stewart, Taneja, and Medow 2007; Tachi et al. 2004) and reports of increased discomfort (Bovenzi and Hulshof 1999; Griffin and Bovenzi 2002; House, Krajnak, and Jiang 2016; Huang and Griffin 2014; Thuong and Griffin 2011; Wyllie and Griffin 2007; Zeeman et al. 2015). This has led researchers and other members of standards committees to suggest that the frequency weighting curve needs to be revised, and either different curves need to be generated for different tools, or different curves need to be generated for different portions of the hand-arm system (Bovenzi et al. 2000b; Dong et al. 2001; Griffin, Bovenzi, and Nelson 2003; Morioka and Griffin 2010; Organization 2005).

Animal studies demonstrated that there are frequency-dependent effects of vibration exposure on the peripheral vascular (Curry et al. 2005; Krajnak et al. 2010, 2012b) and sensorineural system (Krajnak et al. 2012a, 2012b, 2018). Characterization of a rat-tail model of segmental vibration found that the resonant frequency of the rat tail and human fingers are in the same range (Welcome et al. 2008). As in humans, vibration at or near the resonant frequency results in increases in oxidative stress and inflammation, along with changes in vascular morphology, gene expression and physiological function that are consistent with early signs of peripheral vascular disease (Curry et al. 2005; Krajnak et al. 2010, 2009, 2014). Vibration tested at all frequencies affected sensorineural function in the rat-tail model. However, inflammation, oxidative stress and changes in gene expression are more pervasive with exposure at or near the resonant frequency (Govindaraju et al. 2006; Krajnak et al. 2012b, 2016; Loffredo et al. 2009; Matloub et al. 2005; Yan et al. 2005). Data collected in human and animal investigations were employed to improve the diagnosis of HAVS (House, Krajnak, and Jiang 2016; Kao et al. 2008; Krajnak et al. 2007; Poole, Mason, and Harding 2016; Terada et al. 2007), improve tool and glove design (Dong et al. 2014; Hewitt et al. 2015; Krajnak et al. 2015; Welcome et al. 2016; Xu et al. 2011), and help modify standards that suggest limitations regarding exposures based upon the frequency, amplitude and duration of hand-tool use (Kwong et al. 2001; Dong, Welcome, and Wu 2005a, 2005b; Dong et al. 2012; Bovenzi et al. 1980a, 1980b, 2008a; Bovenzi 2010a, 2010b).

Experimental studies of WBV in humans and animal models

Studies in both humans and animals showed that there are a number of different factors that contribute to the development of back and neck pain, sciatica, and shoulder pain in workers exposed to WBV. For example twisting or torque, posture in the seat, and muscle forces and stiffness generated to maintain posture, affect the ligaments, tendons and muscles of the back, and in addition, may alter the spinal load and risk of incurring an injury (Morgan and Mansfield 2014; Rakheja, Mandapuram, and Dong 2008; Wang et al. 2010). Because many patients with back pain do not have injuries to the spine or inter-vertebral disks, which might be detected using imaging methods, understanding the contribution of soft tissue injury (i.e., skeletal muscle, tendons, ligaments) to the incidence of back pain is critical for identifying interventions that will prevent injuries (Du et al. 2018; Bovenzi et al. 2015; Bovenzi 1996, 2010a; Palmer et al. 2003; Bovenzi and Zadini 1992). Data collected in humans, were utilized to alter seat design, reduce vibration transmission and improve comfort in vehicles (Basri and Griffin 2014; Beard and Griffin 2013; Du et al. 2018; Ji, Eger, and Dickey 2017; Johnson et al. 2018; Jonsson et al. 2015; Qiu and Griffin 2012). Metal fatigue and stress might also exacerbate pain. Therefore, taking breaks to stretch and help maintain mental alertness may also improve pain perception (Tachi et al. 2004; Yung et al. 2017).

Research gaps

Etiology of chronic diseases

As mentioned above, exposure to either HTV or WBV often occurs in conjunction with exposure to other occupational or environmental factors that may contribute to the development of chronic disorders such as cardiovascular disease or cancer (Darcey et al. 2018; Kab, Moisan, and Elbaz 2017; Kachuri et al. 2017; Prudenti et al., 2018; Suratman, Edwards, and Babina 2015). Measuring how each exposure variable contributes to the enhanced risk of developing a chronic disease is critical for determining the best interventions for reducing this risk. Therefore, epidemiological investigations describing which factors workers are exposed to in specific jobs may provide information that can be used to design experimental studies examining the risk associated with exposure to each factor in a specific workplace, and how these factors act, either additively or synergistically to affect the risk of developing certain diseases.

The effects of vibration on females

More women are entering professions where they are potentially exposed to vibration. However, there are few studies examining the influence of vibration on the health of female workers (Akesson et al. 1995; Bovenzi 2006; Bovenzi et al. 2005; Seah and Griffin 2008). Because of differences in the distribution of specific neurotransmitter and steroid hormone receptors (Krajnak et al. 2006; Levin 2001), and because cyclic changes in steroid hormones may affect physiological responses to vibration or other occupational hazards (Akesson et al. 1995; Levin 2001; Lindsell and Griffin 2003; Lucca et al. 2015; Masjedi and Ferdous 2015; Seah and Griffin 2008; Welsh and Griffin 2008), epidemiological studies might be undertaken to (1) assess the risk of developing cardiovascular disease, certain cancers, or reproductive problems in women exposed to occupational vibration, and (2) determine how this exposure affects their risk of developing certain disorders or diseases. Experimental studies might more clearly elucidate the role of fluctuating steroid hormones during development, adulthood, and with aging, and how these physiological changes may alter the risk of developing a vibration-induced health problem. Experimental studies might also determine how differences in size, mass, and body structure may differentially modify vibration transmission in males and females. These data may be employed to either adjust standards for exposure, or used by designers of protective equipment to develop protective equipment for workers whose biodynamic responses to vibration may be different.

The effects of vibration on older workers

Most workers with vibration-induced disorders or disease have been exposed to vibration for more than 10 years and tend to be over 40 years of age (Cherniack et al. 2004; Nilsson, Wahlstrom, and Burstrom 2017; Palmer and Bovenzi 2015; Schulte et al. 2007; Sundstrup et al. 2017; Takeuchi et al. 1986). The longer a worker is exposed to vibration, the more likely they are to develop HAVS (Cherniack et al. 2004). However, older workers may be at greater risk of developing a vibration-induced health problem because they show an increased incidence of other personal risk factors or diseases that that exacerbate the effects of vibration, such as type 2 diabetes (Shulte et al. 2007); cardiovascular disease (Hering, Lachowska, and Schlaich 2015); and arthritis or other musculoskeletal problems (Bovenzi 1986; Masjedi and Ferdous 2015; Schulte et al. 2007; Sorelli, Perrella, and Bocchi 2018). In 2008, the US Bureau of Labor Statistic reported that there was an increase in the number of people over the age of 65 in the workforce. This rise in the number of people working into their 70s is predicted to increase until 2024 (Mitra and Elka 2017). Studies that specifically focus on the age of workers exposed to vibration would help determine how if older workers are more susceptible to the effects of vibration, and identify specific measures that might be taken to provide additional protection for workers as they age.

Conclusions

Exposure to both HTV and WBV are associated with a number of serious health consequences, and newer epidemiological studies indicate that WBV may increase the risk of developing prostate cancer (Jones et al. 2014; Kachuri et al. 2017; Nadalin et al. 2012; Schayek et al. 2009; Am Cancer Soc, 2018; Young et al. 2009). Because occupational exposure to vibration occurs in conjunction with other exposures, such as inhalation of toxins, investigations undertaken to examine the precise risk associated with each variable are important because these data may help determine which exposure variables are most dangerous and the best interventions for reducing or preventing exposure to these factors. These data also provide information that might be used to help revise standards published by the International Standards Organization and American National Standards Institute.

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Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

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