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Evidence of Health Risks Associated with Prolonged Standing at Work and Intervention Effectiveness

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Abstract

Purpose—Prolonged standing at work has been shown to be associated with a number of potentially serious health outcomes, such as lower back and leg pain, cardiovascular problems, fatigue, discomfort, and pregnancy related health outcomes. Recent studies have been conducted examining the relationship between these health outcomes and the amount of time spent standing while on the job. The purpose of this article was to provide a review of the health risks and interventions for workers and employers that are involved in occupations requiring prolonged standing. A brief review of recommendations by governmental and professional organizations for hours of prolonged standing is also included.

Findings—Based on our review of the literature, there seems to be ample evidence showing that prolonged standing at work leads to adverse health outcomes. Review of the literature also supports the conclusion that certain interventions are effective in reducing the hazards associated with prolonged standing. Suggested interventions include the use of floor mats, sit-stand workstations/chairs, shoes, shoe inserts and hosiery or stockings. Studies could be improved by using more precise definitions of prolonged standing (e.g., duration, movement restrictions, and type of work), better measurement of the health outcomes and more rigorous study protocols.

Conclusion and Clinical Relevance—Use of interventions and following suggested guidelines on hours of standing from governmental and professional organizations should reduce the health risks from prolonged standing.

Keywords

Prolonged standing; low back pain; leg pain; cardiovascular problems; subjective measures; biomechanical/physiological measures; interventions (floor mats, shoe inserts, sit-stand chairs/ workstations); guidelines

I. BACKGROUND

Many workers are required to stand for long periods of time without being able to walk or sit during the work shift. In operating rooms, for example, nurses and doctors must stand for many hours during surgical procedures. Similarly, direct care nurses, hairdressers, and store

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clerks spend large fractions of their working time standing without the ability to sit down. Briefly, a short summary below outlines the scope of the prolonged standing situation in working populations.

McCulloch (2002) summarized findings from 17 studies that involved standing for more than 8 hours per day (8 h/d). Major health risks identified were chronic venous insufficiency, musculoskeletal pain of the lower back and feet, preterm birth, and spontaneous abortions. Best et al., (2002) reported on the findings from a self-reported questionnaire administered to 204 hairdressers. Back pain was the most reported musculoskeletal disorder followed by neck and shoulder discomfort. Duration of standing was reported to be between 82% and 99% of total work time. Tissot et al., (2005) reported that the standing at work prevalence rate is 58% in the Quebec working population and more common in men, workers >25 years of age, and lower income workers. Meijsen and Hanneke (2007) reported that the average standing time for Dutch perioperative personnel [equivalent to nurses in the US] was 2.5 hours per day, and that 18% of respondents exceeded 4 hours of standing per day and 47% were in the Amber zone, and 17% were classified into the Red zone. According to Dutch ergonomic guidelines for prolonged standing, exposure is classified into one of three zones -- Green (safe-continuous standing ≤ 1h and total/day ≤ 4h), Amber (action recommended-continuous standing >1h or total/day > 4h), or Red (direct action required-continuous standing >1h and total/day > 4h). Werner et al., (2010) in a cross-sectional evaluation of workers at an engine manufacturing plant in jobs that necessitated prolonged standing and walking reported that 24% met the case definition for foot/ankle disorder and that 52% had the symptoms. Sitting, standing and type of work surface did not change the prevalence.

To emphasize the importance of this topic and concern regarding worker safety, the Association for perioperative Registered Nurses (AORN) recently published guidelines and solutions for reducing health risks associated with prolonged standing in perioperative environments (Hughes et al., 2011). In the guideline adopted by AORN, it is recommended that caregivers should not stand more than 2 hours continuously or for more than 30% of the work day without some type of fatigue-reducing interventions, such as anti-fatigue mats, specially designed footstools, sit-stand stools or chairs, or supportive footwear. The AORN guideline also suggests that if the caregiver must wear a lead apron during prolonged standing, that exposure should be limited to 1 hour without some type of intervention.

Additionally, the Canadian Centre for Occupational Health and Safety (CCOHS) (2014) has reported that working in a standing posture on a regular basis can cause sore feet, swelling of the legs, varicose veins, general muscular fatigue, and low back pain, stiffness in the neck and shoulders, and other health problems. According to the CCOHS report, prolonged standing effectively reduces the blood supply to the muscles resulting in the acceleration of the onset of fatigue and causes pain in the muscles of the legs, back and neck, as well as pooling of blood in the legs and feet which leads to varicose veins. The CCOHS suggests that job design can reduce the ill effects of working in a standing position by changing working positions frequently, avoiding extreme bending, stretching, and twisting, pace work appropriately, and allow workers suitable rest periods. The CCOHS report also suggests use of floor mats, shoe inserts, compression hosiery, and ergonomic seating to avoid exposure as well.

The International Labor Organization (ILO) (2011) has also published guidelines for prevention of health effects associated with exposure to prolonged standing at work. According to the ILO, if a job must be done in a standing position, a chair or stool should be provided for the worker and he or she should be able to sit down at regular intervals. The ILO also suggests use of floor mats and good shoes to avoid standing on a hard surface, as well as the availability of footrests to help reduce the strain on the back and to allow the worker to change positions by shifting weight from time to time. Finally, the ILO suggests that the height of the work surface should be adjustable or that the worker should be able to adjust their height relative to the work surface, so that the arms do not have to be held in awkward and extreme positions.

Reid et al., (2010) in a review of several published studies on occupational body postures and the lower extremity body region affected developed a lower extremity discomfort guideline for standing based on published research. Standing >2h/incident affected the hip and >3/h affected the overall lower extremity. Halim and Omar (2012) developed a Prolonged Standing Strain Index (PSSI) in order to attempt to quantify the risk levels with standing jobs and other workplace factors (e.g., posture, injuries, vibration, air quality) with minimum risk levels proposed. The PSSI provides an overall numerical score that can be used to assign risk for a specific job into a “Safe,” “Slightly unsafe,” or “Unsafe” category.

The purpose of this paper is to review existing scientific literature examining the potential health consequences resulting from exposure to prolonged standing at work and to document the effectiveness of various interventions aimed at reducing potential health risks. The review encompasses studies examining a variety of health consequences including musculoskeletal disorders (MSDs), such as low back and lower limb discomfort and pain, local and whole body fatigue, cardiovascular disorders (CVD), cardiovascular insufficiency (CVI), and pregnancy outcomes. The review also examines the effectiveness of interventions to reduce risk of these health outcomes, such as various floor surfaces and use of floor mats, shoe and shoe inserts, use of support or compression hosiery (e.g. stockings), and sit-stand chairs/workstations. The following inclusion/exclusion criteria were used for assessing studies for this review: (1) Review articles and single studies must be available in English and were published in the peer reviewed literature since 1990; (2) Single studies had a clearly identifiable study population and purpose with study designs using independent/dependent variable paradigms; (3) Outcome measurements that focused primarily on prolonged standing and either one of the health issues listed above; and, (4) Intervention studies that evaluated methodology aimed at reducing risk due to prolonged standing. Listed below are short narratives for each study. At the end of each section is a Table that describes the study population and summarizes the major results from each study. Use of volunteers usually indicates laboratory studies. Abbreviations used in text an tables are defined initially.

II. Evidence of Negative Health Outcomes

Low Back Pain

A number of low back pain (LBP) measures have been associated with prolonged standing. By far the most measured outcome is low back fatigue and discomfort. In a study of bank tellers, Roelofs et al., (2002) reported low back discomfort with prolonged standing and Drury et al., (2008) reported that those who stand for long periods during the day reported significantly greater body parts discomfort compared to those who sit most of the day.

A number of studies have been conducted examining potential biomechanical indicators of risk of LBP due to prolonged standing. Researchers have suggested that risk of LBP is increased due to excessive co-activation of muscles involved in postural stability during prolonged standing (Nelson-Wong et al., 2008; Marshall et al., 2011). Specifically, Nelson-Wong et al., (2008) postulated that prolonged standing results in a significant increase in co-activity of the gluteus medius (GM) muscles, a muscle group that serves to stabilize the pelvis during standing by abducting, medially rotating, and laterally rotating the thigh at the hip.

To investigate whether there is evidence of increased GM activity during prolonged standing some studies have been conducted (Nelson-Wong et al., 2008 and Marshall et al., 2011). Using electromyography (EMG) recordings, the researchers found that subjects who reported low back pain showed higher co-activation of the left and right GM muscles versus those who did not report LBP during the standing task. Marshall et al., (2011) used EMG to study the endurance and strength of the GM muscles, as well as the co-activation patterns in subjects free of back pain. Their results indicated that endurance and co-activation were affected by prolonged standing and that this influenced reports of LBP.

Additional evidence of increased symptoms of LBP due to prolonged standing has been shown in studies by Nelson-Wong et al., (2010a,c) who examined subjects' acute biomechanical responses during a set of functional movements following prolonged standing tasks (right single leg stance, forward flexion while standing, unloaded squats and sloped surfaces). The researchers reported that following prolonged standing tasks, 1) 40% of participants developed LBP, (2) there was a decrease in vertebral joint rotation stiffness in lateral bending, (3) there was an increased excursion postural stability Center of Pressure (COP) measurements during unilateral stance, (4) there was no effect of standing on forward flexion, and (5) males had greater COP excursion than females on the single leg-standing task. In a similar study that examined the impact of sloped surfaces and its effect on biomechanical responses to prolonged standing (Nelson-Wong et al., 2010b) found that, for those who developed LBP, standing on sloped surface reduced pain subjective reports. This finding suggests that standing on a sloped surface in some way modifies the way the GM muscles are recruited during prolonged standing to maintain pelvic stability and decreased subjective LBP reports during prolonged standing.

The remaining studies focused on the epidemiological associations between prolonged standing and reported LBP (Engles et al., 1996; Yip, 2004; Andersen et al., 2007; Tissot et al., 2009). Some of the studies showed a moderate positive relationship between exposure to prolonged standing and development of LBP, while some concluded that there was little or no relationship. Engles et al., 1996, found that workers who reported being “hampered by standing” at work had increased risks of LBP and leg pain. Lack of definition of the term “hampered by standing,” makes it difficult to determine if their exposure variable was equivalent to the term “prolonged standing” at work. Yip (2004) did not show a significant relationship between prolonged standing and risk of LBP at work. The study, however, had some weaknesses. The hours of prolonged standing for the comparison may have been insufficient to cause a detectable difference in health outcomes and the level of severity of the LBP outcome measure in the study was very low. In a 24 month prospective study of LBP and other MSD outcomes Andersen et al., (2007) reported that prolonged standing increased reports of LBP and leg pain. In a cross-sectional study examining the relationship between LBP and prolonged standing and sitting, Tissot et al., (2009) reported increased reports of LBP in individuals who reported being constrained during standing. Constrained sitting, however, was not a significant risk factor for LBP in the study.

In a systematic review of scientific citations focusing on the potential **causality** of LBP resulting from exposure to prolonged standing, Roffey et al., (2010) concluded that they were not able to find any high quality studies that met more than two Bradford-Hill **causation** criteria. The inclusion criteria for **causation** in the review were very restrictive and many of the studies that did show a relationship between prolonged standing and development of low back pain were excluded from their review.

We reviewed 11 studies in this section which are presented in Table 1 with the study populations and significant findings. Most studies do report symptoms of Low back pain with prolonged standing.

B. Cardiovascular Problems

A number of studies have investigated the effects of prolonged standing on cardiovascular health outcomes. The measures studied have included carotid arteriosclerosis, leg edema, orthostatic symptoms (light headedness or dizziness), heart rate, blood pressure, and venous diseases (varicose veins, chronic venous disease and chronic venous insufficiency).

Tomei et al., 1999, investigated the relationship between major venous pathologies in the legs and prolonged standing. Clinical tests indicated that prolonged standing and age were related to increased risk of venous pathologies. In a cross-sectional study examining the relationship between prolonged standing and risk of chronic venous insufficiency (CVI), Krijen et al., (1997b) found that 18% were diagnosed with minor CVI and that 11% were diagnosed with major CVI symptoms. In a second paper focusing on the same workers, Krijen et al., (1997c) showed increases in leg volume with prolonged standing. Excess risk of varicose vein occurrence was reported in Danish workers working mostly in a standing position that were followed for three years after first hospitalization (Tüchsen et al., 2000).

In a review of studies examining the health risks associated with prolonged standing for over 8 hours, McCulloch (2002) found significant occurrence of CVI. CVI can lead to more serious health complications. McCulloch recommended employers undertake preventive measures, such as modifying job tasks to reduce risk of cardiovascular health effects due to prolonged standing.

Krause et al., (2000) examined the effect of prolonged standing on workers who were actively working over a 4 year period. Carotid intima media thickness (IMT) over a four year period was significantly greater for men who stand at work “very much,” compared to those who do not stand at work. Partsch et al., (2004) examined the effects of standing on leg edema before and after standing at work. Venous edema increased in the evening and was more pronounced in individuals with evidence of varicose veins.

Ngomo et al., (2008) measured the effect of prolonged standing on self-reported orthostatic symptoms, heart rate, and blood pressure in workers who stand for significant periods of time during their workday (i.e., average of 84–95% of the workday) and reported blood pressure changes. Sudol-Szopinska et al., (2007) conducted a prospective study examining differences in risk of chronic venous disorders (CVD) for workers who are exposed to prolonged standing compared with workers who primarily are exposed to prolonged sitting in the workplace. Prolonged standing did increase CVD symptoms. In a follow-up study with similar methodology but different workers, the findings were much the same (Sudol-Szopinska et al., 2011). It should be noted that the term CVD in this study might be equivalent to the term CVI in other studies. Kraemer et al., (2000) reported on cardiovascular measures from volunteers in a complex standing fatigue protocol while performing various work tasks. Results showed that after 8 hours of standing, there were significant increases in most of the physiological measures and discomfort ratings. Bahk et al., (2012) in a questionnaire survey of several companies reported significantly elevated risks of varicose veins and nocturnal leg cramps in workers standing > 4h/d.

There seems to be agreement among the studies that prolonged standing plays a significant and potentially dangerous role in development of vascular problems for workers who must stand for long periods during the workday. Whether these exposures lead to long-term chronic leg problems is not clear, but acute health effects clearly should be prevented to the extent feasible. We identified 11 studies focusing on the effects of prolonged standing on CV problems which are listed in Table 2.

C. Fatigue/Discomfort

A number of studies have shown that exposure to prolonged standing tasks can increase the physical fatigue and discomfort reported by workers (Jorgensen et al., 1993; Flore et al., 2004; Drury et al., 2008; and Balasuabramanian et al., 2009) in several body regions. Physical fatigue is generally assessed by various physiological/biomechanical measures such as muscle electromyography, postural stability using force platforms, or muscle surface temperatures. Discomfort is typically measured using subjective rating scales that ask individuals to rate their level of pain or fatigue using a body location diagram. Findings from studies that have examined the relationship between prolonged standing and fatigue are summarized below.

Jorgensen et al., (1993) investigated the physiological/biomechanical effects and perceived discomfort/fatigue with different shoes and floor surfaces during prolonged standing. The physiological/biomechanical measures were not affected by exposure time or floor/shoe condition but the subjective ratings were. Unfortunately, with the duration of standing limited to only 2 h, the effects on the biomechanical/physiological measures may not have occurred. Flore et al., (2004) evaluated the changes in venous pressure (before work compared to after work) on standing workers compared to the controls. Standing workers had significantly higher measures of oxidative stress before work, after work, and also the pre-post difference was higher compared to the control group. Drury et al., (2008) examined the effect of work postures on subjective fatigue in baggage security screening workers. Work posture did have an effect on ratings of body part discomfort. Balasuabramanian et al., (2009) measured muscle fatigue and perceived discomfort in workers using static and dynamic standing (move between work stations) work tasks. Fatigue rate and discomfort reports were higher in the stationary static standing posture as compared to the dynamic standing posture. Freitas and colleagues (2005) reported increases on measures of postural stability from adults and elderly individuals after 30 minutes of prolonged standing. Increased sway can indicate less postural control, an indicator of physical fatigue.

There appears to be general agreement among the study findings that prolonged standing without dynamic movement, even for periods as short as 30 minutes, leads to physical fatigue, discomfort, and pain in several body regions. It is also apparent that age affects how individuals respond to prolonged standing. The studies addressing the effects of prolonged standing on fatigue/discomfort are reported below in Table 3.

D. Pregnancy Issues

Several studies have evaluated pregnancy-related health issues associated with prolonged standing during work. Most of the studies below investigated the effects of the combination of prolonged standing and pregnancy on birth related health outcomes, such as stillbirths, spontaneous abortions, birth weights, and preterm deliveries. One study investigated ergonomic issues related to pregnancy and prolonged standing.

Two Canadian studies evaluated several occupational factors and pregnancy outcomes from working women (McDonald, et al., 1988a,b). Increased risk ratios were associated with prolonged standing for several health outcomes, but there was no elevated risk of pre-term delivery or low birth weights. Prolonged standing was defined as standing > 8/d. Teitelman et al., (1990) examined the impact of maternal work activity, including prolonged standing, on pre-term births and low birth weight. Prolonged standing on the job was significantly associated only with increased pre-term births. Klebanoff et al., (1990) evaluated the effect of physical activity during pregnancy on preterm delivery and birth weight. Only standing ≥ 8 hours showed a moderate increase in pre-term delivery rates. Eskenazi et al., (1994) studied the association of standing at work in women whose pregnancies ended in spontaneous abortion and women who delivered live births. Similar to the McDonald et al., results, women standing > 8 h/d at work showed risks of adverse birth outcomes. A study of Danish women between 1989 and 1991 showed significant effects on pre-term delivery rates and birth weight with hours of standing (Henriksen et al., 1995a, b). Mozurkewich et al., (2000) examined the effects of several working conditions on adverse pregnancy outcomes. Prolonged standing was associated with slight increased risk of pre-term birth. The authors estimated that if women discontinued prolonged standing one pre-term birth could be eliminated for every 27–80 women. Ha et al., (2002) reported results of a study of infant birth weight and standing at work. While prolonged standing showed a significant association with reduced birth weight it was not clear whether standing ≥3 hours per day was compared with no standing. Recently, Palmer et al., (2013) reported an updated review with a meta-analysis of work activities and birth outcomes. Newer studies have shown absence of large effects, but there were still small increased risks for pre-term delivery, low birth weight and small birth size for gestational age (SGA) with prolonged standing.

Pompeii et al., (2005) did not find a significant relationship between physical exertion at work and risk of pre-term birth or SGA, but exposure to prolonged standing was not assessed as h/d, but as h/wk. This resulted in the variable for prolonged standing being different from several other studies, which used h/d. In some of those studies standing > 8h/d showed a significant association with adverse pregnancy outcomes. The difference in measuring the exposure variable may be an important factor when studies report conflicting results.

Paul and Frings-Dresen (1994) investigated some of the changes that occur in working postures due to pregnancy. Results showed that the pregnant subjects would stand further from the table, with hips positioned more backwards with increased trunk flexion and with arms more extended. Postural differences in pregnant subjects were the smallest at the self-selected table height. An adjustable workplace was recommended by the authors to minimize postural changes due to pregnancy.

Most of the studies (Table 4) that investigated the effects of the combination of prolonged standing and pregnancy did indicate that prolonged standing increased the incidences of stillbirths, spontaneous abortions and pre-term deliveries. Low birth weight, however, was not consistently affected by prolonged standing and the recent meta-analysis by Palmer et al., (2013) indicates a low risk. Generally, most studies involved > 3 hours of prolonged standing, but exposure duration did vary between studies.

III. Effectiveness of Interventions

A. Compression Stockings

Several studies have investigated the wearing of support stockings or hosiery during standing at work using several subjective and biomechanical/physiological measures. Krijnen et al., (1997a) examined the effects of wearing compression stockings and floor mats on workers who had been diagnosed with Chronic Venous Insufficiency (CVI) and jobs which required prolonged standing. Only the compression stockings showed intervention effectiveness (reduced leg swelling). Kraemer et al., (2000) evaluated the effects of commercial hosiery rated light to moderate compression on reducing lower body edema and discomfort. All commercial hosiery evaluated was rated effective. McCulloch (2002) in a review of several studies done prior to 2000 concluded that support hose did play a positive role in reducing the symptoms of Chronic Venous Insufficiency (CVI) and leg complaints, but the selection of the type of hose and the severity of CVI was important. Consultation with a qualified health professional was recommended, because some support hose may actually be more harmful than helpful if they restrict lower leg venous return. Jungbeck et al., (2002) reported a four-week study to evaluate the effects of compression hosiery in workers who worked in standing professions. Subjective symptom ratings (leg pain, ankle swelling, tired and heavy leg, night cramps) and foot volumetry (foot volume, expelled volume, refilling rate) were objective measurements collected. Only the subjective ratings were statistically significantly. Study problems may have contributed to the lack of definitive findings for the objective measures as not all participants wore the stockings every day.

Partsch et al., (2004) evaluated types of support stockings that were most effective in reducing evening edema which occurs after prolonged standing. Evening edema was significantly reduced with compression stockings. Mosely et al., (2006) compared nurses and factory workers who stood for greater than 4h/d for three weeks while alternately wearing or not wearing stockings. Leg fluid volume was significantly lowered with stockings. Chiu and Wang (2007), however, in a study of footwear (nurse shoes) with prolonged standing that included a condition where the subjects wore compression hosiery did not find that the physiological/biomechanical measurements were significantly changed with compression hosiery but only discomfort ratings were reduced. Flore, et al., (2007) examined the reactive oxygen metabolites (ROS) in workers wearing compression stockings in jobs requiring prolonged standing. Compression stockings showed limited effects on ROS in only the operating room nurses compared to the other workers.

Most of the studies reviewed support the use of compression stockings in the reduction of subjective complaints of leg fatigue, pain, and swelling in work requiring prolonged standing. The findings with the physiological/biomechanical measures are less convincing, although some positive findings in reduction of leg swelling and leg fluid volume have been reported. The benefits of using compression stockings are most pronounced in workers with Chronic Venous Insufficiency (CVI). Based on the results from these studies it would be difficult to recommend what the pressure ranges for effective stockings would be, although the higher compression surgical stockings may be more harmful and whether the wearing of stockings would have a preventive benefit in healthy workers. Major findings from the studies reviewed are listed in Table 5.

B. Floor Surfaces, Mats, Shoes, and Shoe Inserts

The use of floor mats and shoe inserts during prolonged standing compared to prolonged standing on hard surfaces has been evaluated as an intervention procedure to reduce symptoms of discomfort, muscle pain, leg swelling, and tiredness. Biomechanical/ physiological measurements have also been investigated for their usefulness as objective measures.

Redfern and Chaffin (1995) evaluated seven flooring conditions and one shoe insert condition in comparison with a concrete floor surface on factory workers who had jobs requiring standing for an entire 8h shift. The floor surfaces ranged from several types of vinyl and viscoelastic materials. Flooring did affect workers perception of discomfort and all floor surfaces were rated better than concrete. Cham and Redfern (2001) studied the relationship between workers' subjective measures of discomfort and objective measures of fatigue and discomfort on different mat flooring conditions compared with a hard vinyl floor. Floor mats with increasing elasticity, decreased energy absorption and increased stiffness rated less discomfort and fatigue with prolonged standing. Krumwiede et al., (1998) investigated the effects of floor surfaces on comfort ratings in 3h of prolonged standing with 1h on each type of floor surface. Mat compressibility (ranged from 2.2 to 8.9%) was important in the comfort ratings and all surface types rated better than concrete. Madeleine et al., (1998) reported physiological and subjective measurements in a group of volunteers that stood on a hard surface versus soft surface for 2h while performing manual repetitive work tasks (preparing letters for sales campaign). Standing on the soft surface produced less pain and discomfort, which was supported by several of the physiological and biomechanical measurements. King (2002) and Orlando and King (2004 studied assembly line workers standing for 8h/d using different flooring conditions and also comparing floor mats and insoles. Mats and wearing in-soles were rated as more comfortable than standing on the hard floor. Age, height, and job tenure showed strong correlations with some measurements. Zander et al., (2004) measured changes in leg volume following an 8h shift with different flooring conditions. Floor conditions did not significantly affect lower leg volume measurements. Recently, Lin et al., (2012) used a study protocol similar (4 h prolonged standing) to the Cham and Redfern (2001) study, but added a field test component along with the laboratory study. Both floor type and shoe condition lowered foot discomfort and shank circumference increased linearly over the test periods. Significant changes were evident after 1h of prolonged standing in contrast to the Cham and Redfern (2001) study which reported changes in the 3rd and 4th hours.

Redfern and Cham (2000) reviewed 11 studies dating from 1972 to 2000 that had investigated prolonged standing with flooring types that used several different kinds of subjective and measurements. The authors concluded that the mixed and sometimes conflicting results from the many studies were most likely due to methodological differences, primarily with the duration of prolonged standing. Additionally, the biomechanical/physiological measures used have led to conflicting results so there is no consensus regarding the reliability/validity for any biomechanical or physiological measures.

Sahar et al., (2007) reviewed an extensive number of studies that had included insoles for the prevention of back pain. Only randomized control trials and crossover trials were considered. Using fairly rigid acceptance criteria, only 6 of 325 citations met the selection criteria and were reviewed for intervention effectiveness. Effectiveness of insoles was not evident but this conclusion may be influenced by not including studies with the authors' acceptable methodology. Bahk et al., (2012) found that wearing non-heeled shoes reduced the prevalence of varicose veins but not the prevalence of nocturnal leg cramps.

The benefits of floor mats/shoe inserts appear primarily to be in reducing discomfort and fatigue after several hours of prolonged standing. The use of shoe inserts is rated about the same as the most comfortable floor mats and the greatest benefits from mats/shoe inserts may occur after several hours of prolonged standing. Table 6 lists the important results from the studies reviewed.

C. Sit-Stand chairs and workstations

A number of national guidelines have suggested that sit-stand chairs with or without footrests/foot rails and/or adjustable workstations should be used for workers who must work in jobs requiring prolonged standing during the work shift. Some early studies reported conflicting results.

Irving (1982) in a survey of surgeons who stood for long periods of time during surgical procedures reported improvements in low back discomfort when using a standing/sitting pelvic-tilt chair. Nerhood and Thompson (1994) reported the results from a year-long study of workers that had sit-stand workstations installed at their company. Employees were categorized according to risk for discomfort which was determined by computer use and mobility. Discomfort ratings, injuries and illnesses were reduced. Whereas mobility was included in the assignment of the adjustable sit-stand workstations this factor was not reported in the results. Oude Vrielink et. al., 1994, reported that sit-stand chairs were not an effective intervention during a 4h monotonous task when compared to standing. Both physiological/biomechanical and discomfort measures were evaluated but leg movement was not controlled in the experiment making it difficult to compare the conditions. Chester et al., 2002, compared sitting, standing and a sit-stand chair and reported that the sit-stand chair condition increased leg volume. Study design problems (e.g., sit-stand chair position, tilt and no back rest, limited subject movement) suggest that the design of the sit-stand chair condition was not an effective intervention.

Recently more controlled studies and review articles have been published that have evaluated the intervention effectiveness of sit-stand work stations, but not necessarily with prolonged standing but also with prolonged sitting. Husemann et. al., 2009 reported from a randomized control trial (RCT) study that a sit-stand workstation (50% sitting; 25% standing; 25% break-office tasks) reduced physical and psychological complaints compared to a control group (75% seated; 25% break-office tasks). Robertson et al., (2013) conducted a RCT study that evaluated sit-stand workstations and ergonomics pre-training. Ergonomics trained participants (more mobility with mandatory standing) reported less musculoskeletal and visual discomfort than minimally trained participants. Both groups used sit-stand workstations, but there was no prolonged standing condition.

Karakolis and Callaghan (2014) reported a systematic review of studies that included a sit-stand workstation intervention on prolonged sitting, prolonged standing or a combination of both types. Although the studies reviewed involved office environments and not manufacturing processes the results showed sit-stand workstations lowered subjective discomforts. The review also determined that no optimal sit-stand ratio currently exists and that the optimal ratio may be specific for each worker depending on their personal and job requirements. The important results from the seven studies reviewed representative of the area reviewed are listed in Table 7.

Upon examination of the limited studies investigating the effectiveness of sit-stand chairs and workstations to reduce risk of MSDs, the effectiveness of these interventions is not clear. Conflicting results are likely due to study design weaknesses, such posture evaluation, measures of mobility, and ratios of standing to sitting. For example, none of the studies in manufacturing settings allowed the worker to use a dynamic posture during testing that allowed the worker to sit, stand, or lean against the chair, but rather the subject had to adopt a fixed posture (typically seated) for the duration of the testing. Data do suggest that use of sit-stand workstations should be considered as an ergonomic intervention for workers who must stand or sit for long periods of time in their work shift.

IV. Summary/Conclusions

Based on review of the literature there appears to be ample evidence that prolonged standing in the work place leads to a number of negative health outcomes. The studies consistently reported increased reports of low back pain, physical fatigue, muscle pain, leg swelling, tiredness, and body part discomfort due to prolonged standing. The findings from these studies were supported by intervention studies (e.g., compression stockings, floor surfaces, mats, insoles, sit/stand chairs) that show significant reductions in the subjective measures after implementation of the intervention. The findings from objective biomechanical and physiological studies of the effects of prolonged standing frequently correlate with subjective findings, but have not been conclusive. Considerable research has been devoted to trying to establish a biomechanical pathway for low back pain, but the final explanation is still elusive. EMG recordings of trunk muscles, Center of Pressure (COP) measurements using force platforms (posturography), and body kinematics have been used and the most promising result seems to be research involving the Gluteus Medius (GM) muscle group. The studies of prolonged standing and measurements of physical fatigue have shown some significant changes with the biomechanical/physiological measurements, but again there has been inconsistency.

Finally, there was general agreement in the reviewed literature that interventions can be effective, at least in reducing the subjective complaints from prolonged standing. Interventions that reduce the reports of low back pain and venous disorders would be the most effective in prevention of chronic health problems that could occur in older workers. In reviewing the studies examining the effectiveness of interventions, we concluded that dynamic movement appeared to be the best solution for reducing risk of these health problems due to prolonged standing. The ability for workers to “have movement” during work, such as walking around, or being able to easily shift from standing to sitting or leaning posture during the work shift seemed to be a common suggestion in nearly all of the literature but needs more research. In summary, we concluded the following:

1. There is significant evidence that prolonged standing at work (primarily in one place) increases risk of low back pain, cardiovascular problems, and pregnancy outcomes.

2. Interventions designed to reduce risk of adverse health outcomes due to prolonged standing can be effective. Research, however, with scientifically operational definitions of prolonged standing (e.g., hours/day, week, month) and improved design protocols are needed to determine which biomechanical/physiological measures are reliable and valid and correlate best with the subjective reports of effects from prolonged standing. Especially important would be experimental designs that would incorporate morning and evening measurements into

biomechanical or physiological measures of prolonged standing over the course of a work period (e.g., day, week, month) while manipulating the dynamics of standing (e.g., mobility, sit-stand). Morning and evening measurements would allow for the evaluation of whether outcome measurements are within normal limits of recovery or developing into chronic conditions. An ideal study protocol would take measurements daily for a typical workweek, followed by 2 days rest with measurements re-taken the day of work return. Evaluation of extended work shifts beyond the normal 8 h day is also essential.

3. Workplaces should not be static. Work should be designed so that the worker can adopt various postures during the work. For example, the worker should be able to walk around rather than stand in one place, or a sit-stand chair/workstation should be provided. Also, the worker should be encouraged to modify their posture so that they mix sitting, standing, leaning, and use of a foot rail or footrest as much as possible.

4. A reliable characterization of prolonged standing is needed based on a standard workday. Various groups, such as the AORN and the Dutch researchers, have suggested time limits for prolonged standing, which would be effective, but we also believe that a proper work design that includes all aspects of ergonomic intervention is also necessary.

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Table 1

Studies Examining Prolonged Standing and LBP.

Author (Year)	Study Population	Brief Summary
Engles et al., (1996)	846 nursing staff in Netherlands.	Workers who reported being “hampered by standing” at work had an increased risk of LBP (OR=3.07) and leg pain (OR=4.9) compared to those who were not hampered by standing at work.
Roelofs et al., (2002)	30 Australian bank tellers (24 F, 6 M).	Self-reported discomfort was highest for the low back due to standing, compared to those who sit or use a combination of sitting and standing.
Yip (2004)	144 Hong Kong nurses.	In a 12-month prospective study of prolonged standing at work, authors did not show a positive relationship between standing and risk of LBP (p value was 0.19).
Andersen et al., (2007)	5,604 Danish workers from industrial and service companies.	In a 24 month prospective study of LBP and other MSD outcomes, the authors found that prolonged standing of more than 30 minutes per hour was associated with an increased Odds Ratio (OR) for LBP (OR = 2.1) and leg pain (OR = 1.7).
Drury et al., (2008)	United States TSA baggage screeners (7 M, 5F).	Those who stand for long periods during the day reported statistically significant (sig.) greater body parts discomfort in the back, legs, and feet compared to those who sit most of the day.
Nelson-Wong et al., (2008)	23 (12 M, 11 F) Canadian volunteers.	Subjects who reported low back pain showed higher co-activation of the left and right GM muscles versus those who did not report LBP during the standing task.
Tissot et al., (2009)	4517 M + 3213 F responding to the Quebec Social + Health Survey criteria.	Self-reported standing without freedom to sit was associated with increased reports of LBP for men, but not for women.
Roffey et al., (2010)	Review of 2,766 citations (only18 met review criteria).	Concluded that it was unlikely that occupational standing or walking is independently causative of LBP.
Nelson-Wong et al., (2010a,b,c)	2010a-43 (22 M, 21 F) 2010b-16 (8 M, 6 F) Canadian volunteers.	The authors reported evidence of low back problems following exposure to prolonged standing tasks. Standing on 16° sloped surface reduced LBP pain scores for pain development group.
Marshall et al., (2011)	24 (8 M, 16 F) Canadian volunteers.	Evidence suggesting that GM endurance and co-activation were affected by prolonged standing and this influenced reports of LBP.

Table 2

Studies Examining Prolonged Standing and Cardiovascular Problems.

Author (Year)	Study Population	Brief Summary
Krijen et al., (1997b)	387 Dutch Male workers in a standing profession.	Age and body weight were risk factors for presence of CVI and that the number of years having a standing profession was identified as a risk factor for severity of CVI.
Krijen et al., (1997c)	387 Dutch Male workers in a standing profession.	Leg volume increased sig. after two days of exposure to prolonged standing and that the increase in leg volume was associated with subjective complaints in the legs.
Tomei et al., 1999	336 M Italian workers (industrial, office + stonemasons).	Proportion of workers standing for ≥ 50% of the work shift was higher in phlebopathic than in non-phlebopathic workers; and, being over 40 years of age increased risk of phlebopathy.
Krause et al., (2000)	584 Finish men in Kuöpio Ischemic Heart Disease study.	Prolonged standing at work associated with increased risk of development of carotid atherosclerosis, + those with stenosis or Ischemic Heart Disease (IHD) are at sig. increased risk.
Tüchsen et al., (2000)	5940 Danish Workers ages 20–59.	Increased risk ratio for varicose veins for men (1.85, 95% CI 1.33–2.36) and women (2.63, 95% CI 2.25–3.02) when working mostly in standing position. Risk adjusted for age, social group and smoking.
Kraemer et al., (2000)	12 US F volunteers.	Prolonged standing sig. increases orthostatic stress on workers (i.e., increased body mass and total body water + increase in popliteal and posterior vein size + sig. increase in systolic and diastolic blood pressure) and increased discomfort.
McCulloch (2002)	17 studies of workers in jobs requiring standing > 8h from many countries.	In a review of studies examining the health risks associated with prolonged standing for > 8 h, found evidence that prolonged standing was associated with a sig. occurrence of Chronic Venous Insufficiency (CVI).
Partsch et al., (2004)	12 Austrian workers (8 F, 4 M) who worked in compression stocking factory.	Edema in the legs increased between 10.2 and 220.3 mL after standing an average of 3.2 h/d, and patients with varicose veins and with venous edema had more pronounced evening edema than individuals without visible veins.
Ngomo et al., (2008)	Study 1–34 (11 M, 23 F) health care workers. Study 2–36 (21 M, 24 F) factory + laundry. Canada.	Prolonged static standing affects arterial blood pressure (BP) and may result in orthostatic intolerance (OI) and other hemodynamic changes.
Sudol-Szopinska et al., (2007) and Sudol-Szopinska et al., (2011)	2007-160 office + bakery workers (97 F, 63 M). 2011-126 office + laboratory workers. Poland.	Occurrence of CVD symptoms were significantly higher for workers who work in a standing position compared with workers who primarily work in a sitting position.
Bahk et al., (2012)	2165 (1203 F, 962 M) South Koreans. Workers.	Sig. ORs for varicose veins in women (2.99, 95% CI 1.26–7.08) + men (7.93, 95% CI 3.15–19.95) with prolonged standing > 4h/d. Nocturnal leg cramps were sig. only for men (2.93, 95% CI 1.73–4.97).

Table 3

Studies Examining Prolonged Standing and Fatigue/Discomfort

Author (Year)	Study Population	Brief Summary
Jorgensen et al., (1993)	8 F Danish volunteers performing letter sorting task.	There was a 4 to 6 fold increase in subjective discomfort after two hours of work during prolonged standing.
Flore et al., (2004)	62 F Italian Surgery room workers and 65 F Italian outpatient workers.	Workers with predominantly standing occupations increased venous pressure (before work compared to after work) was significantly higher for the standing workers compared to the controls compared to workers who stand less, suggesting that these workers are likely at higher risk of CVI.
Freitas et al., (2005)	14 elderly volunteers + 14 adult volunteers. Brasil.	Postural sway was sig. greater following a prolonged standing task and the increase in sway was attributed to fatigue. Lack of mobility had greater effects on the elderly compared to the adults.
Drury et al., (2008)	US TSA baggage screeners (7 M, 5F).	Standing posture was rated as having the highest level of discomfort, followed by sitting on a high stool, then by sitting at a desk.
Balasuabramanian et al., (2009)	9 M volunteers performing assembly/disassembly task. India.	Fatigue rates in leg and lower back muscles were sig. higher ($p < 0.05$) in stationary standing posture as compared to dynamic standing posture, and perceived discomfort in the legs, shoulders, and overall rating of discomfort were sig. higher for static posture than for dynamic posture.

Table 4

Studies Examining Prolonged Standing and Pregnancy Issues

Author (Year)	Population Studied	Brief Summary
McDonald, et al., 1988a	56,067 Montreal women from 11 obstetrical units.	Elevated rate of spontaneous abortions for standing ≥ 8h/d for all occupations when grouped by work requirements. When broken down by occupation (managerial, health, and clerical), workers in clerical occupations had a sig. elevated risk (1.37 $p < 0.01$). Risk ratios were also elevated for stillbirths in workers standing ≥ 8h/d.
McDonald et al., (1988b)	22,761 Montreal single live births.	Did not find increased risk of preterm delivery or low birth weights from prolonged standing ≥ 8h/d.
Teitelman et al., (1990)	1.206 pregnant Connecticut women.	Standing on the job was sig. associated with increased preterm births (OR = 2.72, 95% CI = 1.24–5.95). Birth weights were reduced in the standing group, but the association was not sig. OR = 1.58, 95% CI = 0.51–4.94).
Klebanoff et al., (1990)	7,101 receiving prenatal care from NY, WA, OK, and TX+ LA clinical centers.	Prolonged standing ≥ 8h/d showed a moderate increased odds ratio of 1.31 (95% CI 1.10–1.71) for preterm delivery, but did not affect preterm delivery rates or birth weight.
Eskenazi et al., (1994)	1894 women (607 spontaneous abortions + 1287 live births. California.	Women standing > 8/d at work showed an increased adjusted odds ratio of 1.6 (95% CI 1.1–2.3) for spontaneous abortion when compared to standing 3h/d per day.
Henriksen et al., 1995a	8711 Danish women with single pregnancies.	Women who reported > 5 h/d of both standing and walking had an adjusted OR of 3.3 (95% CI 1.4–8.0) for preterm delivery when compared to women reporting ≤ 2 h/d of standing and walking. Standing only for 5 h/d when compared to ≤ 2 h/d of standing was not significant (OR = 1.2 95% CI 0.6–2.4).
Henriksen et al., 1995b	8711 Danish women with single pregnancies.	Women who reported standing at work > 5 h/d had birth weights 49g lower than women standing ≥ 2 h/d (95% CI −108 to 10). Higher birth weights were reported, however for women walking > 2 but ≤ 5 h/d (35g, 95% CI 8 to 63).
Mozurkewich et al., (2000)	160,988 women from Asian, European, and North American countries.	In a meta-analysis of 29 studies (case-control, cross- sectional, prospective cohort) involving 160,988 women, authors found that prolonged standing was sig. associated with an increased risk of preterm birth (OR = 1.26, 95% CI 1.13–1.40).
Ha et al., (2002)	1,222 Chinese women working at petrochemical plant.	Adjusting for confounders the association between maternal standing hours and reduced birth weight using a multivariate GAM model showed a sig. ($P = 0.01$) reduction of 16.8g.
Pompeii et al., (2005)	1,908 North Carolina pregnant women.	There were no sig. associations for preterm delivery outcomes or small birth size for gestational age birth (SGA) for pregnant women standing > 30h per week when compared to standing 6–15h per week.
Palmer et al., (2013)	Meta-analysis of articles from 1966–2011. 28 studies involved standing.	Preterm delivery median RR was 1.16 (1.00–1.35); small gestational age (SGA) median RR was 1.00 (0.93–126); low birth weight RR was 1.13 (0.70–1.58) with prolonged standing > 4h/d. Excess risks are low, but still exist.

Table 5

Studies Examining Effectiveness of Wearing Support Stockings or Hosiery

(Year)	Study Population	Brief Summary
Krijnen et al., (1997a)	114 Dutch workers diagnosed with CVI in 14 meat packing plants.	For workers wearing compression stockings, there were sig. reductions in leg complaints and leg swelling when compared to a control group. Floor mats, however, were not effective.
Kraemer et al., (2000)	12 F US volunteers.	Commercial hosiery were effective in reducing edema in the ankles and legs, and also reduced the amount of venous pooling and discomfort in the lower body following prolonged standing.
McCulloch (2002)	17 studies of workers in various jobs requiring standing > 8h from many countries.	Support hose did play a positive role in reducing the symptoms of Chronic Venous Insufficiency (CVI) and leg complaints, but the selection of the type of hose and the severity of CVI was important.
Jungbeck et al., (2002)	52 Swedish F (36 employed in department stores, hotel and restaurants + 16 surgery staff).	Subjective ratings for leg symptoms were all sig. reduced with the use of compression stockings and although the objective measures showed some improvements they were not sig. Compliance with wearing compression stockings everyday was erratic and not monitored.
Partsch et al., (2004)	12 Austrian volunteers (8 F, 4 M).	In workers who stood more than 3.2 h/d, evening edema was sig. reduced with compression stockings, with the reduction being fairly linear with increasing amount of stocking compression pressure. Pressure ranges between 11 and 21 mm Hg were recommended.
Mosely, et al., (2006)	27 nurses (25 F, 2 M), 30 factory workers (16 F, 14 M). Australia.	Below the knee support stockings sig. lowered leg fluid volume and body part discomfort (neck, shoulder, low back) in nurses and industry workers who stood for greater than 4h/d, but only leg discomfort symptoms were sig. lower for nurses.
Chiu &Wang (2007)	12 F volunteers in Taiwan.	Compression hosiery did not affect physiological or biomechanical measurements but did reduce subjective discomfort feelings in the lower back, knee, calf and in the metatarsal and heel regions.
Flore, et al., (2007)	55 operating theater nurses, 23 ironers, 65 outpatient nurses, 35 laundry workers. All Italian females.	Lower limb venous pressure increased sig. after the work shift for nurses and controls, but only the operating room nurses showed sig. higher levels of reactive oxygen metabolites (ROS) when not wearing stockings. When wearing compression stockings no sig. differences were noted in venous pressures or ROS levels in either group.

Table 6

Studies Examining Effectiveness of Floor Surfaces, Mats, Shoes, and Inserts

Author (Year)	Study Population	Brief Summary
Jørgensen et al., (1993)	8 F Danish volunteers performing letter sorting task.	The effect of different shoes and floor surfaces was negligible after 2 h of prolonged standing. Longer durations were not tested.
Redfern & Chaffin (1995)	14 US workers (8 M, 6 F).	Ratings of perceived hardness of flooring affected perception of discomfort and were correlated with measured stiffness. Slip resistant mats and extremely soft mats did not offer marked improvement over mats with more hardness. Use of shoe inserts was perceived as similar to the better-rated cushioning mats.
Krumwiede et al., (1998)	12 US college students.	Mats with the highest compressibility were rated as the most comfortable, but specific mat characteristics that influenced comfort were not apparent.
Madeleine et al., (1998)	13 M Danish volunteers.	Standing on the soft surface produced lower reports of unpleasantness whereas the hard surface showed increased trunk swelling, increased EMG activity in the muscle groups, increased sway displacement, and increased muscle fatigue. Induced muscle pain was lower on the soft surface than hard surface.
Redfern & Cham (2000)	11 studies from 1972–2000 that investigated prolonged standing and floor types.	In a review of 11 studies, authors concluded that softer floors generally resulted in reduced discomfort and fatigue compared to a hard floor, primarily in the lower extremities. Key flooring characteristics influencing discomfort include elasticity, stiffness, and thickness.
Cham & Redfern (2001)	10 US volunteers (5 M, 5 F).	Prolonged standing and floor type had sig. effects on both the subjective and objective fatigue and discomfort, but only during the 3rd and 4th hour of prolonged standing.
King (2002)	22 US assembly line workers (5 M, 17 F).	A mat alone, in-soles alone, and in-soles with mat were rated as significantly more comfortable and less fatiguing than a hard floor condition. No significant differences, however, were noted when comparing the effects of standing on a mat versus wearing in-soles or the combination of standing on a mat with insoles.
Zander et al., (2004)	16 US assembly line workers (2 M, 14 F).	Lower leg volume increased sig. from pretest to posttest while standing for 8h, but there were no sig. differences between any flooring conditions (wood block, anti-fatigue mat, shoe insole).
Orlando & King (2004)	16 US assembly line workers (2 M, 14 F).	Use of mats and insoles reduced ratings of general fatigue, leg fatigue, and discomfort but here were no sig. differences between the flooring conditions (wood block, mat, insoles) compared.
Sahar et al., (2007)	6 randomized control trial studies from US, Denmark, Israel, + South Africa	Based on a review of studies examining effectiveness of insoles, authors concluded that there was no strong evidence that using insoles was effective in the prevention or treatment of back pain.
Bahk et al., (2012)	2165 (1203 F, 962 M) South Korean Workers.	Non-heeled shoes reduced prevalence of varicose veins in women (OR 0.69, 95% CI 0.49–0.97) and men (OR 0.58, 95% CI 0.35–0.96), but not on nocturnal leg cramps with prolonged standing > 4h/d.
Lin et al., (2012)	Expt. 1–13 Taiwan volunteers (10 M, 3 F). Expt. 2–14 Taiwan Workers (6 M, 8 F)	Expt. 1-Foot discomfort ($p<0.01$) and shank circumference ($p<0.01$) sig. lower on soft floor (mat). Shoe condition only sig. for discomfort ($p<0.01$). Sig. effects > 1h standing. Expt. 2-Thigh circumference ($p<0.014$) and shank circumference ($p<0.032$) greater on hard floor. Negative effects after 1h standing.

Table 7

Studies Examining Effectiveness of Sit-Stand chairs and workstations.

Author (Year)	Study Population	Brief Summary
Irving (1982)	55 South African Surgeons.	Use of a sit-stand chair during surgery improved ratings of low back discomfort compared with sitting or standing only. 100% reported an improvement after operations lasting more than 2 hours and 88% of surgeons reported that they would use the sit-stand chair frequently in the future if it was available. Only 12% said they would use it occasionally.
Nerhood & Thompson (1994)	American United Parcel workers. Number not stated.	Body part discomfort decreased by ay an average of 62 % and occurrence of injuries and illnesses by >50%. No sig. changes on absenteeism.
Oude Vrielink et. al., 1994	6 Dutch M volunteers.	Sit-stand chairs were not effective in mitigating fatigue, leg volume or discomfort ratings when compared to a standing only task.
Chester et al., 2002	18 American (7 F, 11 M) volunteers.	Found that the sit-stand chair resulted in higher leg volume changes than standing or sitting only and the most discomfort in the hips.
Husemann et al., 2009	60 M German College volunteers.	Sit-stand workstation across a 1-week period reduced musculoskeletal complaints while performing a data entry task. No sig. effects noted on data entry task performance with sit-stand workstation.
Robertson et al., 2013	22 F American volunteers.	Minimal musculoskeletal and visual discomfort over a 15 day experimental period for participants who used sit-stand workstations with ergonomics training compared to participants with minimal training. 7 body region pain measures showed sig. differences ($p < 0.01$) between regions. Low back, neck, and shoulder highest reported pain areas.
Karakolis & Callaghan (2014)	14 Articles from various countries published between 1950–2011 that met review criteria.	Sufficient evidence to conclude that sit-stand workstations are effective in reducing local discomfort in the low back. Some evidence that sit-stand workstations may increase reported discomfort in hand and wrist. No optimal sit-stand time ratio. No decrease in productivity noted.