

Ceiling lifts as an intervention to reduce the risk of patient handling injuries

A Literature Review

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Introduction

Musculoskeletal injuries (MSI) are the major source of work-related disability among healthcare workers^{1,2,3,4,5,6,7,8,9,10}. The risk of musculoskeletal disorders among healthcare workers is well documented in the literature and in workers' compensation claim statistics. Studies conducted in a number of countries, including Canada¹¹, the United States, the United Kingdom, Holland¹², China¹³, Sweden¹⁴, and Australia¹⁵, and in a number of healthcare settings, including acute care facilities^{12,13,14}, extended care facilities and home care settings¹⁶ have all found a high risk of musculoskeletal injuries among nursing personnel. Higher incidence rates of MSI have been observed in healthcare workers compared to the general population¹⁷ and to other occupational groups¹⁸ such as construction workers, loggers, and truck drivers¹⁹. In Canada, the evidence is similar^{20,21} with the injury rate for the healthcare sector from 1996 to 2000 higher than the average for all other industries combined²². In 2003, the injury rate per 100 Full Time Equivalent (FTE) workers for the Acute and Long term care sectors in British Columbia (BC) were 4.0 and 8.0 respectively, while the injury rate for all other industries in BC was 2.6²³.

There is a high prevalence of back pain among nurses^{5,11,24}, influencing up to 81% of the nursing population with many MSIs not often reported to supervisors. Although definitions of MSI outcomes vary, the reported prevalence of upper-body musculoskeletal symptoms among nursing personnel during the past 12 months, as reviewed by Koehoorn and Sullivan²⁵, ranged from 24% to 60% in published studies^{26,27} and for lower-body symptoms from 33% to 72%^{28,29}.

Risk Factors

Owen³⁰ summarizes the evidence that back injuries are a major problem for those nurses providing direct patient care. Nurses with frequent and direct physical contact with patients have been shown to have a higher incidence of back injuries than those who work with patients infrequently, and nurses who have been injured commonly report patient handling as a major cause of their injury^{11,18,31,32,33,34,35}.

Biomechanical analyses of spinal compressive and shear forces^{36,37} and worker perceptions³⁸ suggest that manual lifting and transferring tasks are particularly high-risk activities. When nursing tasks are rated for the level of back stress, patient handling tasks are listed as more stressful to the back than non-patient handling tasks, both for rankings of perceived stress by nursing personnel and through biomechanical studies³⁹. As well, a recent survey of compensation data in BC reflects that overexertion accidents during patient handling are by far the major cause of injury claims among BC healthcare workers⁴⁰.

Among the types of tasks commonly associated with patient handling, there is extensive evidence to suggest that manual lifting is a major risk factor for MSI. Nurses who generally lift more frequently have been shown to be at increased risk for MSIs^{19,28,41} as have nurses who report frequently lifting heavy objects^{28,42}. Nurses who frequently lift heavy objects are also at higher risk for herniated disc and genital prolapse⁴³. Similarly, both heavy and repetitive lifting has been identified as major risk factors for back injuries in a number of professions⁴⁴.

Manual patient handling such as lifting and transfer patients/residents from one destination to another has been identified as a high risk activity^{7,33,45}. The risk on the musculoskeletal system is due to: the weight or required force to lift/transfer or reposition a patient/resident, the horizontal and vertical location of the patient/resident relative to the healthcare worker, the frequency, duration and orientation of lifting, stability of the patient, workplace geometry, and environment^{36,46,47,48}. The

potential for injury is not only due to overcoming a heavy patient/resident's body weight, but is further compounded by the patient's size, shape, deformities, level of fatigue, cognitive functioning, cooperation as well as the worker's physical impairments or lower limb function, balance, and coordination^{7,49}. Cognitively impaired patients/residents can be unpredictable and may suddenly become combative, resist efforts, or go limp during a transfer, causing a nurse to lose balance and/or make sudden unexpected movements. These sudden unexpected movements and resultant muscular contractions can cause high muscular forces within the erector spinae of approximately 145-187% of one's Maximum Voluntary Contraction (MVC)⁵⁰ leading to fatigue and possible failure of the muscles surrounding the lumbar spine^{51,52,53}.

In addition to the risk from lifting heavy weights, several recent biomechanical studies examining a range of nursing activities found that many nursing postures are "poor" and that poor posture was a risk factor for lower back pain among the nurses examined⁵⁴. Working in a stooped, bent or twisted position has been listed as a risk factor in several other studies of nurses^{7,42,54} and has been well documented in biomechanical studies as a cause of MSI. As well, in a study comparing occupational lifting between nursing aides and warehouse workers, it was suggested that nursing aides perform more lifts of long duration in awkward postures, do more carrying, exert horizontal force more often, and are exposed to more unexpected rapid changes than warehouse workers⁵⁵. It was concluded that such lifting factors placed the nursing aides at greater risk for MSI than the warehouse workers.

Studies examining the biomechanical loads on caregivers during patient handling tasks find that the loads often exceed the permissible limit set by the U.S. National Institute of Occupational Safety and Health (NIOSH) and others^{7,36,39,56}. Maximum allowable limits of 3400 N for compressive forces on the L5/S1 disc have been recommended for occupational manual handling tasks. Estimates of the compressive forces associated with manually handling patients usually exceed this safety guidance^{7,32,36,37,56}.

In addition to the risk for injury due to peak forces during acute events, cumulative loading may also lead to more chronic MSI conditions. In conditions of chronic onset, workers may gradually feel sensations of tiredness, weakness, stiffness, and dull pain. Caregivers often cannot recall a specific acute event causing the injury, thus suggesting cumulative loading as a causative factor, rather than a single event resulting in an injury. Several epidemiological and biomechanical studies have also found evidence to support that cumulative stress may be a risk factor for MSI.

The combination of a high injury prevalence associated with patient handling, and the characteristically large estimates of biomechanical stress associated with manual techniques for patient handling, have spurred considerable efforts by researchers and health and safety practitioners to study interventions that replace manual patient handling techniques with mechanical options such as floor and ceiling lifts, and which also show the effectiveness of these approaches and their favourable cost benefit^{57,58,59,60,61,62,63,64}.

Mechanical Interventions

Many researchers and health and safety practitioners have recommended replacing manual patient handling with mechanical options (engineering controls) through introduction of mechanical floor and ceiling lifts^{14,35,36,55,56,62,63,64} to reduce or eliminate many of the MSI risk factors associated with patient handling. Studies examining the effectiveness of using mechanical equipment have found decreases in injury rates, perceived decreases in risk of injury^{63,65}, as well as decreases in lifting and

stooped and twisted trunk positions⁶⁶; though some potential increased risks of cumulative loading have been noted (cumulative loading may result in chronic MSI conditions).

In an effort to introduce engineering controls to patient handling procedures, numerous healthcare organizations have adopted no-manual-lifting policies⁶⁷. In British Columbia, a Memorandum of Understanding was signed in 2001 between the Healthcare Unions and Employer which stated:

“ all parties agree to establish a goal of eliminated all unsafe manual lifts of patients/residents through the use of mechanical equipment, except where the use of mechanical lifting equipment would be of risk to the well-being of the patients/residents. The employer shall make every reasonable effort to ensure the provision of sufficient trained staff and appropriate equipment to handle patients/residents safely at all times, and specifically to avoid the need to manually lift patients/residents when unsafe to do so. If the use of mechanical equipment would be a risk to the well-being of the patients/residents, sufficient staff must be made available to lift patients/residents safely.

The first approach to the no-manual lift policy was through the introduction of mechanical floor lifts for lifting and transferring patients to reduce the risk of injury to staff^{68,69}. However, according to Garg et al.^{69,70}, patients found certain mechanical lifts to be more uncomfortable and less secure than some manual methods of patient handling. Furthermore, a study by Retsas et al. found that staff reported ease in manual lifting as the primary reason for not using mechanical devices³⁵. Mechanical floor lifts have also been reported to require more time and space to use⁶⁸. In fact, the major problem with using floor style mechanical devices is that they pose a large risk for injury: workers can trip over or run into them; lifts on wheels are not always stable; devices can be bulky, thus requiring space to store and to maneuver; considerable arm strength and back torsion are required to move the lifts when wheels are not in optimal condition; special restrictions in the work environment may make their use very cumbersome; they may not be compatible with the bed design, which may not allow the pushing of the lift's legs far enough under the bed; and they are not always available for easy use^{69,70,71}.

The use of mechanical interventions for lifting, transferring and repositioning patients is better than manually handling patients^{49,72}. However, if the appropriate equipment is not readily available, a sense of frustration is felt by the workers. When work processes are delayed, workers feel guilt and annoyance because patient care cannot be met in an efficient manner³⁵. Many traditional interventions to this problem, based on teaching workers proper body mechanics while manual lifting, have not yielded widespread success in reducing injury rates^{10,73}. The use of overhead ceiling lifts is usually the preferred method for reducing patient lifting injuries and is also favoured by healthcare workers^{74,63} over other types of equipment, such as floor lifts⁶³. Nevertheless, it should be noted that Collins et al.⁶² found floor lifts to be effective in reducing resident handling injuries and other injuries (e.g. slips and falls, struck by items, etc) as well as injuries associated with assaults and violent acts across six nursing homes. Staff did not find any significant differences between mechanical floor lifts and ceiling lifts in terms of perceived risk for injury⁷⁵; but responses were based entirely on perceptions of caregivers and therefore conclusions should not be drawn on the effectiveness of floor lifts.

In recent years, ceiling-mounted lift devices have been increasingly promoted as an alternative to conventional floor lifts for patient handling^{22,59,66,74,76}. Engst et al. describe a ceiling lift as consisting of a ceiling mounted track, an electric motor, and a patient sling. Ceiling lift tracks can be configured in numerous arrangements to accommodate many beds in a single room and even multiple rooms. Since ceiling lifts are positioned above bed level, they solve many of the common problems associated with floor lifts. This style of lift requires minimal physical effort to manoeuvre, offers the added feature of always being available for use in patient care areas, and requires less space to operate and store. There is generally two different types of ceiling lift motors: portable and fixed. Portable motors are easily attached and detached from the ceiling lift tracks, while fixed motors cannot be taken off of the ceiling lift tracks.

Holliday et al. reported significant time-savings when ceiling lifts were used as a method of lifting and transferring patients. Additionally, Zhuang et al.³⁷ found that using ceiling lifts to transfer residents from bed to chair eliminated approximately two-thirds of the exposure to low-back stress, compared to manual methods. Ceiling lifts can reduce many of the variables related to unexpected patient/resident behaviours and create a safer situation for healthcare workers^{10,71}.

Advantages of Ceiling Lifts

Ronald et al. evaluated the effectiveness of a ceiling lift program one year after implementation in a 125 bed extended care facility. Implementing a ceiling lift program significantly reduced (58% reduction, $p=0.011$) the rate of MSI to nurses and care aides caused by lifting and transferring. Spiegel et al. estimated the payback period for direct costs associated with this ceiling lift program to be 3.85 years. A shorter payback period of 1.96 years was estimated if indirect savings and the trend of rising compensation costs were also considered. A follow-up evaluation using three years of additional data revealed a 40% reduction in total claims costs, an 82% reduction in lift and transfer claims costs, and an 83% reduction in lost hours due to lift and transfer injuries, demonstrating the longer term effectiveness of ceiling lift systems⁷⁷.

The Interior Health Authority⁷⁸ conducted a case study of a no lift program at an 257 bed extended care facility with ceiling lifts installed over all of the resident beds. When examining patient handling injuries, there was a 53% reduction in WCB claims costs across the whole facility with one unit decreasing the cost of their patient handling injuries by 93% (\$9837.45 to \$467.87) over a five month period prior to staff using the ceiling lifts and five months after using the lifts. Expanding this analysis to one year pre- one year post installation, there was a 41% reduction in days lost due to patient handling injuries. In addition, the average cost per claim decreasing by 45% indicating that staff injuries were less severe following the ceiling lift initiative.

In a study of overhead ceiling devices in an extended care unit of a hospital, Engst et al.^{79,63} found a greater proportion of nursing staff used ceiling lifts to lift and transfer residents from bed to chair than manually or with floor lifts. In addition, perceptions of pain, discomfort and risk of injury were significantly decreased when lifting and transferring with the ceiling lift. This evaluation of perceptions is important to examine not only as a window into the relative risk of injury but to evaluate the acceptance of ceiling lifts as an effective intervention. In a study conducted by Miller et al. it was shown that when caregivers in both an intermediate care facility and extended care unit of a hospital began to use ceiling lifts, they perceived that the ceiling lifts made their job easier to perform, and preferred them over both mechanical floor lifts and manual methods for lifting and transferring patients. However, when examining perceived discomfort, those caregivers in the facility with the higher ceiling lift coverage perceived themselves to be at less risk for injury than those with

less ceiling lifts. Therefore, the influence of ceiling lifts on perceived risk of injury may be influenced by the relative need, availability of ceiling lifts, and the availability of alternate equipment such as mechanical floor lifts.

The most recent study on ceiling lifts was conducted by Miller et al.⁷⁵ that explored the effectiveness of portable ceiling lifts in a new multi-level care facility. It differs from the majority of other studies in that it evaluates the impact of portable ceiling lifts on extended care residents rather than fixed ceiling lifts; and the ratio of ceiling lifts to residents beds is one to six instead of one to one. Results of the study are consistent with those reported by Engst et al⁶³ in which it demonstrated reductions in patient handling injuries despite the type of ceiling lift used. It is recommended that proactive installation of ceiling lifts in newly built long-term care facility should be considered as an effective method to reduce patient handling injuries and their associated costs.

Many of the current ceiling lift studies have found dramatic reductions in the cost and severity of lifting and transferring tasks^{22,58,61,76,77}. However, studies have shown that ceiling lifts may not be suitable for all patient handling tasks^{58,59,61}. Ronald et al. demonstrated that ceiling lifts did not positively impact rates of MSI caused by repositioning patients in bed and that in a study conducted by Engst et al., repositioning injuries actually increased after the introduction of ceiling lifts into an extended care unit of a hospital even though staff perceived them to be the safest method for repositioning residents.

Conclusion

Patient handling is a high risk activity in healthcare with those nurses providing direct patient care at a higher risk of injury than those who do not. Higher incidence rates of MSI have been observed in healthcare workers compared to the general population. The implementation and use of appropriate engineering controls to reduce patient handling injuries has had a positive impact. However, it has been shown that mechanical floor lifts are more uncomfortable and less secure than some manual methods of patient handling. Therefore, many in healthcare have advocated the installation of ceiling lifts into healthcare facilities. Researchers has found that ceiling lifts eliminated many of the risk factors associated with patient handling and healthcare staff using ceiling lifts have found them to be safe and effective. However, ceiling lifts were not found to have the same impact in reducing the risk of injury or compensation costs when they were used for repositioning tasks, even though perceptions of risk when using ceiling lifts for repositioning were lower than for other methods.

Ceiling lifts are a relatively new intervention to decrease the risk of patient handling injuries and further evaluations and equipment trials are needed to better understand the impact of ceiling lifts on reducing risk of injury related to repositioning tasks and effectiveness in terms of the availability of ceiling lifts when and where needed, and the availability of alternate equipment such as floor lifts.

References

- 1 Wasiak R, Verma S, Pransky G, Webster B. Risk factors for recurrent episodes of care and work disability: Case of low-back pain. *Journal of Occupational and Environmental Medicine* 2004;46(1):68-76.
- 2 Muchmore L, Lynch WD, Gardner HH, Williamson T, Burke T. Prevalence of arthritis and associated joint disorders in an employed population and the associated healthcare, sick leave, disability, and Workers' Compensation benefits costs and productivity loss for employers. *Journal of Occupational and Environmental Medicine* 2003;45(4):369-378.
- 3 National Work Injury Statistics Program: Association of Workers Compensation Boards of Canada, 1998.
- 4 Choi BCK, Levitsky M, Lloyd RD, Stones IM. Patterns and risk factors for sprains and strains in Ontario, Canada 1990: an analysis of the workplace health and safety agency data base. *Journal of Occupational and Environmental Medicine* 1996;38:379-389.
- 5 French P, Flora LFW, Ping LS, Bo LK, Rita WHY. The prevalence and cause of occupational back pain in Hong Kong registered nurses. *Journal of Advanced Nursing* 1997;26:380-388.
- 6 Fujimura T, Yasuda N, Ohara H. Work-related factors of low back pain among nursing aides in nursing homes for the elderly. *Sangyo Eiseigaku Zasshi* 1995;37:89-98.
- 7 Garg A, Owen BD, Carlson B. An ergonomic evaluation of nursing assistants' job in a nursing home. *Ergonomics* 1992; 35: 979-995.
- 8 Leighton DJ, Reilly T. Epidemiological aspects of back pain: the incidence and prevalence of back pain in nurses compared to the general population. *Occup Med (Lond)* 1995; 45: 263-267.
- 9 Smedley J, Egger P, Cooper C, Coggon D. Manual handling activities and risk of low back pain in nurses. *Occup Environ Med* 1995; 52: 160-163.
- 10 Fragala, G., 2004. Striving for zero-lift in healthcare facilities, in: Charney, W., Hudson, A. (Eds), *Back injury among healthcare workers: causes, solutions, and impacts*. Lewis Publishers., Boca Raton, pp. 53-61.
- 11 Yassi A, Khokhar J, Tate R, Cooper J, Snow C, Vallentyne S. The epidemiology of back injuries in nurses at a large Canadian tertiary care hospital, implications for prevention. *Occupational Medicine* 1995;45(4): 215-220.
- 12 Burton AK, Symonds TL, Zinzen E, Tillotson KM, Caboor D, Van Roy P, Clarys JP. Is ergonomic interventions alone sufficient to limit musculoskeletal problems in nurses. *Occupational Medicine* 1997; 47(1):25-32.
- 13 French P, Flora LFW, Ping LS, Bo LK, Rita WHY. The prevalence and cause of occupational back pain in Hong Kong registered nurses. *Journal of Advanced Nursing* 1997;26:380-388.
- 14 Engkvist IL, Hagsberg M, Hjelm EW, Menckel E, Ekenvail L, PROSA study group. The accident process preceding overexertion back injuries in nursing personnel. *Scandinavian Journal of Work and Environmental Health*; 24(5):367-375.
- 15 Ferguson D. Strain injuries in hospital employees. *Medical Journal of Australia* 1970;February:376-379.
- 16 Meyer JD Muntaner C. Injuries in home healthcare workers: An analysis of occupational morbidity from a state compensation database. *American Journal of Industrial Medicine* 1999;35:295-301.
- 17 Fuortes LJ, Shi Y, Zhang M, Zwerling C, Schootman M. Epidemiology of back injury in university hospital nurses from review of Workers' Compensation Records and a case-control survey. *Journal of Occupational Medicine* 1994; 36(9):1022-1026
- 18 Ono Y, Lagerstrom M, Hagberg M, Linden A, Malke B. Reports of work related musculoskeletal injury among home care service workers compared with nursery school workers and the general population of employed women in Sweden. *Journal of Occupational and Environmental Medicine* 1995;52:686-693.
- 19 Jenson RC. Back injuries among nursing personnel related to exposure. *Applied Occupation Environmental Hygiene* 1990;5(1):38-45.

-
- 20 Koehoorn, M., Lowe, G.S., Rondeau, K.V., Schellenberg, G., Wagar, T.H., 2002. Creating high-quality healthcare workplaces: Canadian Policy Research Networks (CPRN discussion paper no. W/14 Retrieved April 21, 2003 from URL: <http://www.cprn.com/cprn.html/>
- 21 Yassi, A., Ostry, A., Spiegel, J., Walsh, G., de Boer, H.M., 2002. A collaborative evidence-based approach to making healthcare a healthier place to work. *Hosp Q.* 5, 70-78.
- 22 Engst, C., Chhokar, R., Miller, A., Yassi, A., 2004 Preventing back injuries to healthcare workers in British Columbia, Canada and the ceiling lift experience, in: Charney, W., Hudson, A. (Eds), *Back injury among healthcare workers: causes, solutions, and impacts.* Lewis Publishers., Boca Raton, pp. 253-63.
- 23 Workers' Compensation Board of British Columbia. 2004 Injury Rates by Year and by Broad Groups of the 1991 SOC, for Injury years 1999-2003. Accessed from the World Wide Web November 15, 2004 from www.worksafebc.com.
- 24 Cato C, Olson DK, Studer M. Incidence, prevalence, and variables associated with low back pain in staff nurses. *AAOHN* 1989;37:321-327.
- 25 Koehoorn M, Sullivan T. The health of nursing personnel: a summary of research findings to inform the development of a national survey in Canada. Working paper #172, Institute for Work and Health, University of Toronto, 2002.
- 26 Niedhammer I, Lert F, Marne M. Back pain and associated factors in French nurses. *International Archives of Occupational and Environmental Health* 1994;66:349-57.
- 27 Josephson M, Lagerström M, Hagberg M, Wigaeus Hgelm E. Musculoskeletal symptoms and job strain among nursing personnel: a study over a three year period. *Journal of Occupational and Environmental Medicine* 1997;54:681-5.
- 28 Larese F, Fiorito A. Musculoskeletal disorders in hospital nurses: a comparison between two hospitals. *Ergonomics* 1994;37:1205-11.
- 29 Moens G, Dohogne T, Jacques P. Prevalence of back pain among health care workers. Landsberg: Ecomed, 1993.
- 30 Owen, B.D., 2004. Magnitude of the problem, in: Charney, W., Hudson, A. (Eds), *Back injury among healthcare workers: causes, solutions, and impacts.* Lewis Publishers., Boca Raton, pp. 5-12.
- 31 Bork, B., Cook, T., Rosecrance, J., Engelhardt, K., Thomason, M., Wauford, I., Worley, R., 1996. Work related musculoskeletal disorders among physical therapists. *Phys Ther.* 76(8), 827-35.
- 32 Garg A, Owen B. Reducing back stress to nursing personnel: an ergonomic intervention in a nursing home. *Ergonomics* 1992;35:1353-1375.
- 33 Hollingdale, R., Warin, J., 1997. Back pain in nursing and associated factors: a study. *Nurs Stand.* 11, 35-38.
- 34 Ostry, A.S., Yassi, A., Ratner, P.A., Park, I., Tate, R., Kidd, C., 2003. Work organization and patient care staff injuries: The impact of different care models for "alternate level of care" patients. *Am J Ind Med.* 44, 392-399.
- 35 Retsas, A., Pinikahana, J. Manual handling activities and injuries among nurses: Australian hospital study. *Journal of Advanced Nursing*, 2000; 31(4):875-883.
- 36 Marras WS, Davis KG, Kirking BC, Bertsche PK. A comprehensive analysis of low-back disorder risk and spinal loading during the transferring and repositioning of patients using different techniques. *Ergonomics* 1999;42:904-926.
- 37 Zhang Z, Stobbe TJ, Collins JW, Hsiao H, Hobbs GR. Biomechanical evaluation of assistive devices for transferring residents. *Applied Ergonomics* 1999;30:285-294.
- 38 Vasiliadou A, Karvountzis GG, Soumilas A, Roumeliotis D, Theodosopoulou E. Occupational low-back pain in nursing staff in a Greek hospital. *Journal of Advanced Nursing* 1995;21(1):125-130.
- 39 Owen BD, Garg A, Jenson RC. Four methods for identification of most back-stressing tasks performed by nursing assistants in nursing homes. *International Journal of Industrial Ergonomics* 1992;9:213-220.
- 40 Workers Compensation Board of British Columbia., 2002. Statistics 2002. WCB of British Columbia, Vancouver, Canada.

-
- 41 Sewell J. Repositioning in bed, Injury prevention. A study of staff repositioning injuries in a 508 bed group of extended care sites. Finding Solutions, Research at the Workers' Compensation Board of BC 1999. WCB of BC, Richmond BC.
- 42 Josephson M, Vingard E, MUSIC-Nortalje Study Group. Workplace factors and care seeking for low-back pain among female nursing personnel. *Scandinavian Journal of Work, Environment and Health* 1998;24(6):465-472.
- 43 Jorgensen S, Hein HO, Gyntelberg F. Heavy lifting at work and risk of genital prolapse and herniated lumbar disc in assistant nurses. *Occupational Medicine* 1994;44:47-49.
- 44 Burdorf A, Sorock G. Positive and negative evidence of risk factors for back disorders. *Scandinavian Journal of Work, Environment and Health* 1997;23:243-256.
- 45 Nelson, A., Fragala, G., 2004. Equipment for safe patient handling and movement, in: Charney, W., Hudson, A. (Eds), *Back injury among healthcare workers: causes, solutions, and impacts*. Lewis Publishers, Boca Raton, pp.121-135.
- 46 Garg, A., Moore, J.S., 1992. Prevention strategies and the low back in industry. *J Occup Med.* 7(4), 629-640.
- 47 Marras, W.S., Lavender, S., Leurgans, S., Fathallah, F., Ferguson, S., Allread, W.G., Rajulu, S., 1995. Biomechanical risk factors for occupationally related low back disorders. *Ergonomics.* 38, 377-410.
- 48 Waters, T.R., Putz-Anderson, V., Garg, A., Fine, L.J., 1993. Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics.* 36, 749-776.
- 49 Lloyd, J.D., 2004. Biodynamics of back injury: manual lifting and loads, in: Charney, W., Hudson, A. (Eds), *Back injury among healthcare workers: causes, solutions, and impacts*. Lewis Publishers., Boca Raton, pp. 27-35.
- 50 Anderson, B.T., 2001. Sudden movements of the spinal column during health-care work. *Int J Ind Ergon.* 28(1), 47-53.
- 51 de Looze, M.P., Zinzen, E., Caboor, D., van Roy, P., Clarijs, J.P., 1998. Muscle strength, task performance and low back load in nurses. *Ergonomics.* 41, 1095-1104.
- 52 Dempsey, P.G., 1998. A critical review of biomechanical, epidemiological, physiological and psychophysical criteria for designing manual materials handling tasks. *Ergonomics.* 41, 73-88.
- 53 McGill, S., 2002. *Low back disorders: Evidence based prevention and rehabilitation*. Human Kinetics, Windsor, Canada.
- 54 Engels JA, van der Gulden JWW, Senden TF, Kolk JJ, Binkhorst RA. The effects of an ergonomic-education course, postural load, perceived physical exertion, and biomechanical errors in nursing. *International archives of Occupational and Environmental Health* 1998;71:336-342.
- 55 Ljungberg AS, Kilbom A, Haag GM occupational lifting by nursing aides and warehouse workers. *Ergonomics* 1989;32(1):59-78.
- 56 Varcin-Coad, L., Barrett, R., 1998. Repositioning a slumped person in a wheelchair. A biomechanical analysis of three transfer techniques. *American Association of Occupational Health Nurses* 46(11), 530-536
- 57 Engst C, Yassi A, Mughal WA. Evaluating the effectiveness and cost-benefit of ceiling lift devices in reducing patient handling injuries to caregivers. In: *Association of Canadian Ergonomists Conference; 2003; London, Ontario.*
- 58 Ronald LA, Yassi A, Spiegel J, Tate RB, Tait D, Mozell MR. Effectiveness of installing overhead ceiling lifts. Reducing musculoskeletal injuries in an extended care hospital unit. *AAOHN* 2002;50:120-127.
- 59 Villeneuve J. The ceiling lift: An efficient way to prevent injuries to nursing staff. *Journal of Healthcare Safety, Compliance, and Infection Control* 1998:19-23.
- 60 Yassi A, Cooper J, Tate R, Gerlack S, Chase R, Marceniuk M, Daynard D, Massey K. A Randomized controlled trial to prevent lift and transfer injury of health care workers. *Spine* 2001;26:1739-1746.

-
- 61 Spiegel J, Yassi A, Ronald LA, Tate RB, Hacking P, Colby T. Implementing a resident lifting system in an extended care hospital. Demonstrating cost-benefit. *AAOHN* 2002;50:128-134.
- 62 Collins, J.W., Wolf, L., Bell, J., Evanoff, B. An evaluation of a "best practices" musculoskeletal injury prevention program in nursing homes. *Injury Prevention*, 2004; 10(4):206-211.
- 63 Engst, C., Chhokar, R., Miller, A., Tate, R.B., Yassi, A. Effectiveness of overhead lifting devices in reducing the risk of injury to care staff in extended care facilities. *Ergonomics*, 2005; 48(2):187-199.
- 64 Siddharthan, Kris. Nelson, Audrey. Tiesman, Hope. Chen, FangFei. Cost effectiveness of a multifaceted program for safe patient handling. *Advances in Patient Safety*, 2005; 3(1):347-358.
- 65 Miller A, Engst C, Yassi A. The influence of ceiling lifts on risk perception in two healthcare environments. 35th Annual Conference of the Association of Canadian Ergonomists 2004. ACE., Windsor, Canada.
- 66 Holliday, P.J., Fernie, G.R., Plowman, S., 1994. The impact of new lifting technology in long term care. *American Association of Occupational Health Nurses Journal* 42(12), 582-589.
- 67 Occupational Health and Safety Agency for Healthcare in British Columbia. Memorandum of understanding with regards to manual patient handling between the Association of Unions and Health Employers Association of British Columbia 2001: (Vancouver, BC: Occupational Health and Safety Agency for Healthcare in British Columbia).
- 68 Owen, B.D. 1988, Patient handling devices: an ergonomic approach to lifting patients, in F. Aghazadeh (ed.), *Trends in Ergonomics/Human Factors V*. (North-Holland: Elsevier Science Publishers, Amsterdam), 721-727.
- 69 Garg, A., Owen, B.D., Beller, D., Banaag, J., 1991. A biomechanical and ergonomic evaluation of patient transferring tasks: bed to wheelchair and wheelchair to bed. *Ergonomics* 34(3), 289-312.
- 70 Garg, A., Owen, B.D., Beller, D., Banaag, J., 1991. A biomechanical and ergonomic evaluation of patient transferring tasks: wheelchair to shower chair and shower chair to wheelchair. *Ergonomics* 34(4), 407-419.
- 71 Daynard, D., Yassi, A., Copper, J.E., Tate, R., Norman, R., Wells, R., 2001. Biomechanical analysis of peak and cumulative spinal loads during simulated patient-handling activities: a substudy of a randomized controlled trial to prevent lift and transfer injury of health care workers. *Appl Ergon.* 32,199-214.
- 72 Zhang, Z., Stobbe, T.J., Collins, J.W., Hsiao, H., Hobbs, G.R., 2000. Psychophysical assessment of assistive devices for transferring patients/residents. *Appl Ergon.* 31, 35-44.
- 73 Keir, P.J., MacDonell, C.W., 2004. Muscle activity during patient transfers: a preliminary study on the influence of lift assists and experience. *Ergonomics.* 47(3), 296-306.
- 74 Gamble, E. 1998, Evaluation of interventions developed to prevent/reduce musculoskeletal injuries in healthcare workers caused by patient handling. Finding Solutions: Research at the Workers' Compensation Board (WCB). Richmond, BC:WCB of British Columbia.
- 75 Miller, A., Engst, C., Tate, R.B., Yassi, Annalee. Evaluation of the effectiveness of portable ceiling lifts in a new long-term care facility. *Applied Ergonomics*, 2006; 37(3):377-385.
- 76 Engst, C., Yassi, A., Mughal, W., 2003. Evaluating the effectiveness and cost-benefit of ceiling lift devices in reducing patient handling injuries to care givers. 34th Annual Conference of the Association of Canadian Ergonomists. ACE., London, Canada.
- 77 Occupational Health and Safety Agency for Healthcare in British Columbia. 2003, The ceiling lift project at St. Joseph's General Hospital: Follow-up evaluation August 2002, Project Update, (Vancouver, BC: Occupational Health and Safety Agency for Healthcare in British Columbia)

78 Interior Health Authority. Cottonwoods extended care unit summary of the No Lift Program review January 2002- December 2002. Interior Health Authority March 2003. Kelowna Canada.

79 Engst, C., Chhokar, R., Miller, A., Tate, R., & Yassi, A. (2003). Effectiveness of overhead lifting devices in reducing the risk of injury to care staff in extended care facilities. (Accepted for Publication in Ergonomics).