Biomechanical guideline for occupational low back disorder prevention: A field assessment and prevention guideline setup

January 2005

Occupational Safety and Health Council

Abstract

The aims of this study were to:

(1) Identify, evaluate and quantify potential ergonomic risk factors of Occupational Lower Back Disorder (OLBD) at low physical and high physical requirement jobs in Hong Kong,
(2) Provide scientific knowledge of OLBD and the safety guideline in preventing OLBD to different tasks.

In this study, the L4-L5 compression force of different working postures by 100 subjects, who work at different companies, were evaluated using 4D Watbak computerized model. Results show that high physical requirement jobs, such as construction worker and bearer, have higher compression values than others. Different sitting postures have different effects on the spine. Not all manual material handling tasks showed risk of low back pain. In conclusion, there was a direct relationship between occupation and low back pain. Correct postures reduced the chance of getting low back pain. Apart from the posture, the weight of objects being carried, duration of the task, workplace design and the speed used to perform the task also affect the forces acting on spine. Therefore, the redesign of workplace and preventative measurement are needed in order to reduce the risk of low back pain.

Introduction

The clinical problem of lumbar region of spine is referred as low back disorder (OLBD) and has long been recognized. Occupational low back disorders (OLBD) include acute low back injury and chronic low back pain. They are the most common and costly occupation health and safety problems in the working population (Waxman R, 2000). According to a 1999 study, in Hong Kong, an estimation of 57.1% and 42.1% of the population suffers from low back pain at least once in their life time and at least once within the past year respectively (Leung ASL, 1999). In comparison with other places internationally, even though the life prevalence rate is lower, its 12-month prevalence rate is considerably higher than other countries in the world (UK 36-40%, New Zealand 30.7%, Denmark 39.1 %, China 30 %, and U.S. 15-20%) (Leung ASL, 1999; Jin K, 2000; Standiford C, 2003). As one can see, low back pain is prevalent in Hong Kong and is one of the most LBP-afflicted communities in the world.

Although 16% to 20% of all workers' compensation cases involved low back pain, 34% to 40% of the total cost was spent on these cases. The low back disorders (LBD) may be asymptomatic but may eventually progress to different stages of illness, sometimes physical disabilities (Ferguson, 1997). OLBD is a wide-spread occupational problem affecting a spectrum of occupations ranging from the manual labourers to the office workers (Lau EM, 1995). More people take off work because of LBD than any other disease or injury. There are about 2% of the employed population who are forced to take off work every year because of low back pain (Lau EM, 1995). Having high economic impact, OLBD is a serious disorder affecting all sectors of the society.

OLBD problems are caused by multiple and complex factors and are rarely induced by direct trauma (Leino-Arjas P, 2002). Most of them are the result of overexertion. There were several studies on different risk factors for low back disorder. One of the important ones is static muscle load. It may be caused by the working posture, work task, bad lighting condition and visual strain (Aaras A, 1997). In addition, studies showed that postures have effects on OLBD. Lifting, pushing, pulling and even sitting postures can induce OLBD when improper tools and techniques were used. According to studies of workers' compensation claims, manual material handling tasks were associated with low back pain in 25%-70% of injuries (Cust et al, 1992). This is mainly due to excessive loading on the spine which creates large spinal compressive forces. It has been suggested that low back loading is responsible for vertebral end-plate fracture, disc herniation and nerve root irritation (Chaffin and Andersson, 1984). In biomechanical assessments models, large moments were observed in the trunk area during manual lifting. Large compressive forces also act on the spine during lifting. Epidemiologic studies indicated that many tasks can cause the onset of low back pain in material handling jobs such as lifting, pulling, pushing, carrying and lowering. Cady et al, 1979 found that bending, twisting, falling and slipping also induce significant risk factors to the onset of low back pain.

Traditionally, assessments of LBD risk were focused mainly on static estimation of spinal compression (NIOSH, 1981). However, biomechanical causes of OLBD were mainly due to spine loading, disc tolerances associated with asymmetric loading of the trunk. Dynamic trunk motion components of lifting were associated with greater spine loading in laboratory experiments (Marras et al, 1995). Studies showed that there was the effect of lateral shear forces on trunk motions and the increase of strain during increased speed of motion which was caused by the viscoelastic properties of the spine (Marras et al, 1995).

On the other hand, several studies stressed that biomechanical considerations are only part of the risk assessment (Waters et al, 1993). Other factors such as age, sex, muscle strength and psychosocial characteristics should be considered as well (Cox JM, 1999). Based on the high correlation between motion dynamics and OLBD, spinal and biomechanical load dynamics may be associated with the mechanism of injury (Marras et al, 1993). It is premature to assume the relationship between OLBD and spinal compression because there is evidence which shows that the biomechanics of low back pain is significantly more complex than simple static estimates of spinal compression (Marras et al, 1993). Therefore preventative measure is the most important solution for OLBD (Staal JB, 2002).

The objectives of this study are (1) to identify, evaluate and quantify potential ergonomic risk factors of OLBD at low physical to high physical requirement jobs in Hong Kong; and (2) to provide scientific knowledge for OLBD and the safety guideline for preventing OLBD to individual working task. The outcome of this study can help both employers and employees to prevent possible risks in OLBD. Identifying some critical risks in workplace may contribute to the development of innovative products for OLBD prevention.

Methods

***Participants**:* Subjects from different occupations were invited to join the study(see Appendix I for occupations). Invitation letters (see Appendix II) with detail information of the project were issued to the participating companies and the list of the companies has been attached in Appendix I. The participation of this study was completely voluntary and with the consent of the subjects. Total 100 subjects were tested in this study.

***Study design**:* The physical characteristics of the participants such as gender, and weight were recorded. The motion of the participants of their routine task was recorded by digital camera. Other task information including load, time and posture were also recorded for analysis. Load represents the force magnitude and its direction acting on each hand. Time represents the total time needed to complete each action. And the posture is represented by the x, y coordinated of the major body joints. All of the data was entered into a computerized model; and the 4D Watbak was used for analysis. The results were interpreted according to the parameters given from the programme such as L4-L5 compression force value. Comparison can be made by dividing the results into different parts according to their different job nature.   Finally, based on the above analysis, advice on OLBD risk prevention is provided to both employers and employees.

***Analysis**:* The collected data was analysed by 4D Watbak, a software developed by University of Waterloo, Canada. The PI of this study was one of the designer for the 4D Watbak. It is a biomechanical modelling tool that calculates, according to the posture of a person and the forces acting his hands, the reaction forces and moments of force at the elbow, shoulder, L4-L5 lumbar spine, hip, knee and ankle joints (see Appendix IV for details). The computed results are then evaluated by another computer programme, a modified NIOSH Tool. The programme is originally based on NIOSH equation. It has been further modified with standard Manual Materials Handling assessment tools Snook Tables (1981) and the University of Waterloo's Back assessment program, Watbak. Summary of forces which acted on different parts of the body was given. The compression force values acting on L4-L5, which are calculated from the software, are compared with the compression limits recommended by NIOSH. These two limits are referred to as Action Limit & Maximal permissible limit (NIOSH, 1981). When a particular task produces lumbar compression values exceeding the Action Limit (AL) of 3433 N, the job is considered potentially hazardous for some workers. In these cases, safety measures such as the introduction of educational programs on how to handle heavy loads and/or protocol redesign of the tasks will be essential for preventing injuries. When the compression values exceed the Maximal Permissible Limit (MPL) of 6376 N, the job is considered hazardous to most workers. Measures such as lifting assists, work place or container redesign are required. By comparing the compression forces of different tasks, the potentially hazardous tasks were identified and the risk of low back pain was estimated. These data can also be helpful for the design of proper postures in lowering the compression force for potentially hazardous tasks.

Results

Within the 100 subjects recruited for this study. We have mainly selected 73 subjects for analysis due to the limited of time and funding from this study. Also, some postures did not fit into our models. Their occupations belong to various job types ranging from low to high physical requirement jobs. Table 1 shows the mean L4-L5 compression force and standard deviations (SD) from different postures of different job types. Results show that a higher potential hazard of low back pain exists for workers whose jobs have high physical requirements. Among the postures analysed in this study, the data obtained from the bearer and construction worker demonstrates that occupation and low back pain are indeed directly related. The compression force values which exceeded the NIOSH recommended limits were 4427 N, 8592 N, 5054 N and 3749 N. However, the results also showed that not all postures involved in these jobs induced low back pain.

Sitting posture is commonly involved in low physical requirement task. It has a relatively low lumbar compression force (394 N, 688 N and 484 N) than the other working postures. However, results showed that the force on L4-L5 during floor sweeping (444 N) is lower than it is during writing (688 N) and driving (484 N). This may imply that factors other than poor sitting postures may also be involved in low back pain (e.g. the ergonomic design of the chair).

Table 1. Lumbar mean compression and SD of different job types.

Job type	Job nature	L4-L5 compression (N)
Waiters	Provide service (10 hrs/day)	2467 ± 322
Construction workers	Road Digging (10 hrs/ day)	4427 ± 392*
	Wall Drilling (10 hrs/ day)	8592 ± 1422*
Nurse (Females)	Patient Lifting(15 mins/day)	1626± 122
Bearer from shipping Co (Males)	Loads Pulling(10 hrs/ day)	1460± 92
	Loads lifting (10 hrs/ day)	5054 ± 292*
Bearer from supermarket (Males)	Loads Pulling(10 hrs/ day)	961± 129
	Loads lifting (10 hrs/ day)	3749 ± 590*
	Loads Carrying(10 hrs/ day)	4042± 1426
	Loads Lifting to 2 m high (10 hrs/ day)	1830± 274
Decorator (Males)	Wall Digging(10 hrs/ day)	1635± 185

Clerk (Females)	Typing (8 hrs/day)	394± 68
	Writing (8 hrs/day)	688± 43
Cleaner (Females)	Table Cleaning (8 hrs/day)	1231± 94
	Floor Sweeping(8 hrs/day)	444± 32
Driver (Males)	Driving (10 hrs/ day)	484± 41

* = Spine compression limits exceed the limits recommended by NIOSH

It was found that there is a difference in spinal compression force in the tasks performed by drivers and by clerical staff who both belong to the low physical requirement task category. Figure 1 shows the comparison of L4-L5 compression for different sitting postures. The sitting posture involved in writing has the highest lumbar compression (688 N) as compared with typing (394 N) and driving (484 N); however, all of the sitting postures do not exceed the NIOSH limits.

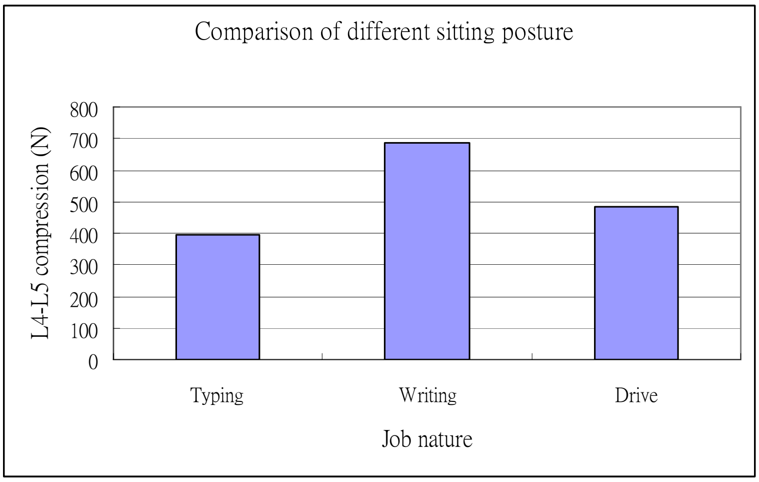
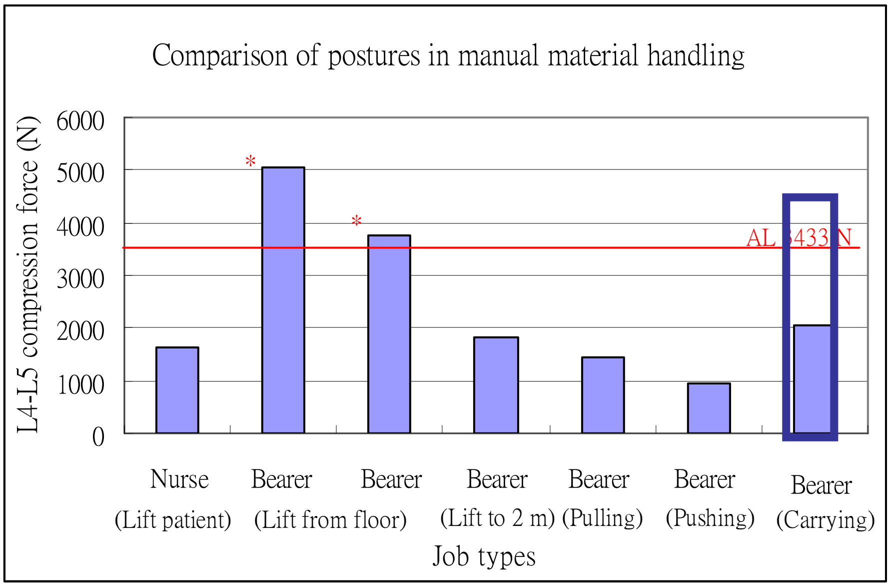


Figure 1. Comparison of different sitting postures
(Representative graph of individual with different sitting postures)

Manual material handling involves various postures such as lifting, pulling, pushing and carrying. Lifting postures are common in most of the job types and previous studies have shown that it is a risk factor to low back pain. **Figure 2** shows the comparison of L4-L5 compression force observed in different postures in manual material handling. Results showed that the lifting posture, which is a common task for bearer, has a high compression force. Among different lifting postures, lifting objects from the floor stresses the spine more than other postures. Such posture produces compression values of 3749 N and 5054 N which exceed the AL recommended by NIOSH. The posture of lifting objects to 2 m high shelf produces a relatively low compression (1830 N) on L4-L5 than the posture of lifting objects from the ground.

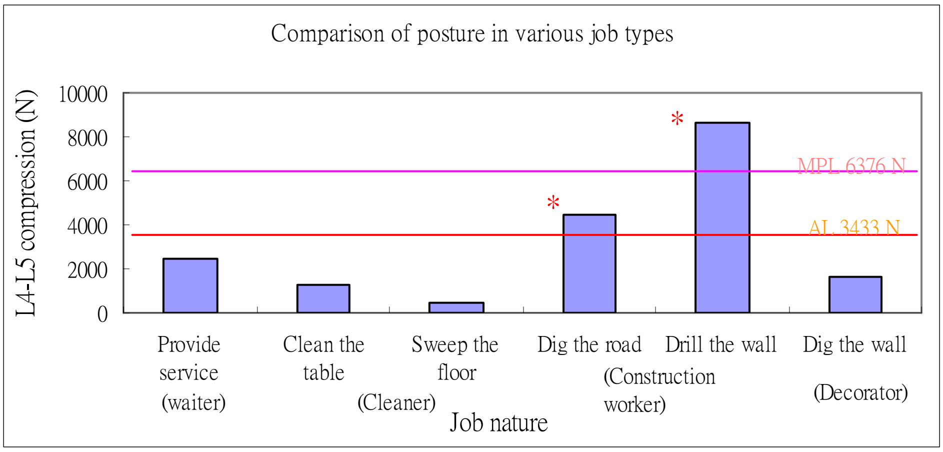
Results also show that compression force acting on the spine is acceptable during pulling (1460 N) and pushing (961 N) but the force for pulling is greater. The posture for carrying objects (carrying objects refer to super market workers) seems to be easier than transporting patient from bed to bed, but the compression force of carrying objects (4042 N) is much higher than that of lifting patient (1626 N) in some cases. However, carrying heavy objects in supermarkets could be prevented by using other equipment, but lifting patients in Hospital in most conditions are taken by nurses.



* = L4-L5 compression exceeds the action limit (AL) of 3433 N.

Figure 2. Comparison of lifting postures in different job types

In this study, other job types are also evaluated. Comparison of L4-L5 compression values of different postures in different job types is represented in figure 3. Results show that the postures involved in construction workers produce the highest compression values (4427 N and 8592 N). Both of them exceed the NIOSH action limit. The posture of wall drilling, (here we mainly analyzed the posture drill to ceiling), a common task of construction workers, gives the values of 8592 N. This data exceeded the MPL of 6376 N. It indicates that this task is considered hazardous to most construction workers. The postures of wall drilling for construction workers and wall digging for decorators are similar, but the resulting compression forces are quite different. The compression force for wall or ceiling drilling (8592 N) is five times more than that of wall digging (1635 N). For the intermediate physical requirement jobs such as floor sweeping and table cleaning, the postures involved produce low compression values. The compression force produced by the floor sweeping posture is the lowest one (444N).



* = L4-L5 compression exceeds the action limit (AL) of 3433 N.

Figure 3. Comparison of posture in different job types

Discussion

The objectives of this study were to identify and evaluate potential ergonomic risk factors of OLBD in Hong Kong and to provide the safety guideline for prevent OLBD to each individual working task. It was found that it is the improper postures involved in some occupations which may lead to low back pain. Results show that adopting a proper posture can reduce the risk of low back pain even when heavy physical work is performed. The weight of objects, duration of the task, workplace design and the speed used to perform the task also affected the forces acting on spine. Therefore, the redesign of workplace and preventative measurement are required to reduce the risk of low back pain. Safety guideline was given to the employers and employees about performing different tasks that exceeding 80% of NIOSH Limits (2746 N) as their reference to prevent from damage to the spine.

In this study, subjects at different sitting postures during typing, writing and driving were observed. In comparing the compression forces between these tasks, it was found that the compression force observed in typing was lower than that in writing (Table 1). During writing, subjects typically adopt a forward leaning posture which maintains the minor lordosis of the spine. On the other hand, during typing, an upright posture was observed. To maintain the upright trunk posture, the lumbar spine must adjust for lordosis when the pelvis rotates forward (Chaffin et al, 1991). Moreover, the additional lumbar support of the chair during typing further reduces the compression force (Chaffin et al, 1991). Therefore, a lower compression force was observed for typing as there is lumbar support. The force increases when support of the spine is no longer available which is observed in the case of the writing postures.

For the driving posture, a compression force of 484 N acting on the spine is observed. The observed force comes from the adoption of backward leaning posture which is obtained by a backward rotation of the pelvis. The spine tends to become kyphotic (Chaffin et al, 1991). The compression force on the spine is increased when this posture is adopted. Conversely, when the driver leans on the backrest, part of the body weight is transferred to the backrest. Therefore, the load on the lumbar spine caused by the upper body weight is reduced. (Chaffin et al, 1991) In addition, the more the driver leans backward, more load is transferred to the backrest. This further lowers the compression force on the spine during driving. (Chaffin et al, 1991). Therefore, the spines of drivers usually experience higher compression force when they are exposed to vibrational forces. The reason being the moment arm of spine is increased during vibration which may cause additional pelvic rocking and amplification of vibration. (Chaffin and Andersson,1984). Also, ligaments become softer and weaker from fatigue due to vibrational loading (Riddell et al, 1966; Hertzberg and Manson, 1980; Wiesman et al, 1980). Consequently, the fatigued back muscles are unable to protect the spine from adverse loads due to the vibrational environment. (Pope et al, 1985).

Sitting is a common posture in the workplace and is typical in office setting. However, prolonged period of sitting can lead to discomfort which is caused by the continuous static loading of muscles and joints. In the study, Hult et al has demonstrated that there is an increase in back symptomology in subjects with back pain when required to sit for prolonged period (Hult et al, 1954). Andersson and Chaffin has shown that prolonged sitting, along with vibration exposure, increases the risk of low back pain.

Lifting is a common task preformed on manual material-handling job. Our results show that lifting objects from the floor generates more loading on the spine than lifting objects to elevated shelves. In our study, different lifting postures were adopted by the bearers (see Appendix III). As the weights of objects are different, it is difficult to make a direct comparison between this two lifting actions. Both of their actions involved bending their spines but one with a large degree of knee flexion. Flexion of spine leads to the centering of the weight towards the spine. It also increases the length of moment arms which creates a large torque on the spine. And these are the reasons why there is a higher compression force (5054 N and 3749 N) acting on spine. Lifting objects to elevated shelf has a relatively low compression force (1830 N) because shoulder and arm muscles are involved in this posture.

Pulling and pushing of objects are commonly assisted by material handling devices such as trolley rather than on the objects directly. Figure 2 shows that the compression force is higher during pulling (1460 N) than pushing (961 N). For pushing, the external force moments act in extension and is stabilized by the muscles rectus abdominus rather than the erector spinae (Andersson GBJ et al, 1997). As for pulling, the compression force depends on the grip height (Andersson GBJ et al, 1997). Moreover, the torso tends to incline more in pushing which helps counterbalancing the push force on the hands. (Andersson, 1997).

Among all the analysed postures, the compression force on spine is highest for construction worker in road digging (4427 N) and wall drilling (8592 N). During road digging, flexion of the spine exerts force on the lumbar. The use of the drill further increases the compression forces due to the excessive vibrational effects on the entire body. The postures of wall drilling and wall digging are similar. Wall drilling exerts greater force on the spine because the drill itself (load) is heavier and the vibrational force generated is greater. The posture for wall digging, however, involves both the shoulder and the arm muscles which help to lower the compression force on the spine (1635 N).

Heavy manual work is associated with low back pain (Frymoyer, 1991). There is a significant association between low back pain and improper lifting with a flexed spine (White and Panjabi, 1990). Among different lifting techniques, stooped posture, in which the spine is bent forward and the legs are kept straight, is commonly used but is regarded to be ergonomically incorrect. Instead, squat posture should be used for lifting. During squatting, the spine is kept upright and the lower extremities are bent, which altogether generate less compression force on spine. Semi-squat posture is the hybrid of stooping and squatting. Thus, the load on the spine is also between that of stoop and squat lifting. In both the stoop and the squat lifting, the center of mass is located outside of the body. However, for stoop lifting, the weight is centered in the middle of the back; while in the squat lifting, the weight concentrates directly vertical to the knee. Consequently, squat lifting generates a reduced torque and requires less overall motion, which would reduce the chances of injury on the lower back. However, loss of balance during lifting remains to be the risk of squat-lifting and may cause excessive loading on the spine. Therefore, albeit squat lifting is useful, it should be used for light-weighted objects only.

From this study, we have the difficulties to suggest the correct postures for each job we have observed, this is one of the limitations. So far, we have not found reported correct postures in published papers for most of the jobs that were included in this study. The reasons may be the job nature is complicated, the suggested correct posture may not be suitable for every person, or there is no ideal posture to suggest for the time being. Furthermore, to effectively prevent low back injuries, training ourselves to fit the jobs is also important and related workshops, training class should conducted to meet the purpose.

In conclusion, shearing forces, axial torsion and flexion-relaxation forces increase the spinal load during lifting (Frymoyer et al,1980). Bending and twisting during lifting have also been linked to low back pain (Frymoyer et al, 1980). Thus, lifting can be quite hazardous for low back injuries as compared with other analyzed, routine occupational tasks.

It is surprising to observe that the spinal compression force is relatively low (1626 N) for nurse in this study. According to a report (Royal College of Nursing, 1980), nurses have high low back pain incidences because of their heavy physical activity requirements such as patients' physical manipulation and common occurrence of sudden, awkward lifts (Kumar S, 1999). It is suggested the lower compression force is resulted from the shortened time required for nurses in performing these tasks. Other factors may also involved regarding higher low back pain incidences.

Most of the highly physical intensive tasks are performed by male which means that male would have a higher risk of low back pain than female would. Occupations such as construction workers and bearers are generally prone to experience a higher force on the spine which effectively increases their risk of low back pain.

Low back pain can be prevented by using several approaches such as ergonomic workplace design, education, training, and fitness programs. It is estimated that up to 50 % - 80% of low back injuries can be prevented if workplaces are properly designed.

Workplace design and Ergonomics

Designing a proper workplace is crucial to minimize the stresses on the spine and to prevent low back pain. Study shows that low back pain is often caused by slipping, tripping and falling (Chaffin et al, 1991). Proper design of workplace reduces the accident rate caused by common risk factors such as slipping and hence prevents low back pain (Chaffin et al, 1991).

In work place design, adequate leg room should be considered for seated workers. If there is insufficient free space, the body is unnaturally positioned; employees are prone to fatigue (Andersson GBJ et al, 1997). Properly designed chairs should be used for seats. A forward-sloped seat helps to prevent the cause of compression of the posterior thighs (Chaffin et al, 1991). The backrest should be adjustable both in horizontal and vertical planes so that the lumbar spine can be supported and movement of the spine or arms are not restricted. The backrest should be convex in shape from top to bottom to conform to the normal lumbar lordosis and concave from side to side to conform to human anatomy and to support the occupant in the chair (Chaffin et al, 1991). The armrests should not be too high so that the occupant does not raise the shoulders and abduct the arms (Chaffin et al, 1991). Apart from the workplace redesign, organization of working time is also important so that changes of work and rest are provided (Andersson GBJ et al, 1997).

Preventative measure for manual material handlings can be done by the design of equipments and proper lifting techniques (Andersson GBJ et al, 1997). Trolleys, tractors, trucks should be used as substitution for manual handlings, so that the forces acting on spine can be reduced (Chaffin et al, 1991). Containers can be manufactured in proper weight and size (Andersson GBJ et al, 1997). Handles on containers should help the distribution of forces over the largest possible palm area and should allow users to bring the load as close to the centre of gravity of the body as possible. (Andersson GBJ et al, 1997). Loads to be lifted from the floor should be minimized. Pushing and pulling forces of various materials handling devices should be well below 225 N and the devices should be designed to move easily. (Chaffin et al, 1991).

Education and training

Education and training programs have been used to prevent low back pain. Studies showed that the cases of low back pain have been reduced through various education and training programs. (Chaffin et al, 1991).

Physicians and safety professionals recommend the squatting posture instead of the stooped posture for lifting objects on the floor (Asmussen et al, 1965; Ayoub and El-Bassoussi, 1978; Adams and Hutton et al, 1999). Squat lifting is preferred because the load is transferred to the legs and the load is closer to the body (Kumar S, 1999) which result in a smaller moment arm to the spine.

Physical training for the muscle physical capacities, endurance and flexibility is crucial for reducing and preventing the onset of low back pain.

Reference

1. Aaras A, Fostervold KI, Ro O, Thoresen M, Larsen S. Postural load during VDU work: a comparison between various work postures.
Ergonomics.1997 Nov; 40(11):1255-68.
2. Chaffin DB, Andersson GBJ. Occu-pational biomechanics. New York, NY: John Wiley and Sons. 1991
3. Freivalds A., Chaffin DB, Garg , A. and Lee , K. S. 1984, A dynamic biomechanical evaluation of lifting maximum acceptable loads, Journal of Biomechanics, 17, 251-262.
4. Gallagher S, Marras WS, Davis KG, Kovacs K. Effects of posture on dynamic back loading during a cable lifting task.Ergonomics 2002 Apr 15;45(5):380-98
5. Granata KP, Marras WS. Relation between spinal load factors and the high-risk probability of occupational low-back disorder.Ergonomics. 1999 Sep;42(9):1187-99.
6. Kelsey KL., Githens PB., White Aa. Iii, Holford TR., Walter SD., O' Conner T., Ostfeld AM., Weil U., Southwick WO. And Calogero JA 1984. An epidemiologic study of lifting and twisting on the job and risk for acute prolapsed lumbar intervertebral disc, Journal of Orthopedic Research, 2, 61-66.
7. Kostova V, Koleva M. Back disorders (low back pain, cervicobrachial and lumbosacral radicular syndromes) and some related risk factors. J Neurol Sci 2001 Nov 15;192(1-2):17-25
8. Marras WS, Lavender SA, Leurgans SE, Fathallah FA, Ferguson SA, Allread WG, et al. Biomechanical risk factors for occupationally-related low back disorders. Ergonomics 1995, 38(2):377–410.
9. Schultz A. And Anderson , G. 1981, Analysis of loads on the lumbar spine. Spine, 6, 76-82.
10. Yip Y. A study of work stress, patient handling activities and the risk of low back pain among nurses in Hong Kong. J Adv Nurs 2001 Dec;36(6):794-804
11. Marras WS, Davis KG, Ferguson SA, Lucas BR AND Gupta P. Spine loading characteristics of patients with low back pain compared with asymptomatic individuals. Spine 2001, 26(23):2566-2574
12. Van Dieen JH, Hoozemans MJM, Toussaint HM. Stoop or squat: a review of biomechanical studies on lifting technique. Clinical Biomechanics 1999, 14:685-696
13. Kumar S. Biomechanics in Ergonomics. London: Taylor & Francis 1999
14. Pope MH, Andersson GBJ, Frymoyer JW and Chaffin DB. Occupational low back pain: assessment, treatment and prevention. St. Louis: Mosby-year book 1991
15. Levy BS, Wegman DH. Occupational health: recognizing and preventing work-related disease and injury. Philadelphia: Lippincott Williams & Wilkins 2000

16. Nordin M, Andersson GBJ, Pope MH. Musculoskeletal disorders in the workplace: principles and practice. St. Louis: Mosby-year book 1997
17. Cox JM. Low back pain: Mechanism, diagnosis and treatment. USA: Williams & Wilkins 1999
18. Burgess-Limerick R (1999). Squat, stoop or something in between? http://cyberg.curtin.edu.au/members/papers/104.shtml
19. Straker L (1999). Evidence for using a stoop technique to lift low-lying objects. http://cyberg.curtin.edu.au/members/papers/99.shtml
20. Straker L. Lifting technique. http://www.curtin.edu.au/curtin/dept/physio/pt/staff/straker/publications/1999Encycliftfolder/1999Encyclift.html
21. Schmidt R, Salomone M (1999). Biomechanical comparison of squat lift vs stoop lift. http://www.umich.edu/~mvs330/f96/ergo/main.html
22. Brooks A, Poggioli B (1999). A comparison of squat lift vs stoop lift. http://www.umich.edu/~mvs330/f96/lifting/main.html
23. Cowan L, Hoyme E, Munoz K (1999). Squat lift vs back lift: a biomechanical comparison. http://www.umich.edu/~mvs330/f98/backbreakers/main.html
24. Molle E, Bolton A, Weber H (1999). Stoop lift vs squat lift in reference to back pain. http://www.umich.edu/~mvs330/f00/backaches/main.html
25. Browning GW (2003). Biomechanical low back pain: prevention. http://www.vhct.org/case1699/prevention.shtml
26. Leung ASL (1999). Low Back Pain in Hong Kong Frequency and Utilisation of Services. Health Services Research Committee Report #9
27. Jin, K., Sorock, G.. S., Courtney, T. K., Liang, Y., Yao, Z., Matz, S., & Ge, L. (2000). Risk factors for work-related low back pain in the People's Republic of China. *Int J Occup Environ Health*, 6, 26-33.
28. Standiford, C., Green, L., Harrison, V. (2003). Guidelines for Clinical Care: Acute Low Back Pain. University of Michigan Health System. http://cme.med.umich.edu/pdf/guideline/backpain03.pdf

Appendix I **List of company involved in this study**

1. The Chinese University of Hong Kong (Dept of Orthopaedics & Traumatology)
2. Prince of Wales Hospital
3. Queen Mary Hospital
4. Wai Hong Cleaning Company
5. Sing Fat Decoration Company
6. Shui On Construction and Materials Ltd
7. Jaguar Shipping & Transportation Co. Ltd.
8. Hutchison Whampoa Limited (Park'N Shop)
9. Maxim's Caterer Ltd
10. Right Key Engineering Co Ltd
11. Wing Lee Building Materials Co
12. Dah Chong Hong (Motor Serv Centre) Ltd
13. Gates Unitta Asia Trading Co Pte Ltd
14. Wil-Can International Removal Ltd
15. Minico Self-Storage
16. Schenker International (HK) Ltd
17. Cleaning Doctor Building Services Ltd
18. Carpet Concept Company Limited
19. Kwong Kee Motor Co Ltd
20. United Friendship Taxi Owners & Drivers

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HEAD OF DEPARTMENT
PROF. KDK Luk

PROFESSOR

W W Lu
Tel: (852) 2819 9595

Appendix II: Sample Letter to Local companies

To: ABC Co.

From: Dr William Lu / Miss Jessie Chiu

Re: A field assessment and prevention guideline setup for occupational low back disorder

We are now conducting a research project "Biomechanical guideline for occupational low back disorder prevention: a field assessment and prevention guideline setup". Our studies aim to identify, evaluate, quantify potential ergonomic risk factors of occupational low back disorders (OLBD) in Hong Kong and also to provide scientific knowledge for OLBD and the safety guideline to prevent OLBD in each individual working task. The outcome of this project will help both employer and employee to prevent possible risk in OLBD and its secondary economic loss.

We would like to take 4 to 5 photos of working posture in your company so as to estimate the risk of injury associated with a variety of occupational actions including pushing, pulling, lifting and other actions by computer software. All information collected is used only for our study. We will not disclose any information to the public. A summary of our study is attached for your reference. It is grateful if you can make an arrangement for out assessment. If you have any enquires, please feel free to contact Miss Jessie Chiu at 97575685 or email to jessiechiu@hgcbroadband.com.

I'm looking forward to hearing from you.

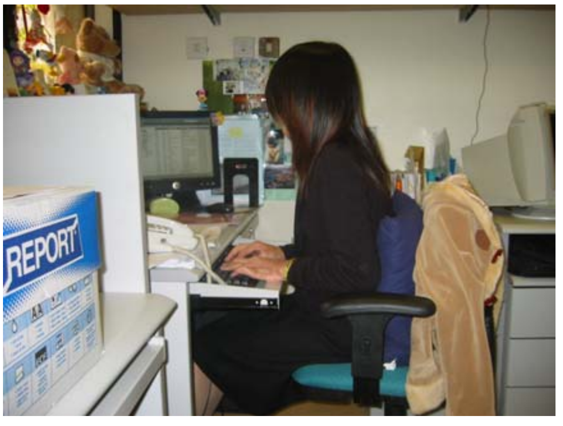
Yours Sincerely,

Prof. William Lu
Associate Professor

Appendix III: Postures and site visiting

Company: CUHK

Job nature 1: Typing



Job nature 2: Writing

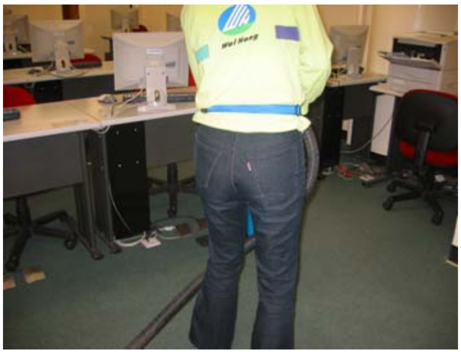
Company: QMH Hospital

Job nature: Transporting patient from bed to bed

Company: Wai Hong Cleaning Company

Job nature 1: Sweeping floor

Job nature 2: Cleaning table



Road workers hold heavy drills.

Carrier and construction site visiting.

Appendix IV. Research Protocol

Total subjects = 100 subjects from 20 companies.

The personal information, including family, economical and education situation will be noted. The physical characteristics of the worker, like gender, height, weight and length of limbs, will be recorded. The motion of the subject for his/her routine task will be recorded by digital video camera.

Then, other task information will include:
1) load: magnitude and direction of force acting on each hand,
2) time: total working time/ shift and time spent performing each action,
3) Posture: x,y coordinates of the major body joints.

(1). The Photo or video information(Fig.1) and other recording data (Fig.2,3) will be input to computer. The low back biomechanical loading(Fig 4,5) will be calculated by a computerized model, 4D Watbak.

4D WATBAK is an easy to use biomechanical modelling tool that calculates acute and cumulative loads at the major body joints, particularly the lumbar spine region. It can be used to estimate the risk of injury associated with a variety of occupational actions including pushing, pulling, lifting, lowering, holding, carrying, etc.,.

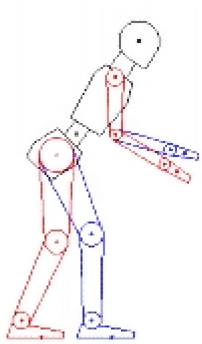


Figure A1Body posture and motion information

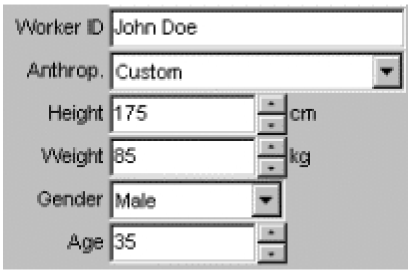


Figure A2 Physical characteristics input

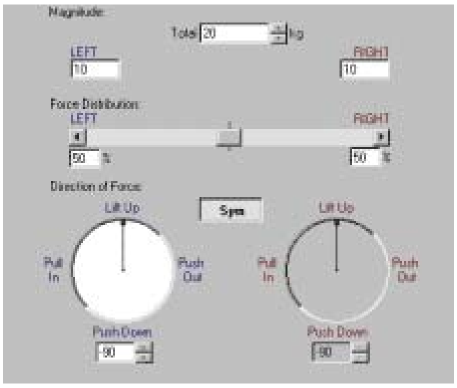


Figure A3 Load input

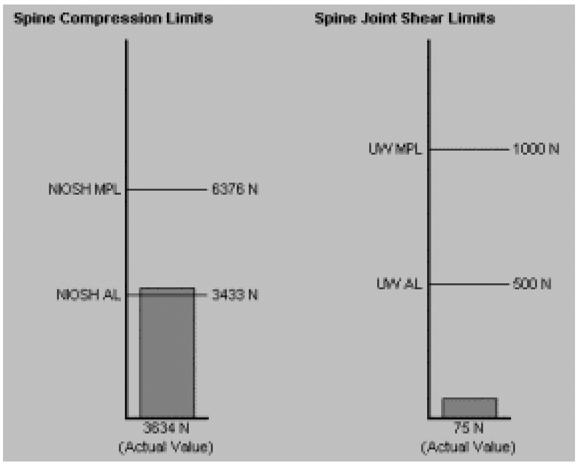


Figure A4

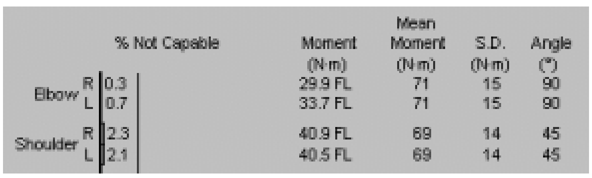


Figure A5

The output of biomechanical calculation will be evaluated using a computer programme, modified NIOSH Tool (Fig.6). This programme is originally based on NIOSH(1981) equation and NIOSH(1991) revised equation. We have further modified it with standard Manual Materials Handling assessment tools Snook Tables (1981) and the University of Waterloo's back assessment program, Watbak. It will quickly identify, evaluate and quantify potential ergonomic risk factors .

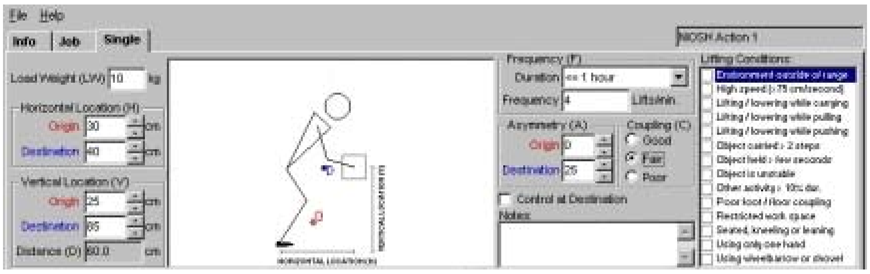


Figure A6

The critical stage or action of a working operation will be identified and analysis.

The advice to prevent the risks based on above analysis will be provided to both employee and employer. The right operation will be demonstrated on a computer model and re-analysis by our programme to verify the safety. The sample output from the software is shown in Fig. A7.

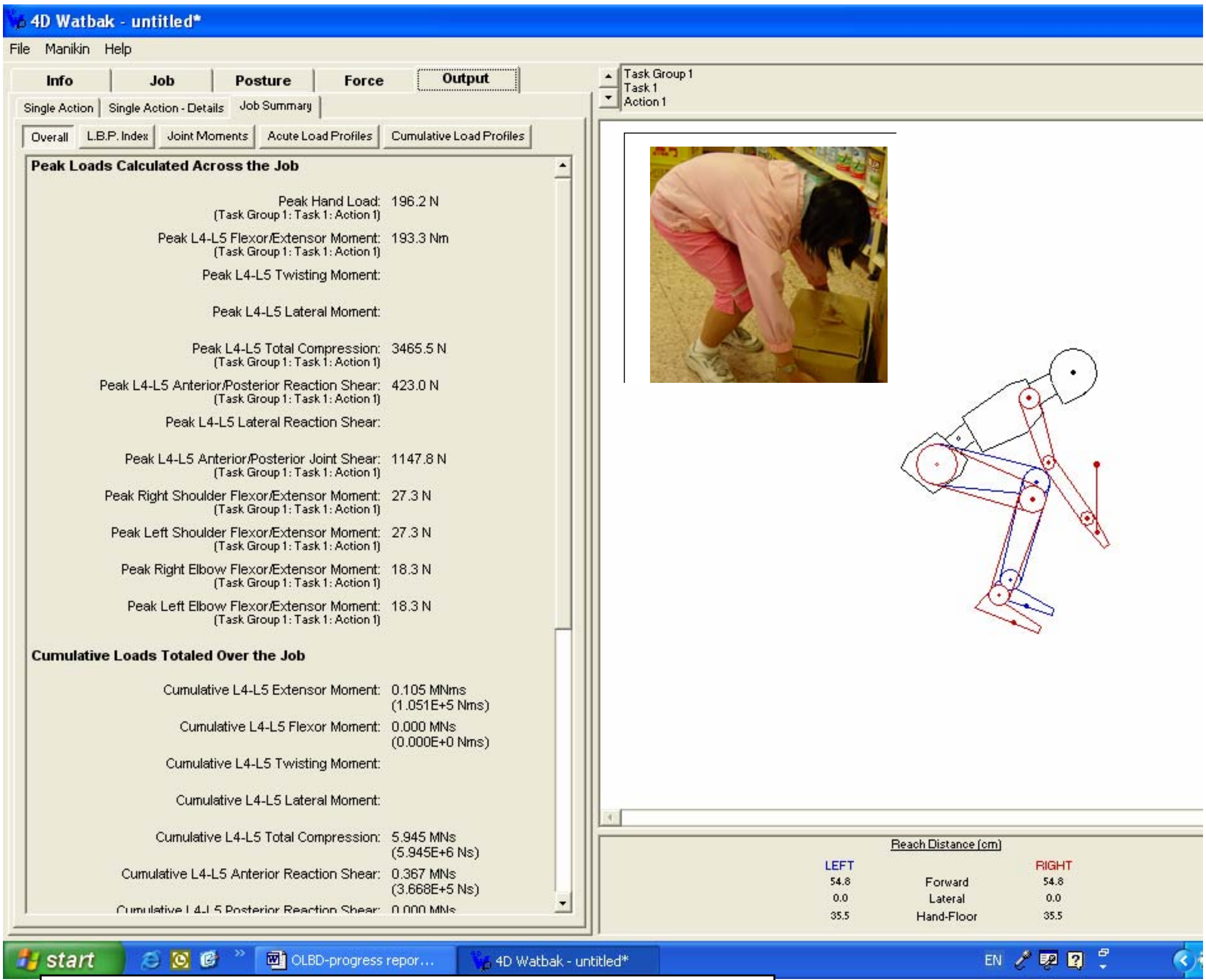


Fig. A7 Sample output from 4D WATBAK