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Applied Ergonomics 36 (2005) 85–95

APPLIED ERGONOMICS

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Workplace design guidelines for asymptomatic vs. low-back-injured workers

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Received 19 November 2003; received in revised form 17 July 2004; accepted 21 July 2004

Abstract

While numerous efforts have attempted to provide quantitative guidelines for the prevention of initial low back disorders during material handling tasks, none have appeared in the literature that address the issue of recurrent low back disorders due to materials handling when returning to the workplace. A study comparing the spine loads of low back pain patients and asymptomatic controls was conducted. Subjects lifted weights varying from 4.5–11.4 kg at four vertical heights, two horizontal distances and five task asymmetries collectively representing common industrial lifting situations. Spine loading was calculated using a validated EMG-assisted biomechanical model. Spine loads observed during lifting tasks were compared to spine tolerance values believed to initiate low back injuries. In addition, the percentage of patients successfully performing the lift was noted and used as an indication of the willingness of the subject to perform the task. These evaluations are summarized in a series of three lifting guidelines indicating safe, medium risk and high risk lifting tasks for low back patients as well as asymptomatic workers. It is believed that adherence to these guidelines can minimize the risk of recurrent low back disorders due to occupational lifting.

Keywords: Spine loading; Return to work guidelines; Low-back pain

1. Introduction

The literature indicates that one of the best predictors of low back pain (LBP) is previous history of LBP (Papageorgiou et al., 1996; Ferguson and Marras, 1997; Smedley et al., 1997; van Poppel et al., 1988). One potential cause for this increased risk of recurrent injury might be the poor understanding of how the biomechanics of spine loading are altered when one experiences low back disorder (LBD). Historically, return to work guidelines have been vague and non-specific and have not attempted to address how the spine is loaded in a LBP patient. It is common for a low back injured worker to return to work with restrictions that are no more instructive than to not lift more than a given magnitude of weight (e.g. 5–10 kg) without regard for the location of the weight when lifting or the posture of the body when lifting (both established risk factors).

Guidelines or recommendations for prevention of initial low-back injury have been under development for decades. Initially, the National Institute of Occupational Safety and Health (NIOSH) developed a lifting guide based on epidemiological, biomechanical, physiological, and psychophysical evidence (National Institute for Occupational Safety and Health NIOSH, 1981). Snook and Ciriello (1991) developed recommendations not only for lifting but also lowering, pushing, pulling, and carrying based on psychophysical studies. Waters et al. (1993) revised the NIOSH lifting equation to include asymmetry and coupling factors. The most recent

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0003-6870/$ - see front matter
doi:10.1016/j.apergo.2004.07.002

recommendations are the American Conference of Governmental Industrial Hygienists Threshold Limits Values (TLVs) in 2001. The recently developed TLVs combine the results of the NIOSH lifting guide, biomechanical spine loading studies, and biomechanical epidemiology. Many of these guidelines are based upon the level of spine loading during a manual material handling activity. However no studies have been identified that quantitatively assess the degree of spine loading experienced by those already experiencing a LBD. Hence, we do not know whether these guidelines are appropriate for workers returning to the workplace after a low back injury.

Recent studies indicate that spine loadings of LBP subjects may be greater than that of asymptomatic individuals (Marras et al., 2004a; Marras et al., 2001a). Hence, a significant void in the practice of ergonomics is the lack of objective guidelines for minimizing the risk of recurrent LBP for those workers returning to work after a low back injury. The goal of this study is to develop lifting guidelines for low back injured workers based on quantitative biomechanical principles.

2. Methods

2.1. Approach

In this study spine loadings in LBP patients as well as asymptomatic individuals lifting under a variety of conditions were quantitatively assessed and compared to benchmark spine tolerance limits. Using this approach, recommendations for low risk, medium risk and high risk lifting conditions were made for both LBP patients and asymptomatic controls.

2.2. Subjects

One hundred and twenty-three subjects participated in the study. Sixty-two LBP patients and 61 age and gender matched controls. In the patient population there were 32 males and 30 females. The LBP group was diagnosed with muscular LBP and no radiculopathy (diagnosed by their orthopedic surgeon). The median duration of pain symptoms was 5.5 months. Forty-eight percent of the patients had a history of previous LBP. Eighty-eight percent of the patients had returned to work at the time of testing and the median number of lost days from work was 14. The average functional performance probability for the patient population was 0.12 (0.17) and the asymptomatic group had a functional performance probability of 0.82 (0.25) from the lumbar motion monitor (Marras et al., 1999). Table 1 lists pain, impairment of daily activities measured by the Million Visual Analog (Million et al., 1982) and SF-36 health survey results for the LBP population. Patients were excluded from the study if physical examination showed signs of lower extremity deficit or hyperreflexia.

Table 1
Pain and SF-36 health survey results for low-back pain patients

Impairment measure	Mean	SD
Pain level (0–10 scale)	5.0	1.9
Duration (months)	10.2	13.6
Million visual analog	68.4	26.6
SF-36 Physical functioning	20.7	5.5
SF-36 Role—physical	4.8	1.3
SF-36 Bodily pain	6.1	2.2
SF-36 General health	17.9	5.1
SF-36 Vitality	12.2	4.1
SF-36 Social functioning	7.3	2.2
SF-36 Role emotional	4.5	1.3
SF-36 Mental health	20.9	4.9
SF-36 Reported health transition	3.3	0.8

2.3. Experimental design

Independent variables consisted of: (1) subject low back health status, (2) weight lifted, (3) lift origin, and (4) lift asymmetry. Subject health status was deemed as either LBP or asymptomatic. All subjects performed a low back functional assessment (Marras et al., 1999) to quantify the extent of low back impairment prior to performing the lifting tasks. Four weight magnitudes were lifted consisting of 4.5, 6.8, 9.1 and 11.4 kg. The weight levels were selected based upon light duty work restrictions commonly suggested by physicians. Lift origin varied in both vertical height off the floor and horizontal distance from the body. Lift origin regions were based on the TLV guidelines and included vertical heights relative to the floor, knee, waist, and shoulder. The horizontal distances consisted of "close" and "far" distances describing the load origin distance from the spine. The "close" regions were 30 cm from the spine and the "far" regions were 60 cm from the spine. Task asymmetry consisted of lifts close to sagittally symmetric (similar to the TLV guidelines) as well as rotational lift origins of 45° degrees clockwise and counter-clockwise and 90° clockwise and counterclockwise. The symmetric lifts were performed in all regions. To minimize subject risk, the floor region lifts were not performed at the 45° and 90° asymmetries. The frequency used in the study was comparable to the lifting frequency of lifting tasks <2 h / day with <60 lifts / h. This lifting frequency was used in order to protect the patients from further injury.

Two types of dependent measures were observed. First, spine loading, consisting of spine compression, lateral shear, anterior/posterior (A/P) shear was recorded. The second type of dependent measure consisted of capacity, which indicated the percentage of each group able to perform each task.

2.4. Apparatus

Surface electrodes were used to collect electromyography (EMG) activity of 10 major trunk muscles including right and left erector spinae, latissimus dorsi, rectus abdominus, external oblique and internal oblique. Raw EMG signals were preamplified, high-pass filtered at 30 Hz, low-pass filtered at 1000 Hz, rectified and smoothed with a 20-ms sliding window filter. Skin impedances were below 100 kΩ·

Trunk kinematics were measured with the lumbar motion monitor (LMM). The LMM acts as an exoskeleton of the spine and measures position, velocity and acceleration in all three planes (Marras et al., 1992). Ground reaction forces were measured using a force plate (Bertec 4060A, Worthington, USA). Two sets of electrogoniometers in conjunction with the force plate were used to quantify moments and forces about L5/S1 (Fathallah et al., 1997). The electrogoniometers measure the position of L5/S1 and the pelvic orientation of the subject relative to the center of the force plate. Based on the relative position, the three-dimensional forces and moments measured at the force plate were mathematically translated and rotated up to L5/S1.

All the signals from all the instruments were collected simultaneously using customized software developed in our laboratory. The processed signals were collected at 100 Hz and recorded on computer by means of an analog to digital converter.

2.5. EMG normalization procedure

An EMG normalization procedure has been developed that does not require a maximum exertion in order to normalize the EMG signal (Marras and Davis, 2001). Typically, EMGs are normalized relative to a maximum voluntary contraction (MVC), however LBP patients may not provide a MVC due to fear of reinjury or residual pain. The new procedure estimates the slope of the EMG-force relationship and predicts the maximum contraction. The EMG-force relationship was established with a series of low level exertions performed in flexion, extension, and axial twisting. Marras et al. (2001b) reported only minor differences in EMG-assisted model results between the new normalization procedure and traditional maximum exertion procedures.

2.6. Procedure

Upon arrival, subjects were informed of study procedures and consent to participate was acquired using a University Institutional Review Board form. Next, anthropometric measurements were collected and surface electrodes were applied. EMG normalization procedures were performed that did not require a maximum exertion, but instead a series of submaximal exertions (Marras and Davis, 2001).

Lifting exertions began after a brief rest break. In order to ensure patient safety, all lifting conditions were completed at each weight level before increasing to the next weight. The symmetric lifts were completed first and the left and right side asymmetric conditions were counterbalanced. Subjects were required to keep their feet stationary on the force plate during the lift but were free to move the rest of the body as they wished. Between lifts subjects were allowed to move their feet on the force plate.

2.7. Spine loading assessment

During the past two decades, our laboratory has developed a three-dimensional dynamic biomechanical model that determines spine loading at L_5/S_1 (Marras and Reilly, 1988; Reilly and Marras, 1989; Marras and Sommerich, 1991a, b; Granata and Marras, 1993, 1995a, b; Marras and Granata, 1995, 1997a, b; Granata et al., 1999). The model predicts compression, A/P shear and lateral shear forces experienced by the subject during an exertion. The model assumes two imaginary transverse planes pass through the torso, one at the thorax and the other at the pelvis. Only muscles that pass through both of these planes can impose loads on the lumbar spine. EMG is used to monitor every major muscle group that passes through both planes. Recently, magnetic resonance imaging data have been collected to ensure the origin and insertions of muscle vectors are anatomically correct and adjusted for gender differences and muscle fiber orientation (Marras et al., 2001c).

2.8. Analysis and interpretation

The compression, A/P shear and lateral shear forces generated by LBP patients and asymptomatic controls were compared to benchmark spine tolerance limits. Spine loads exceeding these limits are suspected of leading to LBDs. In addition, the percentage of participants completing the tasks was used as an indication of willingness to complete a given lifting situation and was also used as another form of lift tolerance. Table 2 lists these two types of tolerance limits that result in low risk, medium risk, and high risk tasks. The compression values in Table 2 match those in the National Institute for Occupational Safety and Health (NIOSH), 1981 Lifting Guide. The 3400 N criteria in our study is the action limit criteria in the NIOSH, 1981 Lifting Guide and the 6400 N limit is the same as the maximum permissible limit. The criterion for the subject's "willingness to complete the task" listed in Table 2 was similar to psychophysical acceptance criteria adopted by NIOSH, 1981. The NIOSH Guide considers the action limit to be lifts that are acceptable

Table 2
Criteria levels for low- medium- risk and high-risk lifting conditions

	Compression	A/P shear	% Completing task
Low risk	<3400 N	<750 N	>75%
Medium risk	$3400\,N<x<6400\,N$	$750\,N<x<1000\,N$	25%<x<75%
High risk	>6400 N	>1000 N	<25%

to 75% of women and 99% of men and the maximum permissible limit to be acceptable to 25% of men and 1% of women. The criterion for A/P shear listed in Table 2 is from the work of McGill. McGill et al. (1998) suggested an action limit for A/P shear of 500 N. However McGill (2003) recently presented work indicating the 750 N of A/P shear may cause injury to spinal structures. McGill (2002) clearly indicates that 1000 N of A/P shear loading will cause injury. Therefore, 750 N of A/P shear was used as the medium risk criteria and 1000 N was used as the high-risk criteria as listed in Table 2. Lateral shear loading was not considered, as the experimental tasks did not induce significant lateral shear forces on the subject spines. If all three criteria in Table 2 were considered medium risk then the lift was considered high risk due to synergistic effect of combined loading.

2.9. Limits for asymptomatic subjects

Since safe spine loading for the asymptomatic group was expected to exceed those defined by these experimental conditions, the upper limits for safe lifting were adapted from the TLV guidelines. These guidelines were based on previous studies using similar procedures as described here (American Conference of Governmental Industrial Hygienists ACGIH, 2001). The TLV guidelines were developed for lift asymmetries within 30° of the sagittal plane. Thus, for task asymmetries greater than 30° a discounting factor was determined from our data to determine the maximum safe load.

3. Results

The study results are presented in two ways. First, a series of figures indicating the conditions under which a load magnitude exceeds one of the threshold limits for both LBP an asymptomatic subjects are summarized in Figs. 1–3. In order to use the figures, one must decide if the worker is healthy (asymptomatic) or has a LBD. The height of the lift, horizontal distance of the lift and task asymmetry must be determined. All three figures apply to lifting tasks with a frequency of < 2 h of lifting per day with < 60 lifts per hour.

The second method for presenting the results is a table format. Tables 3–5 list the percentage of subjects performing each lift as a function of group, weight and region. In addition the tables list the percentage of the population, experiencing spine loading within each category during the lift. The tables can be used in conjunction with the figures to assist the reader in determining the percentage of the population protected by the guideline. The shaded regions in each row of the table were the critical factors in determining the medium or high risk level for that lifting condition. The percentage of the population performing the lifts criteria, applied primarily to the patient population as all the asymptomatic population performed well within the tolerance limits of acceptability, as indicated in the tables.

Fig. 1 and Table 3 correspond to illustrate the study results for lifts within 30° of the sagittal plane. The low risk regions in Fig. 1 do not have a corresponding shaded region in Table 3, because the compressive load was less than 3400 N and the A/P shear was less than 750 N and more than 75% of the population was performing the task. In the shoulder, waist and waist-far regions the medium risk at 11.4 kg for the LBD group were due to the percentage of subjects performing the lift. In the knee region the medium risk was due to both the percentage of subjects performing the lift and the compressive load exceeding 3400 N. In the floor region for the asymptomatic group the medium risk was caused by both the compressive and A/P shear load, whereas the high risk lifts were caused by the A/P shear exceeding 1000 N. Note that in the floor condition nearly 50% of the low back population was exceeding the 1000 N criteria at the 6.8, 9.1 and 11.4 kg conditions.

Marras et al. (2004b) have found significant differences in spine loading for LBD patients between the clockwise and counter-clockwise lifting conditions however, when comparing these loads to the tolerance levels few differences in risk level resulted. Therefore, the asymmetry results combined both clockwise and counter-clockwise tasks. Fig. 2 and Table 4 correspond to demonstrate the study results for lifts between 30° and 60° of the sagittal plane. The shoulder, waist and waist-far regions tend to be driven by the percentage of complete data for the LBP group. However, in the shoulder region at 11.4 kg the A/P shear also caused the medium risk decision. In the knee region the medium risk was caused by compressive loading and the high risk level for the LBP group at the 11.4 kg resulted from of all three criteria being in the medium risk group. In

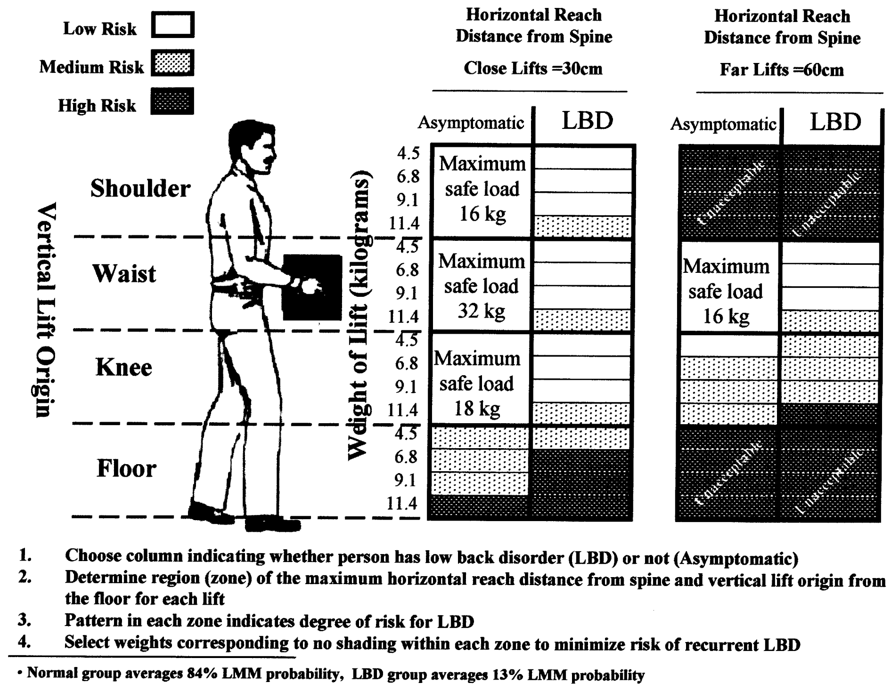

Fig. 1. Guidelines for lifts within 30° of the lift origin asymmetry.

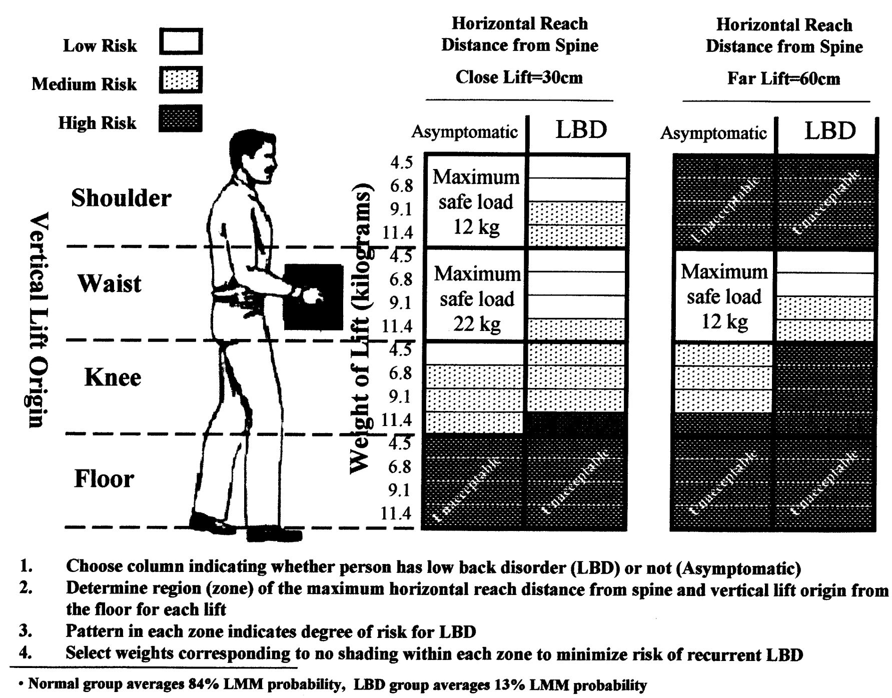

Fig. 2. Guidelines for lifts between 30° and 60° of the lift origin asymmetry.

the waist-far region high risk was the result of the *A*/*P* shear exceeding 1000 N. Note that nearly 60% of the LBD group exceeded the 1000 N criteria for *A*/*P* shear.

Fig. 3 and Table 5 correspond to show the study results for lifts between 60° and 90° of the sagittal plane. The high risk in the knee region for the LBD group was the result of all three criteria being in the medium-risk group. In the waist-far region the LBD group high-risk level was caused by the *A*/*P* shear exceeding the 1000 N criteria. Also note that even for the asymptomatic group

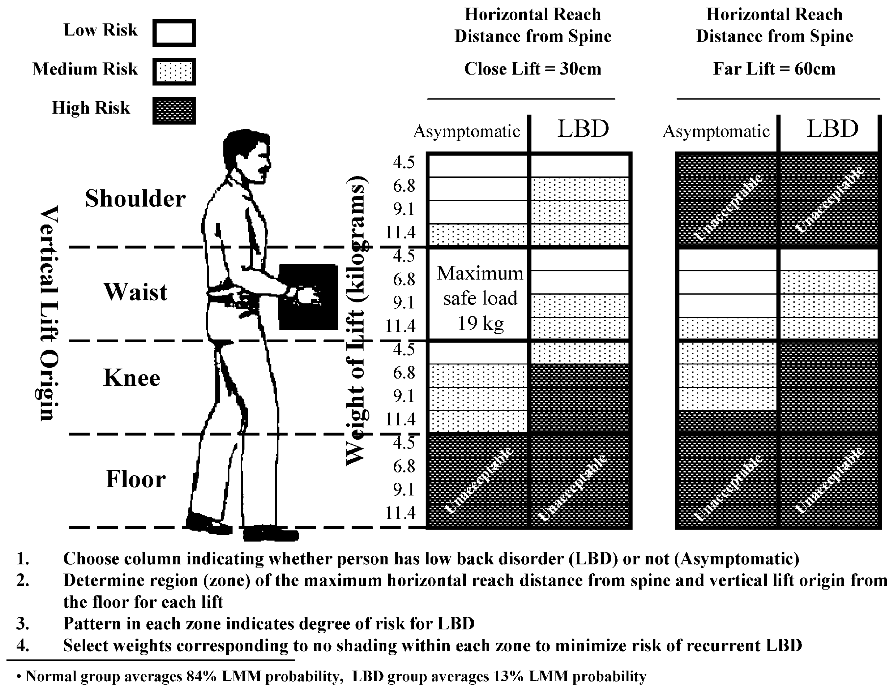

Fig. 3. Guidelines for lifts between 60° and 90° of the lift origin asymmetry.

43% of the population exceeded 1000 N of A/P shear at the knee-far 11.4 kg condition.

There is one discrepancy between the figures and the tables. This occurs in the guidelines for asymptomatic group performing lifts between 60° and 90° of lift origin asymmetry. Fig. 3 indicates that lifts in the shoulder region at 11.4 kg were medium risk whereas Table 5 shows that shoulder region lifts at 11.4 kg were low risk. The difference occurred because of the methods used to calculate the maximum safe load for the asymptomatic group. The maximum safe load limits for the asymptomatic group for lifts within 30° of the origin asymmetry (Fig. 1) are from the lifting TLV (American Conference of Governmental Industrial Hygienists ACGIH, 2001). The lifting TLV guideline was not developed for task asymmetries greater than 30°. Therefore, the safe limits for the asymptomatic group in Figs. 2 and 3 were calculated from our data and the symmetric limits from the TLV. For example, in Fig. 2 the maximum safe load in the waist region was 22 kg. The average increase in spine loading for the waist region as asymmetry increased from symmetric to 45° was 30%. Thirty percent of 32 kg is approximately 10 kg. Thus, subtracting 10 from 32 gives the result of 22 kg reported in Fig. 2. Similar methods were used to calculate the maximum safe load in the shoulder and waist-far regions. In the shoulder region for lifts between 60° and 90° of lift origin asymmetry resulted in 9.6 kg using this method. Therefore, the 11.4 kg in the shoulder region is medium risk.

4. Discussion

This is the first study to quantify spine loading in LBD patients and compare the loads to known spine tolerance levels in order to develop return to work guidelines. The guidelines are presented in an "easy to use" format that is consistent with some of the best spine biomechanics assessment tools currently available. Currently, most return to work practices are based upon subjective impressions as opposed to biomechanical logic. This study represents a first step in providing a scientifically valid rationale rooted in spine loading as a basis for returning a worker to the workplace following a low back injury. Further research will be necessary in order to expand these guidelines to a greater variety of work conditions and more thoroughly understand the recovery process in order to prevent recurrent low back injury or disability.

Often return to work or work restrictions consist of "no lifting more than 4.5 kg". As most ergonomists would suggest, the loading experienced by the spine while lifting 4.5 kg would change greatly depending on the lift. The current guide shows that the load on the spine would be within a safe limit or low risk for symmetric lifts in the shoulder, waist, knee and waist-far regions however even the 4.5 kg weight would create spine loads generating a medium risk of injury in the knee-far condition. Thus depending on the horizontal distance, task asymmetry and vertical height of the lift the spine loading will change thereby influencing the risk

Table 3
Percentage of subjects performing each task and the percentage of those subjects experiencing loads within each spine loading category for lifts within 30° of the lift origin asymmetry

				Compression (%)			A/P shear (%)		
Region	Wt. (kg)	Group	% Complete	<3400	3400<x<6400	>6400	<750	750<x<1000	>1000
Shoulder	4.5	Asymptomatic	100	100	0	0	98	2	0
	4.5	LBD	100	98	2	0	82	10	8
	6.8	Asymptomatic	100	100	0	0	96	4	0
	6.8	LBD	94	98	2	0	76	15	9
	9.1	Asymptomatic	100	100	0	0	95	5	0
	9.1	LBD	79	97	3	0	73	14	12
	11.4	Asymptomatic	100	100	0	0	95	5	0
	11.4	LBD	**56**	97	3	0	71	20	9
Waist	4.5	Asymptomatic	100	100	0	0	98	2	0
	4.5	LBD	100	100	0	0	94	6	0
	6.8	Asymptomatic	100	100	0	0	98	2	0
	6.8	LBD	98	100	0	0	90	8	2
	9.1	Asymptomatic	100	100	0	0	98	2	0
	9.1	LBD	84	100	0	0	86	10	4
	11.4	Asymptomatic	100	100	0	0	97	3	0
	11.4	LBD	**65**	97	3	0	82	13	5
Knee	4.5	Asymptomatic	100	85	15	0	95	5	0
	4.5	LBD	100	77	21	2	92	8	0
	6.8	Asymptomatic	100	85	15	0	95	2	3
	6.8	LBD	94	71	29	0	89	9	2
	9.1	Asymptomatic	100	86	13	0	98	2	0
	9.1	LBD	81	56	44	0	86	14	0
	11.4	Asymptomatic	100	80	19	0	93	5	2
	11.4	LBD	**60**	57	**43**	0	86	11	3
Floor	4.5	Asymptomatic	100	56	**41**	3	57	**18**	24
	4.5	LBD	84	25	**67**	8	46	**17**	36
	6.8	Asymptomatic	100	47	**49**	3	62	**15**	23
	6.8	LBD	77	21	60	19	37	12	**50**
	9.1	Asymptomatic	98	39	**52**	8	56	**15**	28
	9.1	LBD	74	13	65	22	41	15	**43**
	11.4	Asymptomatic	98	29	61	10	48	15	**37**
	11.4	LBD	52	16	56	28	34	19	**49**
Waist far	4.5	Asymptomatic	100	98	2	0	96	2	2
	4.5	LBD	100	90	10	0	92	6	2
	6.8	Asymptomatic	100	97	3	0	93	7	0
	6.8	LBD	95	85	15	0	88	8	4
	9.1	Asymptomatic	100	93	5	2	96	2	2
	9.1	LBD	81	76	22	2	86	12	2
	11.4	Asymptomatic	98	90	10	0	90	8	2
	11.4	LBD	**53**	78	21	0	75	15	9
Knee far	4.5	Asymptomatic	100	49	**48**	3	75	8	16
	4.5	LBD	87	37	**50**	13	66	15	18
	6.8	Asymptomatic	100	38	**52**	10	72	13	15
	6.8	LBD	82	21	**63**	16	66	14	20
	9.1	Asymptomatic	98	24	**64**	11	62	**15**	23
	9.1	LBD	76	17	**55**	28	68	**6**	25
	11.4	Asymptomatic	98	26	**61**	13	60	**18**	22
	11.4	LBD	47	17	48	34	52	10	**38**

Bold text indicates the criteria that resulted in medium or high risk level.

of injury. This lifting guide provides a more specific indication of which lifting tasks are safe for those with recent low back injuries.

These guidelines may be used by two types of practitioners. First, the ergonomist may use the guidelines to identify light duty jobs within a facility or design

Table 4
Percentage of subjects performing each task and the percentage of those subjects experiencing loads within each spine loading category for lifts between 30° and 60° of the lift origin asymmetry

Region	Wt. (kg)	Group	% Complete	Compression (%)			*A/P* shear (%)		
				<3400	3400<*x*<6400	>6400	<750	750<*x*<1000	>1000
Shoulder	4.5	Asymptomatic	100	100	0	0	100	0	0
	4.5	LBD	100	100	0	0	78	18	4
	6.8	Asymptomatic	100	100	0	0	100	0	0
	6.8	LBD	83	98	2	0	71	1	11
	9.1	Asymptomatic	100	100	0	0	98	2	0
	9.1	LBD	**60**	100	0	0	77	21	2
	11.4	Asymptomatic	100	100	0	0	95	5	0
	11.4	LBD	**40**	94	6	0	61	**30**	9
Waist	4.5	Asymptomatic	100	100	0	0	100	0	0
	4.5	LBD	100	100	0	0	95	5	0
	6.8	Asymptomatic	100	100	0	0	98	2	0
	6.8	LBD	90	96	4	0	93	6	1
	9.1	Asymptomatic	100	100	0	0	99	1	0
	9.1	LBD	78	93	6	0	93	5	2
	11.4	Asymptomatic	100	100	0	0	96	4	0
	11.4	LBD	**50**	97	3	0	92	8	0
Knee	4.5	Asymptomatic	100	58	42	0	88	4	8
	4.5	LBD	95	46	**47**	6	79	9	12
	6.8	Asymptomatic	100	56	**44**	0	86	8	6
	6.8	LBD	90	37	**54**	8	77	11	11
	9.1	Asymptomatic	100	44	**54**	2	79	10	11
	9.1	LBD	73	23	**67**	10	77	14	8
	11.4	Asymptomatic	100	35	**61**	4	75	11	14
	11.4	LBD	**40**	20	**70**	10	66	**20**	13
Waist far	4.5	Asymptomatic	100	99	1	0	99	1	0
	4.5	LBD	100	81	20	0	94	6	0
	6.8	Asymptomatic	100	94	6	0	99	1	0
	6.8	LBD	80	75	22	3	91	9	0
	9.1	Asymptomatic	100	90	10	0	96	3	1
	9.1	LBD	**55**	77	23	0	91	9	0
	11.4	Asymptomatic	100	87	13	0	96	3	1
	11.4	LBD	**30**	84	12	4	96	4	0
Knee far	4.5	Asymptomatic	100	37	**38**	5	64	**15**	21
	4.5	LBD	93	17	54	28	48	15	**36**
	6.8	Asymptomatic	100	24	**62**	14	57	**12**	30
	6.8	LBD	**73**	20	**55**	25	54	**9**	36
	9.1	Asymptomatic	100	16	**62**	21	52	**15**	32
	9.1	LBD	43	10	51	39	32	19	**49**
	11.4	Asymptomatic	100	14	58	28	55	12	**32**
	11.4	LBD	25	9	68	23	23	18	**59**

Bold text indicates the criteria that resulted in medium or high risk level.

light duty jobs within a facility. Second, the physician may use the guidelines to write more specific return to work guidelines or job restrictions for patients returning to work after a low back injury. A more scientific basis for return to work and light duty jobs may reduce the risk of recurrent low back injury or disability. From an economic perspective, it is very important to reduce recurrent low back injury since these injuries tend to be the highest cost injuries (Hamrick, 2000).

As these guidelines indicate, the LBP patients experienced higher risk under the same lifting conditions because the patients generated increased spine loading (Marras et al., 2001a; Marras et al., 2004a). The increased spine loading in LBP patients compared to asymptomatic controls was due to increased levels of "guarding" or muscle co-activity. The difference influenced the lifting guidelines because in several cases the co-activity in patients created *A/P* shear levels exceeding 1000 N resulting in high-risk classification. Hence, practitioners must be sensitive to the greater loading to which LBP patients are exposed when returning to the workplace. Ergonomists have long argued that it

Table 5
Percentage of subjects performing each task and the percentage of those subjects experiencing loads within each spine loading category for lifts between 60° and 90° of the lift origin asymmetry

Region	Wt. (kg)	Group	% Complete	Compression(%)_			*A*/*P* shear (%)		
				<3400	3400<x<6400	>6400	<750	750<x<1000	>1000
Shoulder	4.5	Asymptomatic	100	100	0	0	99	1	0
	4.5	LBD	90	98	3	0	86	11	3
	6.8	Asymptomatic	100	99	1	0	99	1	0
	6.8	LBD	**65**	96	4	0	75	21	4
	9.1	Asymptomatic	100	100	0	0	97	3	0
	9.1	LBD	**50**	97	3	0	77	30	3
	11.4	Asymptomatic	100	100	0	0	91	8	1
	11.4	LBD	**33**	100	0	0	69	27	4
Waist	4.5	Asymptomatic	100	100	0	0	97	3	0
	4.5	LBD	93	97	3	0	93	7	0
	6.8	Asymptomatic	100	100	0	0	100	0	0
	6.8	LBD	78	92	8	0	95	5	0
	9.1	Asymptomatic	100	99	1	0	96	3	1
	9.1	LBD	**58**	98	2	0	98	2	0
	11.4	Asymptomatic	100	99	1	0	98	2	0
	11.4	LBD	**35**	100	0	0	93	7	0
Knee	4.5	Asymptomatic	100	61	39	0	81	11	7
	4.5	LBD	90	45	**49**	6	79	10	11
	6.8	Asymptomatic	100	51	**48**	1	79	12	9
	6.8	LBD	**68**	33	**63**	4	78	**13**	9
	9.1	Asymptomatic	100	47	**46**	6	76	7	16
	9.1	LBD	**53**	30	**57**	13	62	**20**	18
	11.4	Asymptomatic	100	37	**54**	9	72	**9**	19
	11.4	LBD	**28**	30	**55**	15	35	**50**	15
Waist far	4.5	Asymptomatic	100	94	6	0	96	4	0
	4.5	LBD	85	83	17	0	98	2	0
	6.8	Asymptomatic	100	89	11	0	98	1	1
	6.8	LBD	**63**	76	22	2	100	0	0
	9.1	Asymptomatic	100	84	16	0	95	4	1
	9.1	LBD	**43**	76	21	3	97	3	0
	11.4	Asymptomatic	100	70	30	0	94	6	0
	11.4	LBD	**25**	68	32	0	89	11	0
Knee far	4.5	Asymptomatic	100	34	**54**	12	52	**19**	29
	4.5	LBD	78	24	62	13	52	26	**22**
	6.8	Asymptomatic	100	29	**52**	19	51	**18**	31
	6.8	LBD	55	24	53	22	40	22	**38**
	9.1	Asymptomatic	100	21	**54**	25	47	**15**	39
	9.1	LBD	25	20	50	30	35	15	**50**
	11.4	Asymptomatic	100	12	65	23	36	21	**43**
	11.4	LBD	**15**	18	64	18	27	27	**46**

Bold text indicates the criteria that resulted in medium or high risk level.

makes little sense to return workers to the same job that injured them. Now that we have begun to appreciate the implications of LBP (greater loadings) it makes even less sense to return a recovering worker to the same job. These guidelines are offered as a means by which workplace designers can develop a rationale for workplace redesign for those returning to the workplace.

One issue worthy of consideration in conjunction with these guidelines is the transition time between the LBP state and asymptomatic state. Ferguson (1998) evaluated time to recovery in acute muscular LBP patients. On average the occupational LBP patients required 12 weeks to recover functional performance whereas non-occupational patients required 8 weeks. Hence, in general when returning a symptomatic worker with muscular LBP to work it may be necessary to follow the "LBD" guideline for a minimum of three months. Further studies are necessary to determine the length of recovery in those with low back injuries involving the disc.

In comparing the results of our study to the TLV guidelines (American Conference of Governmental

Industrial Hygienists ACGIH, 2001) there is one interesting difference. In the floor condition the TLV guide indicates that lifts up to 14 kg would be safe. Our study results show that lifts from the floor at 11.4 kg would create high risk loads. The high risk was due to A/P shear exceeding 1000 N and not due to compressive load exceeding 6400 N. The compressive load for all lifts in the floor region was between 3400 N and 6400 N creating medium risk. Based on the data from our study none of the floor level lifts would be considered safe.

The TLV guideline was developed with a frequency factor (American Conference of Governmental Industrial Hygienists ACGIH, 2001). The frequency of the lifts in the current study corresponded to the slowest lifting frequency in the TLV guideline. The TLV guideline was developed for those without history of back injury and shows a decrease in acceptable loads with increased frequency. It is hypothesized that an increase in frequency would also reduce the tolerance level in those with low back injuries. Furthermore, the rate of tolerance reduction with increasing task frequency would be different in those with LBD compared to asymptomatic individuals therefore one could not use the reduction rates in asymptomatic individual and apply them to the low back injured population. Further studies with LBD patients at increased frequencies would be necessary to determine the acceptable tolerances.

The guidelines developed in this document used multiple criteria. The criteria included the commonly used compression values and the more recently developed criteria of A/P shear. The criteria for the percentage of the population performing the task can be found in the 1981 NIOSH lifting guide however the criteria is not as commonly sited. It is interesting to note that 74% all of the lifting conditions that classified as high-risk were due solely to A/P shear exceeding 1000 N. Norman et al. (1998) also showed the importance of shear force in predicting injury in an industrial population. All of the medium-risk lifting tasks in the shoulder, waist and waist-far regions for the patient population were due to the percentage of patients capable of performing the task. The differences in decision making criteria illustrate the need to evaluate more than just compressive loading when determining risk.

4.1. Limitations

The TLV guidelines cover multiple lifting frequency however, the current study only had one frequency. Further studies evaluating different lifting frequencies using LBP patients may expand our knowledge of spine loading in LBP patients. In addition, this analysis assumes that the risk is related to spine loads. One should understand that this is only one potential mechanism for LBP. However, this is believed to be one of the major injury pathways for work-related LBP.

5. Conclusions

This paper provides guidelines for low risk lifting conditions for those returning to work after a muscular low back injury.

Acknowledgements

This study was funded by the Ohio Bureau of Workers' Comprensation. The assistance of Ms. Swetha Sivakumar, Mr. Erich Theado, and Mr Christopher Hamrick in the execution of this study is gratefully acknowledged. In addition, we are grateful for the efforts of Dr. Robert Crowell and Dr. Daryl Sybert in subject recruitment.

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