■ The Influence of Psychosocial Stress, Gender, and Personality on Mechanical Loading of the Lumbar Spine

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Study Design. The effects of psychosocial stress on muscle activity and spinal loading were evaluated in a laboratory setting.
Objective. To evaluate the influence of psychosocial stress, gender, and personality traits on the functioning of the biomechanical system and subsequent spine loading.
Summary of Background Data. Physical, psychosocial, and individual factors all have been identified as potential causal factors of low back disorders. How these factors interact to alter the loading of the spine has not been investigated.
Methods. Twenty-five subjects performed sagittally symmetric lifts under stressful and nonstressful conditions. Trunk muscle activity, kinematics, and kinetics were used to evaluate three-dimensional spine loading using an electromyographic-assisted biomechanical model. A personality inventory characterized the subject's personality traits. Anxiety inventories and blood pressure confirmed reactions to stress.
Results. Psychosocial stress increased spine compression and lateral shear, but not in all subjects. Differences in muscle coactivation accounted for these stress reactions. Gender also influenced spine loading; Women's anterior–posterior shear forces increased in response to stress, whereas men's decreased. Certain personality traits were associated with increased spine loading compared with those with an opposing personality trait and explained loading differences between subjects.
Conclusions. A potential pathway between psychosocial stress and spine loading has been identified that may explain how psychosocial stress increases risk of low back disorders. Psychosocially stressful environments solicited more of a coactivity response in people with certain personality traits, making them more susceptible to spine loading increases and suspected low back disorder risk. [Key words: electromyography, gender, lifting, low back pain, personality, psychosocial stress, spinal loads]
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In recent years, the etiology of low back disorders (LBDs) in the workplace has been vigorously debated. Historically, research has attempted to assess how the physical characteristics of the workplace might influence biomechanical spinal loading and subsequent injury risk. More recently, psychosocial work characteristics have been implicated as a possible cause of LBD. Other findings suggest that risk may be a function of individual susceptibility. The literature is far from clear, however, as to the

mechanism or pathway by which these factors may influence LBD risk in the workplace.

■ Physical Factors

Physical workplace factors are believed to influence the risk of LBD by imposing loads on the spinal structures and muscles that exceed its mechanical tolerance.[22] Laboratory studies have indicated that increases in the load magnitude handled[8,13,14,18,26,27,33,45,58,71,82,84,85], and dynamic and nonneutral postures[1,14,15,18,26,27,50,60,69,71,82] can increase the loads imposed on these structures. Several epidemiologic studies have supported the premise that there is an association between lifting or forceful movements and LBD risk.[11,31,42-44,63,64,75,76,78,79,81] Magora[52,53] and Skov et al,[86] however, found LBD risk to be associated with sedentary work, whereas Videman et al[93] found increased rates of disc pathology in cadavers of those with histories of both sedentary or heavy work. Thus, the association between mechanical loading of the spine and risk of LBD does not appear to be linear or even monotonic.

■ Psychosocial Factors

Researchers have suspected that reactions to the psychosocial environment may help explain the association between work and LBD. More evidence has linked psychosocial risk factors to the occurrence of LBD, particularly monotonous work, high perceived workload, time pressure, and mental stress.[2,6,17,21,32,34-36,48,70,88,89,91,95] It is unclear, however, whether these factors are independent of physical loading.[5,12,20] Although several authors have found a significant correlation between biomechanical and psychosocial factors,[36,38,49,89,90] few studies have controlled for biomechanical effects when exploring psychosocial factors and LBD.[12] Hence, there appears to be a complex relation between psychosocial work factors and job demands.

■ Individual Factors

This relation may be complicated further by individual factors that may play a role in the development of LBD. Epidemiologic evidence indicates that the effect of psychosocial stress on LBD may be dependent on gender and the type of occupation.[9,34,35,48,86,95] Physically demanding jobs also have been associated with poor psychosocial environments for women, but not for men.[39,90]

Table 1. Stress Indicators, Anthropometry, and Personality Traits for Each of the Participants

| Subject* | Rating of Anxiety | | | Systolic Blood Pressure (mm Hg) | | Diastolic Blood Pressure (mm Hg) | | Heart Rate (bpm) | | Anthropometry | | | | | MBTI Personality |
	INT‡	UNS‡	STR‡	UNS§	STR§	UNS§	STR§	UNS§	STR§	Sex	Age (yrs)	Weight (kg)	Height (cm)	Spine Length (cm)	
1	26	25	43	106.3	122.1	70.4	78.1	95.8	104.3	F	21	72.7	164.1	53.7	ESTJ
2	28	36	63	102.1	108.3	71.1	74.5	70.7	71.7	F	20	53.6	156.5	54.4	ENFJ
3*	47	29	36	115.4	112.7	74.5	75.4	65.9	64.4	F	21	72.7	168.8	55.1	ESFJ
4	37	37	37	134.5	136.5	93.8	91.5	106.6	114.3	M	23	75.9	179.8	60.3	ISFJ
5	38	36	48	113.7	131.7	71.6	86.3	71.6	69.3	M	23	64.5	172.9	58.5	ISTJ
6	35	32	50	114.8	111.1	66.9	66.3	75.2	75.9	M	22	75.0	166.2	56.7	INTJ
7	24	28	56	117.7	125.7	83.9	85.8	109.5	110.9	M	21	84.1	191.2	63.2	ENTP
8	35	34	47	128.0	127.6	81.4	83.9	79.8	77.6	M	23	70.5	174.8	59.2	ESTJ
9	21	21	21	129.3	136.7	84.4	101.3	105.4	99.7	M	23	110.0	187.5	62.9	ENTP
10	29	26	40	110.4	110.5	70.9	69.9	106.1	111.9	F	19	65.5	163.0	48.1	INFJ
11	22	29	64	138.0	138.1	79.2	88.4	74.9	71.8	M	22	72.7	178.5	52.4	ESTJ
12	36	34	40	125.7	141.3	78.9	81.1	82.5	95.5	M	20	83.2	183.5	58.2	ESTJ
13	41	37	46	100.9	103.3	70.0	67.6	67.4	70.9	F	31	65.9	166.9	54.9	ESFJ
14	30	30	37	114.7	120.2	80.3	81.5	81.6	82.9	F	20	68.6	178.9	60.5	ENFP
15	45	44	54	104.7	103.5	71.7	68.1	81.6	88.6	F	24	72.7	167.5	53.9	ENFP
16	25	29	21	127.3	141.0	87.9	96.5	87.7	91.8	M	22	80.9	165.0	56.1	ESTP
17*	23	23	31	111.4	111.7	66.8	67.9	103.1	100.5	M	22	86.8	180.6	60.0	ESTJ
18	71	48	80	128.7	129.1	90.0	83.2	86.4	90.7	F	20	75.0	166.9	55.0	ENFJ
19	38	37	43	126.7	135.4	78.7	76.7	73.1	69.5	M	19	63.6	170.2	57.8	INTJ
20	48	42	56	120.7	118.6	79.9	78.5	87.6	81.5	M	23	65.9	172.5	59.3	ENTJ
21	35	30	57	111.7	117.8	74.8	68.9	97.4	102.4	F	29	67.7	166.4	53.4	INTJ
22	30	22	43	137.1	137.7	94.3	92.0	89.3	84.6	M	23	88.6	173.4	59.7	ENFP
23	29	25	42	115.9	119.2	84.6	82.3	80.4	77.8	F	29	65.0	180.2	56.8	INTJ
24	38	29	50	116.1	121.3	79.4	80.7	78.5	85.5	M	22	62.7	167.4	64.6	Unavailable
25	30	28	45	123.5	136.2	86.5	87.9	98.9	110.0	M	21	72.3	189.9	56.6	ESTP
Male†	37.1	33.4	51.3	125.2	131.6	81.9	85.6	81.9	85.6		21.9	76.4	176.6	59.0	
	(14.2)	(8.4)	(13.8)	(10.2)	(13.2)	(10.2)	(10.6)	(10.2)	(10.8)		(1.3)	(12.6)	(8.7)	(3.2)	
Female†	32.6	31.3	44.4	110.6	114.9	75.9	74.9	75.9	74.9		23.7	67.4	167.8	54.5	
	(7.6)	(5.9)	(12.1)	(10.1)	(10.8)	(9.4)	(9.2)	(9.4)	(9.2)		(4.7)	(6.3)	(7.5)	(3.3)	

* Subjects eliminated from analyses because of inadequate stress manipulation (an increase in anxiety rating less than 8 and an increase in systolic pressure of less than 2 mm of Hg).
† Average values with standard deviations in parentheses.
‡ INT = stress rating at start of experiment; UNS = stress rating after no-stress session; STR = stress rating after stress session.
§ UNS = recordings taken during initial session with no stress manipulation; STR = recordings taken during follow-up session with stress manipulation.
MBTI = Myers-Briggs Type Indicator: introversion (I)/extraversion (E), sensing (S)/intuition (N), thinking (T)/feeling (F), judging (J)/perceiving (P).

Personality also may play a role in one's susceptibility to LBD risk factors, in that they might potentially influence the response to psychosocial stress. Although the literature evaluating personality and LBD is limited, a recent study suggests that a link may exist and may be moderated by the job's physical requirements (unpublished dissertation).[3] In jobs that placed low physical demands on employees, workers whose personalities were less matched with their work environment reported more low back discomfort than did those whose personalities better matched the workplace. In high physical demand facilities, however, no back discomfort differences existed among those with varying personalities. These results also indicated that introverts generally reported greater levels of low back discomfort than did extroverts. Glasscock et al[29] also found personality to influence the biomechanical response in the elbow in terms of muscle coactivity.

The present studied tested the hypothesis that there is a complex relation between psychosocial work factors, physical job demands, and individual parameters (gender and personality). Further, the authors contend that for factors such as psychosocial stress and personality to have an impact on anatomically detectable spine damage (e.g., disc problems), a pathway to spine loading must be present. Hence, the study's objective was to investigate the impact of psychosocial stress and individual factors on variables that influence spine loading.

■ Methods

Subjects. Subjects consisted of 15 male and 10 female students that were asymptomatic for low back pain in the previous year. Subject age, anthropometric characteristics, and personality type are presented in Table 1.

Experimental Design. A repeated measures within-subjects experimental design was used by having subjects performing standard lifts under both unstressed and stressed conditions. The Ohio State University Institutional Review Board approved the experimental protocol.

Independent variables consisted of two psychosocial stress conditions (stressed and unstressed). Dependent measures consisted of trunk kinematics, torso kinetics, electromyographic (EMG) activities of 10 trunk muscles, and the peak spinal loads. Subjective anxiety, blood pressure, and heart rate were recorded for both conditions to verify the level of stress manipulation.

Occupational stress is a complex and dynamic process where stressors, perceived stress, and short-term stress re-
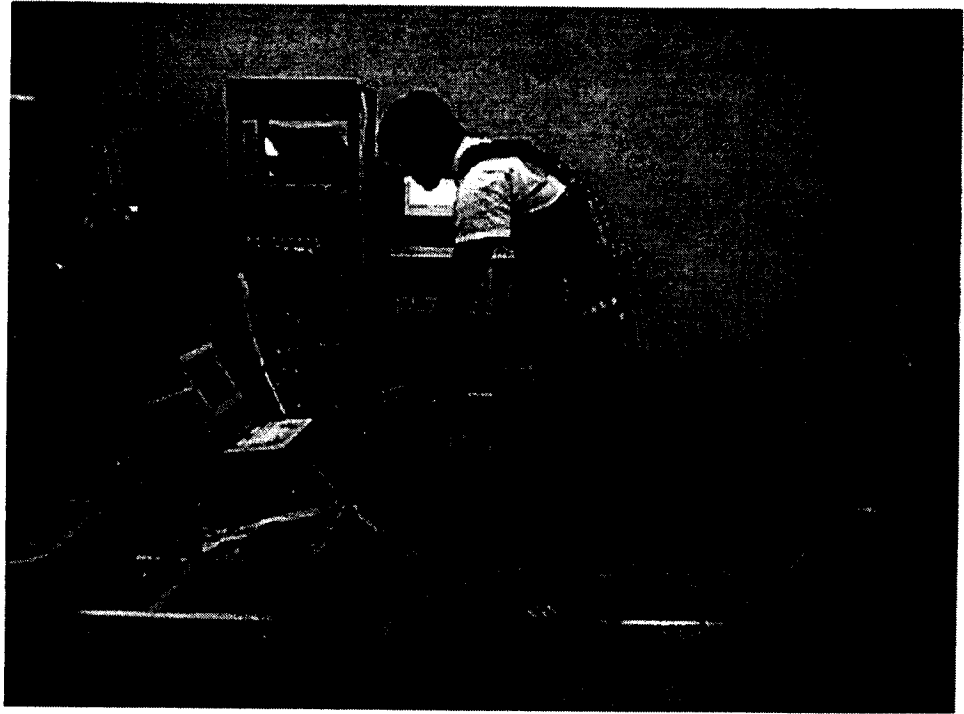
Figure 1. A participant performing a lift condition while controlling the trunk velocity using a computer display.

sponses interact.[23,41] Work conditions are stressors if they are perceived as harmful or bothersome or if they place a demand that causes a physiologic adaptational response.[47,83] Therefore, for the purposes of this study, the stress state was operationally defined in terms of a response (e.g., elevated blood pressure and reported anxiety) to a stimulus. The current study evaluated the short-term responses to perceived stress.

Apparatus. Trunk kinematic information was recorded using the Lumbar Motion Monitor (LMM). Its design, accuracy, and application have been reported elsewhere.[56]

The activities of the right and left muscle pairs of latissimus dorsi, erector spinae, external and internal obliques, and rectus abdominus were collected through bipolar surface electrodes using standard EMG techniques.[54,77] Specific electrode locations have been reported elsewhere.[73] The EMG signals were band pass filtered between 30 Hz and 1000 Hz, rectified, and integrated through a 20 millisecond sliding window hardware filter.

A forceplate and a set of electrogoniometers were used to measure the three-dimensional external moments (kinetics) supported by the trunk. The goniometers measured the position of L5/S1 relative to the center of the forceplate as well as the subject's pelvic/hip orientation. The forces and moments were translated and rotated from the forceplate to L5/S1 by methods developed previously.[19]

An automatic blood pressure and heart rate monitor was used to confirm the stress manipulation. The blood pressure cuff was placed on the left arm one inch above the elbow crease. All processed EMG, kinematic, and kinetic information was digitized at 100 Hz and collected on a microcomputer.

Experimental Procedure. On arrival, subjects completed a consent form and two questionnaires—the Myers–Briggs Type Indicator (MBTI)[74] assessed personality, and the Spielberger' State-Trait Anxiety Inventory (STAI)[87] measured anxiety to confirm whether the stress condition solicited a significant re-

action. Subjects completed the STAI at three times: before the unstressed condition, after the unstressed condition but before the stressed condition began, and after the stressed condition was completed. The subject then performed maximum voluntary contractions in six directions that were used to normalize the subsequent EMG data.[66]

The experimental lifting task for both the stressed and unstressed conditions required the subject to complete five controlled lifts while moving at three different trunk extension velocities (15, 30, and 45 deg/s). Subjects were required to precisely control their trunk velocity (using computer feedback) throughout the lift by maintaining their position within a tolerance ($\pm$ 1.5%) while lifting a 13.6 kg mass (Figure 1). Velocity control was necessary to ensure that the physical requirements were consistent between the stressed and unstressed conditions. Blood pressure and heart rate were measured after each lift.

During the unstressed session, the experimenters used positive language and actions to encourage the subject (Table 2). When the unstressed session was completed, the experiment was interrupted with the experimenters leaving the room. On returning to the room, the experimenters appeared distraught and used nonsupportive language and actions (Table 2) when interacting with the subject. Subjects completed the same set of lifts as described above, except that the visual feedback was manipulated to appear to fall outside the prescribed tolerance, providing a reason for the experimenters to criticize the subject's performance. The manipulation had no effect on actual trunk motions because it affected the latter portion (minimal loading) of the lift task only. The velocity conditions were randomized within the unstressed session but were counterbalanced during the stressed session, because lifts of the same velocity had to be performed in succession to provide the appearance of failure. Finally, a debriefing session was conducted where the subjects were informed about the true nature of the study (i.e., to evaluate stress).

Table 2. Description of the Words and Actions Used During the Unstressed and Stressed Sessions

Unstressed Session	Stressed Session
Script provided to participants before each session	
The following lifts will be practice to allow you to become familiar with the lifting tasks and blood pressure collection.	The following lifts will be the same as you just performed, and it is important that you perform the lifts as well as you did in the practice.
Words used by the investigators	

Use "please" and "thank you" a lot.
Provide encouragement:
  "Good job!"
  "You are really good at this."
  "All of our subjects should be like you."
  "You are a quicker learner."
  "Excellent!!"
  "That was perfect"
  "You're a natural."
Provide reinforcement:
  "You can do it."
  "You'll do fine."
  "It gets easier with practice."
	Avoid using "please" and "thank you".
	Provide no praise or encouragement:
	  "Not good enough"
	  "You've got to try harder."
	  "Pay attention!"
	  "That will have to do"
	
	Provide feedback about poor performance:
	  "What happened? You were doing so well before."
	  "You need to control the lift better."
	  "Are you concentrating too much?"
	  "What are you doing?"

Actions used by the investigators	
Smile Good eye contact Nodding Make small talk between lifts	Frowning No direct eye contact Head shaking side to side Looking at the floor in disgust Very limited talking

Personality Typing. Subject's personality was characterized using the MBTI.[74] Briggs-Myers and Myers[7] developed this personality inventory, which consists of four independent scales: 1) introversion (I)/extraversion (E); 2) sensing (S)/intuition (N); 3) thinking (T)/feeling (F); and 4) judging (J)/perceiving (P). The MBTI is based on the original work of Jung,[40] who proposed that human behavior is predictable, and personality type remains constant throughout life. Each of these personality traits is associated with certain preferences that may influence subject's responses to a given work situation or task and with certain circumstances that can energize or stress an individual.[7,46] Theoretically, a person prefers one or the other of each opposing pair of preferences, and one preference is always favored. Reliability and validity of the MBTI has been reported by Bayne[4] and Harvey,[29] and it has been used in more than 700 published studies.[10] The MBTI has been widely used to assess "white collar" workers, but seldom for physical labor.

Predictions of Spinal Loads. Three-dimensional spine loading was assessed using an EMG-assisted biomechanical model developed and validated in this laboratory during the past 17 years.[14,18,26-28,55,58-60,67-69,73,80] This model has high fidelity in all three motion planes (forward bending, lateral bending, and twisting)[14,18,26-28,55,58-60,69,73] and has recently been adjusted for gender differences.[37,62] A description of model performance has been widely reported in the biomedical, spine orthopaedics, and ergonomics literature.[14,18,26-28,55,58-60,69,73]

Analyses. Repeated-measures analysis of variance (ANOVA) statistical analyses were performed on all dependent variables. Those with significant effects were analyzed further using *post hoc* analyses using Tukey multiple pairwise comparisons.

■ **Results**

Two of the 25 subjects did not respond to the stress manipulation (*e.g.*, insignificant increases in anxiety and blood pressure), and their information was eliminated from the analyses. Subjects' responses are shown in Table 1.

Statistically significant spine loadings, muscle responses, and kinetic responses to the psychosocial stress manipulation were observed (Table 3). Figure 2 shows a typical response to the stress. This figure indicates that the response was characterized by a modest increase in load for all three dimensions throughout the lift. Peak spine compression increased under the psychosocial stress condition by approximately 75 N (approximately 2.6%). When the response of men and women was contrasted, a larger difference was observed for men (114 N or 4%) compared with women (16 N). A 12% increase in lateral shear was observed when stress was present, which was unexpected because the task involved only sagittally symmetric lifting. Yet no statistically significant increase in lateral trunk motion was observed. A significant difference in anterior–posterior (A–P) shear also occurred and was linked to gender. In the stressed condition, men decreased their A–P shear by approximately 5%, compared with approximately 1.5% for females. The sagittal moment also decreased by 3.5% in the psychosocial stress trials. This difference was much greater for women (approximately 8%) compared with men (approximately 1%). When spinal moment was taken into account, differences in A–P shear per unit mo-

Table 3. Statistical Summary (P Values) of Significant Analyses of Variance for the Trunk Moments, Spinal Loads, and Trunk Muscle Activities

Effect	Absolute Spinal Loads			Normalized Spinal Loads			Kinetics			
	Compression Force *	Lateral Shear Force	A-P Shear Force	Compression Force Per Unit Moment	Lateral Shear Force Per Unit Moment	A-P Shear Force Per Unit Moment	Sagittal Trunk Moment	Lateral Trunk Moment	Twist Trunk Moment	Resultant Trunk Moment
Gender	0.48	0.24	0.05†	0.50	0.32	0.09	0.40	0.13	1.00	0.26
Stress	0.02†	0.04†	0.31	0.002†	0.03†	0.12	0.05†	0.75	0.90	0.09
Gender*Stress	0.09	0.30	0.04†	0.06	0.91	0.01†	0.10	0.55	0.56	0.38

Effect	Muscle Activity									
	Right Latissimus Dorsi	Left Latissimus Dorsi	Right Erector Spinae	Left Erector Spinae	Right Rectus Abdominus	Left Rectus Abdominus	Right External Oblique	Left External Oblique	Right Internal Oblique	Left Internal Oblique
Gender	0.02†	0.0004†	0.02	0.04†	0.18	0.30	0.39	0.35	0.20	0.17
Stress	0.45	0.73	0.01†	0.06	0.66	0.55	0.08	0.01†	0.01†	0.01†
Gender*Stress	0.47	0.78	0.49	0.22	0.31	0.68	0.58	0.37	0.38	0.36

*Interaction effect.
† Significant effects at $P < 0.05$; bold values represent significant effects at $P < 0.10$.

ment increased dramatically for women (16%) in the stress condition, whereas a decrease of 4.5% occurred for men (Table 4). The kinematic data also indicated a significant difference in hip motion between genders. Women reduced their hip motion, resulting in a reduced trunk moment during the stress condition, whereas men's hip motions were relatively unchanged (Figure 3).

Table 3 also indicates that psychosocial stress was associated with muscle activity increases in several trunk muscles. The erector spinae, internal oblique, and external oblique muscles generally exhibited greater mean activities of between 3.5% to 6.5% during the stress conditions, indicating an increase in coactivation in response to stress (Figure 4), as well as increases in spinal loading.

Significant differences were noted between subjects in their reaction to psychosocial stress. Figure 5 shows that the range of spine compression varied markedly when different individuals were subjected to the stressed con-

Figure 2. Representative data for the three-dimensional spinal loads for an unstressed and stressed lift.

dition. Some subjects demonstrated substantial increases in compression, whereas others exhibited little difference. Personality differences were evaluated in an effort to explain this variability. Many personality–stress interactions were significant, indicating that people with different personality traits responded to psychosocial stress differently. Table 5 indicates that most personality traits were associated with some sort of increase in spine compression when psychosocial stress was introduced. Shear loadings, however, were associated with only a few personality traits. Introversion and intuition preferences were associated with large increases in lateral shear. Introverts increased shear by increasing trunk acceleration and increasing external oblique muscle activity, whereas intuitors increased their lateral trunk motion. Anterior-posterior shear was uniquely associated with the thinker/feeler trait. Thinkers increased internal oblique activity along with erector spinae and abdominal muscle activity. The horizontal vector component of the oblique muscle most likely resulted in an increase in A–P shear.

■ **Discussion**

This study provides an indication, for the first time, that there is a biomechanical pathway to spine loading associated with psychosocial stress. This study suggests that the pathway is complex, in that spine loading is a mixture of physical work demands, one's reaction to the psychosocial environment, and the unique attributes of the person. This indicates a psychosocial–biomechanical interaction that defines physical loading on the spine. A possible mechanism by which psychosocial stress increases spine loading, as shown in this study, is through alterations in muscle coactivity and trunk kinematics.

Previous studies have suggested that this psychosocial-biomechanical link might exist. Those who assessed reac-
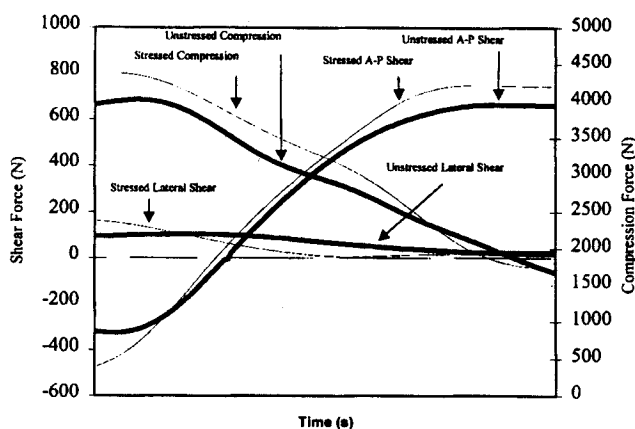
Table 4. Sagittal Trunk Moment and Three-Dimensional Spinal Loads (Absolute and Normalized) for the Unstressed and Stressed Sessions for Men and Women

	Condition	Absolute Loads and Moments			
		Compression Force (N)	Lateral Shear Force (N)	A-P Shear Force (N)	Sagittal Moment (Nm)
Male	Unstressed	**2895.0 (770.3)**	**77.9 (52.0)**	**199.6 (85.8)**	108.3 (41.1)
	Stressed	**3008.7 (817.0)**	**89.7 (53.9)**	**189.2 (53.9)**	107.1 (28.0)
Female	Unstressed	2722.3 (673.1)	59.3 (31.5)	283.3 (127.5)	99.1 (24.1)
	Stressed	2738.7 (722.3)	63.1 (29.2)	288.0 (129.5)	91.5 (27.9)
All	Unstressed	2827.5 (737.7)	70.6 (46.0)	232.3 (111.6)	104.7 (35.7)
	Stressed	**2901.8 (790.9)**	**79.2 (47.5)**	228.3 (114.5)	100.9 (35.2)

	Condition	Normalized Loads		
		Compression Force Per Unit of Moment (N/Nm)	Lateral Shear Force Per Unit of Moment (N/Nm)	A-P Shear Force Per Unit of Moment (N/Nm)
Male	Unstressed	28.01 (4.97)	0.87 (0.71)	2.24 (1.48)
	Stressed	29.09 (5.23)	0.97 (0.71)	2.14 (1.42)
Female	Unstressed	28.00 (5.27)	0.62 (0.33)	**3.08 (1.50)**
	Stressed	**31.34 (7.94)**	0.72 (0.35)	**3.57 (2.03)**
All	Unstressed	28.01 (5.08)	**0.77 (0.60)**	2.57 (1.54)
	Stressed	**29.98 (6.53)**	**0.87 (0.61)**	2.90 (2.77)

Bold values indicate significant difference between stressed and unstressed conditions.

tions of mental stress on the shoulder musculature have reported that psychosocial work characteristics (e.g., concentration demands) and responses to the psychosocial environment (e.g., mental stress) influence muscle activity.[3,16,51,92,94] These studies certainly support the mechanism of biomechanical loading identified in the present study.

The current work has imposed moderate loads on the spine and has found that small increases in spine loading occurred in response to psychosocial stress. The compressive loads increased by an average of 7% with even larger increases seen for certain types of individuals (e.g., introverts (13.7%) and intuitors (10.8%)). The response

to stress may be a function of magnitude of the external load. The objective in this study was simply to establish whether there was a biomechanical pathway for spinal loading associated with psychosocial stress, so only one external load was evaluated. Nearly all previous studies reporting significant muscle activity responses to stress have involved low external loads of the shoulder and typically involve postural support musculature.[3,16,51,94] During low physical demands, psychosocial stress may manifest itself by increases in muscle activity. During greater demands, however, the physical requirements imposed may negate any stress-induced increase in activity. Based on this logic, it is hypothesized that the effect of
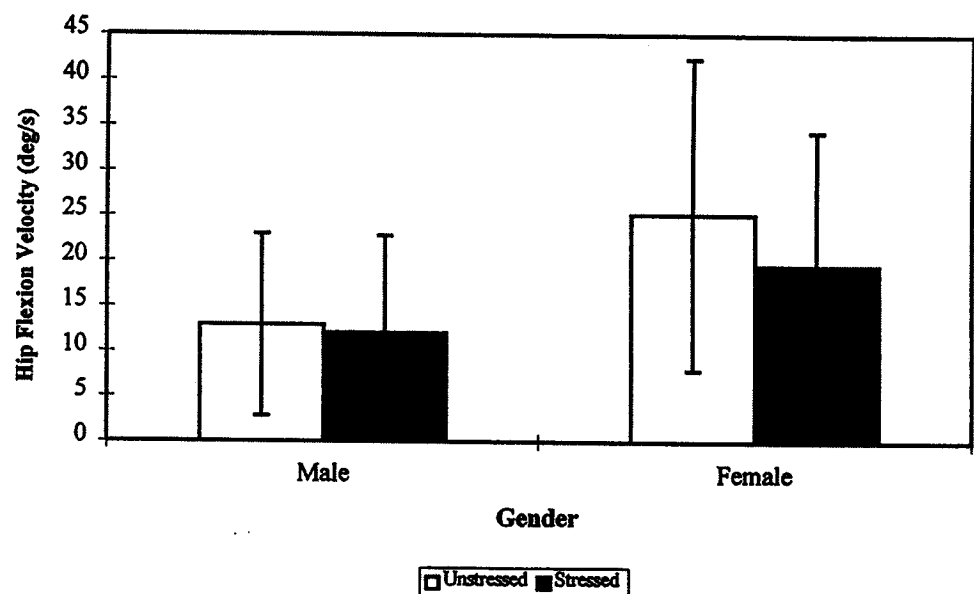

Figure 3. Hip flexion velocity for men and women during the unstressed and stressed conditions.
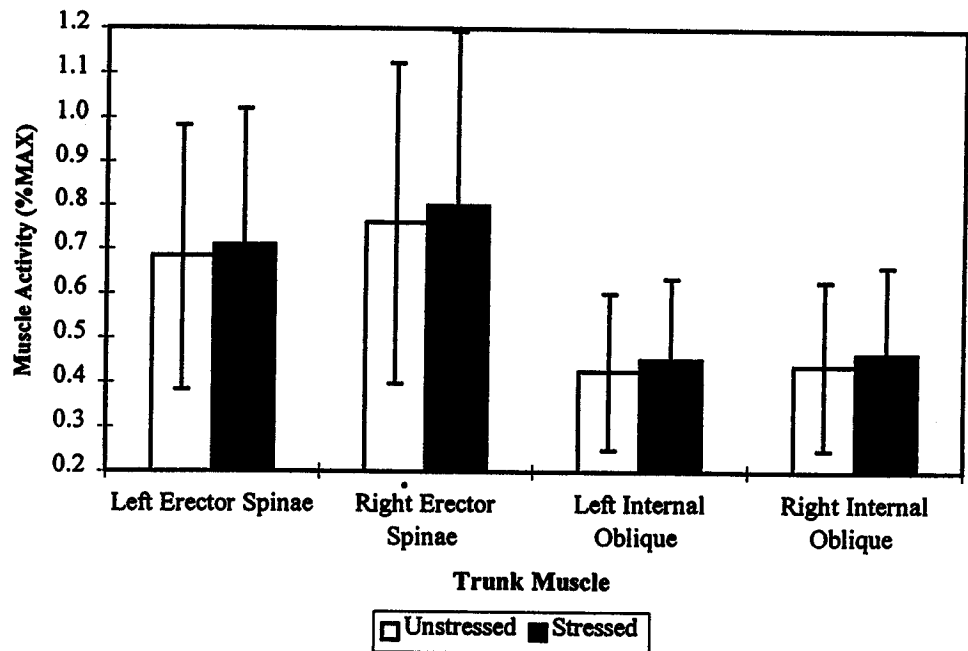
Figure 4. Normalized activity (% of maximum voluntary contraction) for the erector spinae and internal oblique muscles during the un-stressed and stressed conditions.

psychosocial stress would be more prominent for low physical demands, whereas the biomechanical demands at heavier loads would outweigh the effects of stress, resulting in a "J" relation. This might help explain the findings of Videman et al.[93]

It is possible that the impact of the psychosocial stress in this study may be underrepresented for several reasons. First, these results represent short-term responses to stress. The impact of long-term exposure may increase coactivation compared with the short-term exposure used here and possibly result in more permanent changes in the neuromuscular system.[57,65] The cumulative effect of stress on

muscle activity and spinal loads may prove to be a significant mechanism by which stress leads to low back pain.

The association between psychosocial and biomechanical exposures on the risk of LBD also appears to be dependent on gender. The present study indicated that gender plays a role in the effect of stress on spine shear loading. Differences in muscle lines of action between men and women resulted in different loading patterns of the spine in response to psychosocial stress.[37] In addition, women compensated for psychosocial stress through altered hip kinematics, reducing the moment imposed on the spine.
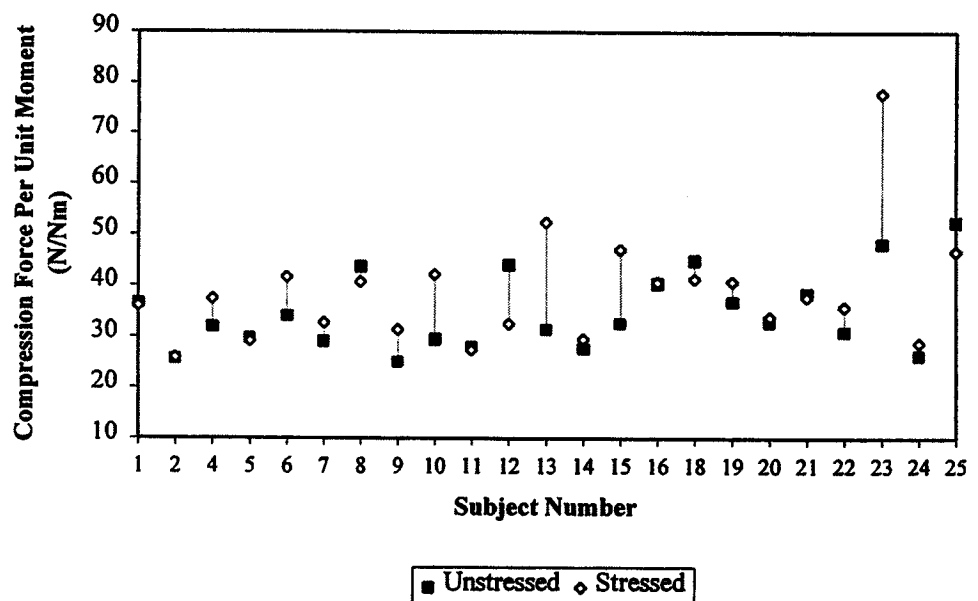

Figure 5. The maximum compression force per unit of sagittal trunk moment for each of the subjects during the unstressed and stressed conditions.

Table 5. Summary of the Differences Between Personality Traits for Spinal Loads, Trunk Moments, Trunk and Hip Kinematics, and Muscle Activity

Personality Trait	Compression Force		Lateral Shear Force		A-P Shear Force		Kinematics		Kinetics†	Muscle Activity‡
	Absolute*	Normalized*	Absolute*	Normalized*	Absolute*	Normalized*	Trunk†	Hip†		
Extraverts		↑ 4.0%		↑ 6.2%			Lat acc ↓ 14.9%			LEO ↑ 5.6%
Introverts		↑ 13.7%		↑ 27.2%			Lat acc ↑ 10.8%			LEO ↑ 18.7%
Sensors		↑ 2.5%	↑ 1.3%	↑ 1.5%			Lat vel ↓ 7.5%		Sag mom ↑ 1.3%	
Intuitors		↑ 10.8%	↑ 20.3%	↑ 25.1			Lat vel ↑ 16.8%		Sag mom ↓ 6.5%	
Thinkers	↑ 4.2%				↓ 3.7%			Hip flex vel ↓ 11.2%	Sag mom ↓ 1.1%	LES ↑ 6.3% RAB ↑ 5.2% RIO ↑ 9.3% LIO ↑ 9.8%
Feelers	↑ 0.2%				↑ 1.6%			Hip flex vel ↓ 25.4%	Sag mom ↓ 8.4%	LES ↑ 0.1% RAB ↓ 5.2% RIO ↑ 1.0% LIO ↑ 1.0%
Judgers	↑ 1.6%						Twt pos ↑ 1.9%			
Perceivers	↑ 5.0%						Twt pos ↑ 26.8%			

* Absolute represents differences in the magnitudes of the spinal load (N) while normalized represents differences in the spinal loads relative to the sagittal moments (N/Nm).
† Lat vel = lateral trunk velocity, Lat acc = lateral trunk acceleration, Twt pos = twist trunk position, Twt vel = twist trunk velocity, Hip flex vel = hip flexion velocity, Sag mom = sagittal trunk moment.
‡ LES = left erector spinae, RAB = right rectus abdominus, LEO = left external oblique, RIO = right internal oblique, LIO = left internal oblique. Bold values were significant at $P < 0.05$.

One of the more surprising findings associated with this study was the fact that personality traits may be responsible for spine loading differences due to stress(Table 5). Different personality types responded to psychosocial stress in very different ways. Introverts appeared to have one of the largest reactions to psychosocial stress, with increases in normalized compression and lateral shear. One characteristic of introverts is they tend to internalize their thoughts and feelings.[7,23] This internalization may result in increased coactivation as a means of controlling the situation, resulting in the higher spinal loading. Intuitors also displayed increases in lateral shear and normalized compression that may be related to their adversity to performing repetitive tasks.[7,46] In this experiment, velocity feedback was manipulated, making it appear that the lift needed to be repeated, potentially influencing the control strategy of the lift. Similarly, the thinker personality trait was associated with an increase in absolute spine compression. Thinkers are typically uncomfortable dealing with other people's feelings, and the negative reactions of the investigators may be stressful to these subjects, resulting in increases in muscle activities and compression.[7,23] Wilson and Languis[96] have demonstrated that people of different personality types generate different brain activity patterns. Thus, these coactivity responses might be "hard-wired" to personality.

These findings may help place much of the previous conflicting literature in perspective. Because people of different personality traits respond to psychosocial stress differently, a physical task may be stressful for one personality type and may increase LBD risk. Further, because certain personality types are attracted to certain types of work, this study might help determine why previous studies have found conflicting results in the psychosocial stress literature.[2,9,30,34-36,48,88,95]

A potential limitation should be considered when interpreting these results. The design of the study was less than optimal because it was not possible to counterbalance the conditions. Because the stress manipulation was expected to influence the subject's performance of the lifts, the unstressed conditions were completed before the stress lifts. In ideal circumstances, subjects would forget previous experimental sessions, and there would be no carry-over effects. A strong carry-over effect would be expected to occur, however, if the stressed condition were performed first. Given the current design, if carry-over effects were present, the response to stress would have been lessened because subjects had time to become comfortable with the environment. Thus, this limitation is not believed to have greatly impacted the results.

This study has shown, for the first time, that there is a potential biomechanical pathway associated with psychosocial stress. In addition, individual factors, such as gender and personality traits, dictate how psychosocial stress manifests itself—with increases in muscle coactivity and spine loading. Collectively, these results suggest that one should consider these factors' effects on the hu-

man system when attempting to evaluate causality of LBD in the workplace.

■ Key Points

• For the first time, a potential pathway between psychosocial stress and spine loading has been identified.

• Responses to stress appeared to be mediated by gender and personality type.

• The introduction of stress increased muscle activity, hip kinematics, and spine loads.

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