Static Lower Back Stress Analysis in Citrus Harvesting

T. M. Conlan, J. A. Miles, W. E. Steinke

Abstract. *The dramatic increase in worker injuries and Workers' Compensation insurance costs have created a need to reduce worker mechanical stress in harvesting citrus. This analysis implemented occupational biomechanics to evaluate lower back stress in the current citrus harvesting operation. The object of this investigation was to identify activities which induce excessive lower back stresses on citrus workers. Lower back stress was evaluated under static conditions in three commonly occurring citrus harvesting positions and compared with National Institute for Occupational Safety and Health established limits on lower back stress. Three commonly occurring positions were analyzed—descending the citrus ladder, walking with a full citrus bag, and bending over to pick citrus from the ground. Sensitivity analysis was performed to determine if the citrus bag weight, abdominal pressure, height, weight, and physical size of the worker affects lower back stress. Some of these activities cause lower back force to exceed established industrial limits. Current citrus harvesting systems could be redesigned to reduce physical stress encountered by citrus pickers.*

Keywords. *Citrus harvesting, Ergonomics, Biomechanics, Lower back stress.*

California workers' compensation insurance rates for harvesting citrus in late 1993 were 17.23% of the wages paid for harvesting citrus, up from 7.44% in 1981. These insurance rates represent the costs of many types of injuries, some of which may be prevented by altering the harvesting system. In studying the workers' compensation claims from a southern California citrus grower, it was determined that 18% of the occurrence and 33% of the cost of citrus harvesting injuries were related to lower back injuries. This is consistent with compiled data on worker injuries in industrial settings (California Department of Industrial Relations, 1991).

The current citrus harvesting procedure is effective at removing the desired citrus from the tree with a minimal amount of damage to the fruit. Some of the main reasons for this effectiveness include the citrus pickers being paid for the amount of citrus that they individually pick, "piece rate", and labor is readily available. The piece rate method stimulates picker productivity and allows growers to effectively determine picking costs before picking. The piece rate varies from orchard to orchard depending upon the field conditions, tree size, amount of citrus, and size of fruit being harvested. The average wage for the southern California citrus grower monitored in 1992 was in excess of $8/h. One downfall of the piece rate method of picking citrus is the pickers, in order to increase productivity, have a tendency to rush which can lead to injuries.

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The authors are **Tye M. Conlan**, ***ASAE Student Member***, Graduate Research Assistant, **John A. Miles**, ***ASAE Member Engineer***, Professor, and **William E. Steinke**, ***ASAE Member Engineer***, Specialist, Biological and Agricultural Engineering Dept., Univ. of California, Davis.

In discussions with the safety supervisor at a southern California citrus grower, questions were asked about the types of picking activities which he recognized as leading to injuries in harvesting citrus. These activities included running with a full citrus bag, over extending to pick citrus not within reach of the citrus ladder, and not positioning the citrus ladder firmly within the tree before ascending. These activities occurred because the citrus picker is rushing to maximize the amount of citrus picked, thereby maximizing the amount of money made.

Citrus harvesting accidents can be grouped into two categories. The first, single incident injuries, are injuries that occur due to a single incidence or mishap. An example of this type of injury is the citrus ladder slipping within the citrus tree, causing the worker to fall. The second, cumulative trauma injuries, are the type of injuries that occur due to long exposure to a repetitive activity. An example of this type of injury is a sore lower back caused by the repetitive lifting of the citrus harvesting bag, leading to discomfort, injury, and lost time.

Current citrus harvesting equipment includes a canvas citrus harvesting bag, aluminum ladder, a pair of leather gloves, canvas arm guards, citrus clippers, and appropriate personal protective gear. The picker places the ladder into citrus tree, ascends the ladder, and picks citrus until the citrus bag becomes full. Once full, the citrus picker descends the ladder and carries the full citrus bag to an assigned bin. A typical harvest crew member and a typical ladder placement within a citrus tree is shown in figure 1.

Groups of citrus trees and a citrus bin are assigned to each citrus picker. The bins are usually 1.2 m^2 with a 0.8 m height. These bins are placed between every fourth tree row. The soil between every fourth tree row has a packed surface for equipment travel under various weather conditions. Bins are placed in close proximity to a group of trees assigned to each citrus picker to minimize the distance the worker must carry the fruit to the bins. A typical citrus harvesting layout is shown in figure 2.

(a) (b)

Figure 1–Current citrus harvesting equipment. (a) Typical picker and equipment, and (b) ladder placement in citrus tree.

Problem Statement

This analysis focuses on determining the static lower back stresses induced on the citrus pickers. Citrus harvesting activities that expose citrus pickers to excessive stresses are identified. Recommendations are made on how the current citrus harvesting procedure should be altered. These alterations focus on decreasing excessive and repetitive stress on the citrus picker.

Review of Literature

Methods of Measuring Stress

The most widely used job stress analysis procedures include energy expenditure and biomechanical analysis. Energy expenditure analysis determines the total body energy output when performing a certain job task. This type of analysis is primarily used to determine overexertion and fatigue in extended work exposures (Suggs and Splinter, 1958). Biomechanical analysis determines musculoskeletal stress at joint locations in the human body (Chaffin and Andersson, 1991). Since the focus of this research evaluated lower back stress in the current citrus harvesting procedure, a biomechanical analysis was performed.

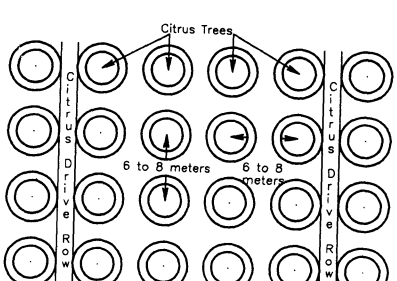

Figure 2–Typical citrus harvesting layout.

The general field of biomechanics was defined as follows (Frankel and Nordin, 1980):

> "Biomechanics uses the laws of physics and engineering concepts to describe motion undergone by various body segments and the forces acting on these body parts during normal daily activities."

By this definition, biomechanics is a multi-disciplinary activity, which requires combining knowledge from the physical and engineering sciences with knowledge from the biological and, to a lessor extent, behavioral sciences. A large variety of human disorders and performance limitations have been shown to be amenable to biomechanical interpretation and resolution (Chaffin and Andersson, 1991).

The focus of this biomechanical analysis was to determine the static lower back force encountered by the citrus picker when exposed to frequently occurring citrus harvesting positions and loads. Lower back stress at the lumbosacral disc (L5/S1 disc) was calculated. Over 85% of all disc herniations occur at the L4/L5 and L5/S1 levels (Krusen et al., 1967; Smith et al., 1944; Armstrong, 1965). Since the L5/S1 disc incurs the greatest moment in lifting activities, it was chosen to represent lumbar stresses during lifting (Chaffin and Andersson, 1991).

Stress Limits

The National Institute for Occupational Safety and Health has recommended that jobs which are potentially hazardous to some workers occur when L5/S1 lower back compression forces values exceed 3400 N (Waters et al., 1993). If the compression values are greater than 6400 N, the job is hazardous to most workers (National Institute for Occupational Safety and Health, 1981). If the compressive force estimate is above the lower limit, the task should be redesigned to reduce the compression forces on the L5/S1 disc. This is particularly needed if the compression forces are repeated, since the strength of the lumbar discs decrease greatly under frequent loads (Brinkmann et al., 1987).

Many suggested limits have been established for general guidelines to repetitive lifting. These limits range from 17 kg (National Institute for Occupational Safety and Health, 1981) to 24.5 kg (International Labour Organization, 1962). These limits were determined from industrial situations in which workers were exposed to repetitive lifting environments in ideal lifting conditions. In some cases, the scientific rationale for these limits is not well stated.

Biomechanical Analysis

The force induced at the L5/S1 disc from both loading and the musculoskeletal reaction to loading was estimated by the following procedure.

- Estimated the magnitude and position of upper body and citrus bag weight with respect to the centroid of the L5/S1 disc.
- Calculated the loading moment at the L5/S1 disc.
- Determined musculoskeletal reaction moment at the L5/S1 disc created by abdominal pressure.
- Balanced moments on the L5/S1 disc with the contraction of the back muscles.

- Balanced the forces on the L5/S1 disc and determine the L5/S1 disc compression force.

From the estimation of loading force (W_{cm}) and moment (M_v) on the L5/S1 disc, musculoskeletal reactions of the human body were analytically calculated. The musculoskeletal moment reactions at the L5/S1 disc to loading were back muscle contraction and abdominal force. The compression force in the L5/S1 disc then balances the forces induced by the back muscle contraction, abdominal force, and loading force (Chaffin and Andersson, 1991). This musculoskeletal reaction to loading is shown in figure 3.

The moment and force equations which calculate compression in the L5/S1 disc are labeled equations 1 and 2, respectively. It should be noted that the orientation of the L5/S1 disc is tilted forward as compared to the other spinal discs. To simplify these calculations, the L5/S1 compression force (F_c), abdominal force (F_A), and back muscle compression force (F_m) all act parallel to the line formed between (X_{cm},Y_{cm}) and (X_v,Y_v).

$$F_m * d_m + F_A * d_A = W_{cm} * (X_{cm} - X_v) \qquad (1)$$

where

$$F_m = (W_{cm} * (X_{cm} - X_v) - F_A * d_A)/d_m$$

$$F_c + F_A = F_m + W_{cm} * \cos(phi)$$

$$phi = \text{Arctan}((X_{cm} - X_v)/(Y_{cm} - Y_v)) \qquad (2)$$

where

$$F_c = F_m + W_{cm} * \cos(phi) - F_A$$

Estimation of two-dimensional (2-D) body joint locations was achieved by building a 120 cm wide × 240 cm high rectangular frame with tape measures on the vertical legs. Body joint locations for three commonly occurring citrus harvesting positions were estimated by recreating the positions within the rectangular frame and measuring 2-D body joint locations. These three commonly occurring citrus harvesting positions are shown in figure 4.

This analysis was 2-D in the sagital plane (side view of human body). To simplify this analysis, all upper body

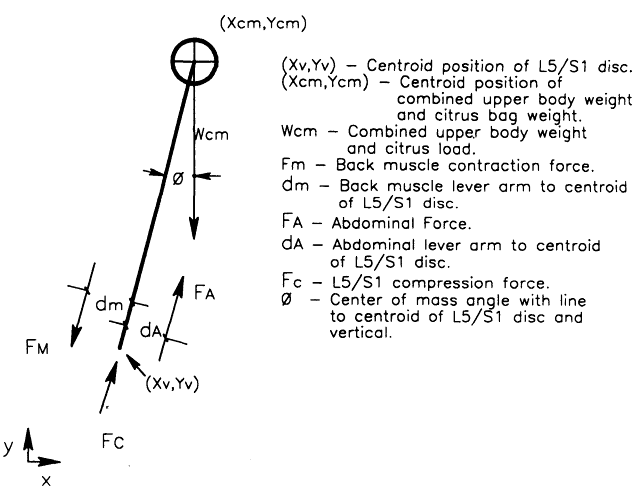

Figure 3–Static musculoskeletal reaction of the human body to loading.

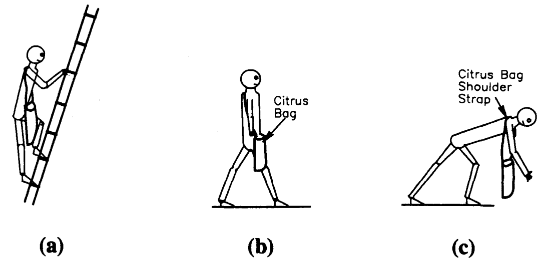

Figure 4–Three commonly occurring citrus harvesting positions. (a) Descending ladder, (b) walking, and (c) bending.

limbs occupied the same 2-D position. The human body was modeled as a structure. The human body was represented as a stick figure with appropriate joint, body mass, and citrus load locations. This stick figure was considered "rigid" between all joint locations. The weight of the citrus bag was modeled as a vertical point load on the shoulder of the worker, where the shoulder meets the back of the neck. The intent of these calculations was to develop force and moment data from loading by the weight of the human body and the citrus harvesting bag.

The weight of body segments was taken from data published by Webb Associates (1978). Webb collected body segment weight data as compared to total body weight. A linear regression was used to determine body part weight if only the total body weight of the person is known (Webb Associates, 1978).

A biomechanical analysis was used to estimate the compression force in the lower back. This compression force is caused by the external loading on the lower back and the musculoskeletal reaction to this loading. To estimate the L5/S1 disc compression, loading force, and moment induced by the upper body and citrus bag weight was calculated. The human musculoskeletal system reacts to moments from static loading with equal and opposite reaction moments. The external forces acting on the L5/S1 disc in the lower back were upper body weight and the citrus bag weight. The upper body weight includes head, neck, arms, hands, and trunk. The citrus bag load was analyzed as a vertical point load on top of the shoulders, behind the neck. The combined center of mass position of upper body weight and citrus bag load was then determined with respect to the L5/S1 disc. The center of mass locations of body parts were estimated by analyzing each body part as a geometric object. Specifically, the hands (fists) and head were assumed to be spheres, the neck and trunk as cylinders, and the limbs as frustum of a cone. These center of mass locations were incorporated into calculations as a percent of distance between joints. This allowed a center of mass location change with respect to the limb length of the subject, where the limb length changed linearly with respect to the total height of the subject.

Since this analysis focused on induced forces and moments at the L5/S1 disc, a 2-D centroid was calculated to combine upper body weight and citrus bag weight into a single force and point of action. This combined center of mass location was labeled (X_{cm}, Y_{cm}), where X_{cm} is the sum of the product of horizontal limb position and weight divided by the total weight. The Y_{cm} was determined in the same manner as X_{cm}, except vertical limb position was used. The W_{cm} is the sum of the upper body part and citrus bag weight above the L5/S1 disc.

The position of the centroid of the L5/S1 disc was determined from a cross-sectional view of the human body. The centroid of the L5/S1 disc was estimated as a percent of total thickness of the human body at the lower back, 35% of the total distance from the back to the stomach. The back position measurement was taken at the spine immediately above the hips, and the stomach position measurement was taken 5.1 cm below the naval (Koritke and Sick, 1983).

Under static loading, the musculoskeletal system of the human body reacts to induced moments at the L5/S1 disc with two reaction moments. First, abdominal pressure over the abdominal cavity creates an abdominal force. This force in combination with the abdominal lever arm produces the abdominal reaction moment. The abdominal lever arm was then estimated as the distance from the centroid of the abdominal cavity to the centroid of the L5/S1 disc. The second musculoskeletal reaction at the L5/S1 disc is contraction of the back muscles. The back muscle contraction lever arm is the distance from the centroid of the back muscles to the centroid of the L5/S1 disc. The product of the back muscle contraction force and back muscle lever arm is the back muscle reaction moment.

Abdominal pressure values of 7.9 and 13.3 kPa were published by Davis and Stubbs, 1978. Since published values of abdominal pressure have a wide range, calculations will be performed using three abdominal pressure values. These values were 0 kPa (no abdominal pressure) and the two published values of 7.9 and 13.3 kPa (Davis and Stubbs, 1978). These calculations were performed to evaluate the effect of different abdominal pressures on the compression force in the L5/S1 disc. These calculations were performed on the three citrus harvesting positions, two different citrus bag loads, and the mean-sized citrus picker. Once back compression force values were estimated at these three different abdominal pressures values, the published abdominal pressure of 7.9 kPa will be used for all further calculations.

The abdominal pressure in any lifting activity varies due to many factors. Some factors include the magnitude and rate of lifting, the moment induced on the human body, characteristics of how the individual lifts, etc. Also, since the load and moment on the human body change through the lifting task, the abdominal pressure will also vary. Due to these many variations, the abdominal pressure used for this analysis will be the lower of the two published values, 7.9 kPa.

The abdominal area at which the abdominal pressure applies itself was then estimated. An anatomical cross-sectional view of the human body at the L5/S1 disc was observed and the abdominal area was determined graphically as compared to the total cross-sectional area of the human body at the L5/S1 disc. The abdominal area was estimated as a percent of cross-sectional area of the human body at the L5/S1 disc. This graphical method determined that 50% of the cross-sectional area of the body, at the L5/S1 disc was abdominal area. This estimation of abdominal area as compared to total cross-sectional area of the body provided a basis for estimating abdominal area when only outside dimensions of the human body are available. The subject observed in this analysis was estimated to have a total cross-sectional area of 520 cm^2, and the abdominal area estimation for this analysis was 260 cm^2.

The abdominal lever arm is the distance from the centroid of the L5/S1 disc to the centroid of the abdominal cavity. The abdominal centroid was estimated graphically, due to its resemblance to the shape of a kidney bean. The centroid of the abdominal area for estimating abdominal lever arm was determined graphically by estimating the centerline where half the abdominal area is on each side of the centerline. This procedure produced an estimated abdominal lever arm length of 6.4 cm. Since the abdominal area and pressure were estimated to be 260 cm^2 and 7.9 kPa, respectively. The abdominal reaction moment was estimated to be 13.1 N m, this value was used for the rest of this analysis.

The second musculoskeletal reaction at the L5/S1 disc is contraction of the back muscles. An estimation of back muscle lever arm was performed graphically by estimating the distance from the centroid of the back muscles to the centroid of the L5/S1 disc. This evaluation produced a back muscle lever arm estimate of 5.1 cm (Koritke and Sick, 1983). This value is consistent with the value of 5.0 cm (Bartelink, 1957; Perey, 1957; Thieme, 1950).

A computer program was written to incorporate the force and moment equations at the L5/S1 of the human body. The inputs to this program include dimensions of the human body in the three positions mentioned previously, total body weight, height, and citrus bag weight. The program analyzed the three citrus harvesting positions and performed a sensitivity analysis by changing citrus bag weight and the height and body weight of the worker. The height and weight of the worker were changed in standard deviations from the mean height and weight of the worker. A worker with a height of $^{+}2$ standard deviations greater than the mean height would also have a weight of $^{+}2$ standard deviations above the mean weight. This observation of height and weight as compared to the mean height and weight will be considered as "size" for this analysis. This observation allowed sensitivity analysis to be performed.

Statistical data on the height and weight distribution of humans was taken from a sample size of 1,067 people of all races. The mean height for people in this sample, 25 to 34 years of age was 177 cm with a standard deviation of 6.86 cm. Heights of ± 2, ± 1, and 0 standard deviations from the mean height were determined. Mean weights were determined by interpolating weight data at these specific heights. Height and weight data used in this analysis are presented in table 1 (National Center for Health Statistics, 1987).

Table 1. Height and weight data, standard deviations from the mean

Standard Deviations from the Mean	Height (cm)	Weight (kg)
−2	163	68.2
−1	170	74.1
0	177	78.4
+1	184	83.7
+2	191	91.4

Two-dimensional body segment locations were determined by analyzing a 175-cm-tall subject in the three citrus harvesting positions mentioned. Body joint locations were then standardized to accommodate body joint link length data (Roebuck et al., 1975). Roebuck showed that link length is directly related to a person's height. The body segment joint locations determined in the three citrus harvesting positions were then linearly recalculated when the height of the subject was changed. If the height of the subject was changed from the initial subject height of 175 cm, all the limb length and joint locations were then recalculated. This kept the limb positions in the same configuration for that specific lifting position, but allowed for the calculation of back compression force in different sized subjects. This procedure involved changing the limb length, starting at the feet and maintaining the same 2-D angle from joint to joint.

Equations were developed and L5/S1 back compression was calculated based on the picking position, citrus bag weight, and size of the citrus picker. These back compression force values presented in table 2 were calculated using an abdominal pressure of 7.9 kPa, abdominal lever arm of 6.4 cm, and back muscle lever arm of 5.1 cm. The data presented in table 2 was for a subject with the mean height of 177 cm and a mean weight of 74.8 kg (Najjar and Rowland, 1987).

High compressive forces in the lower back primarily occur when the musculoskeletal system reacts to large loading moments. These moments were created by the center of mass of upper body and citrus bag weight being forward of the L5/S1 disc. The citrus harvesting positions observed to have the possibility of inducing large forces and/or moments on the L5/S1 disc included descending the citrus ladder, walking with a full citrus bag, and bending over picking (legs extended).

Sensitivity analysis was performed to determine the variation of lower back compression force when the citrus bag weight and size of the worker was varied. Plots of this sensitivity analysis performed on the three citrus harvesting positions are presented in figure 3.

Table 3 shows that the abdominal pressure inversely effects the L5/S1 back compression force. Increased abdominal pressure increases the abdominal reaction moment to induced loading and decreases the L5/S1 back compression force.

Sensitivity analysis was performed to determine the variation of lower back compression force when the height and weight of the worker was varied. The height and weight of the worker were varied in standard deviations from the mean height and weight, as shown in table 1. This analysis is presented in table 4.

Table 2. Static loading force, moment, and L5/S1 disc compression data

Position	Citrus Load (kg)	Force (R_v) (N)	Moment (M_v) (N m)	Back Comp. Force (N)
Descending ladder	16	68.3	088.5	1760
Descending ladder	32	84.3	103.0	2192
Walking	16	68.3	015.3	0463
Walking	32	84.3	012.8	0562
Bending	08	60.3	198.1	3282
Bending	16	68.3	233.9	3996

Results and Discussion

The current citrus harvesting procedure exposes pickers to repetitive loads in excess of 25 kg throughout a long working season. The National Institute of Occupational Safety and Health has set a limit of 17 kg for repetitive lifting in ideal conditions using proper lifting technique (National Institute for Occupational Safety and Health, 1981). Also, the current citrus harvesting situation involves ascending and descending the citrus ladder, bending over to pick citrus, and transporting the full citrus bag. All of these activities expose the citrus picker to nonideal lifting conditions and loading over an extended period of time.

The 16-kg citrus bag weight for descending ladder and walking, and the 08-kg citrus bag weight for bending represent how L5/S1 disc compression can be reduced if the citrus bag weight is reduced. The 32-kg citrus bag weight for descending ladder and walking, and the 16-kg citrus bag weight for bending represent the current citrus harvesting situation. Lower back stress values calculated in the three citrus harvesting positions are discussed individually.

Walking with a 32-kg citrus bag produces the lowest back compression force values of the three citrus harvesting positions analyzed. This is due to the citrus bag load being positioned vertically above the lower back, which produces a minimal loading moment at the L5/S1 disc. Any deviation of the upper body and citrus bag weight forward of the L5/S1 disc will cause these back compression values to increase. This could occur when the citrus picker is negotiating tree limbs or walking over uneven terrain when transporting citrus.

Descending the citrus ladder with a full citrus bag produces L5/S1 back compression force values below the National Institute for Occupational Safety and Health Back Compression Design Limit values. These values were established for healthy workers under ideal lifting conditions. Descending the citrus ladder with a full citrus bag is not an ideal lifting condition. The citrus ladder moves when loaded due to a lack of rigidity in the tree limbs supporting the ladder. This movement can lead to instability, which is compounded as the citrus bag weight increases. A benefit of the ladder not being rigidly supported is the ladder having a spring-dampener effect when dynamically loaded. This reduces the dynamic loading as compared to a rigid ladder. Although these static L5/S1 back compression force values are below the back compression design limit, the nonideal conditions give reason to change the current citrus harvesting situation to reduce back compression force.

Bending with a 16-kg citrus bag produces the highest back compression values of the three citrus harvesting positions. The citrus bag weight in this analysis was half that used in the analysis of walking and descending the citrus ladder. These L5/S1 back compression force values were in excess of the back compression design limit established by the National Institute for Occupational Safety and Health (1981). The main reason these back compression force values were so high is the citrus load is extended forward of the L5/S1 disc, causing a large loading moment.

The biomechanical model indicates high compressive back forces are expected when the musculoskeletal system reacts to large moments. The two musculoskeletal reactions

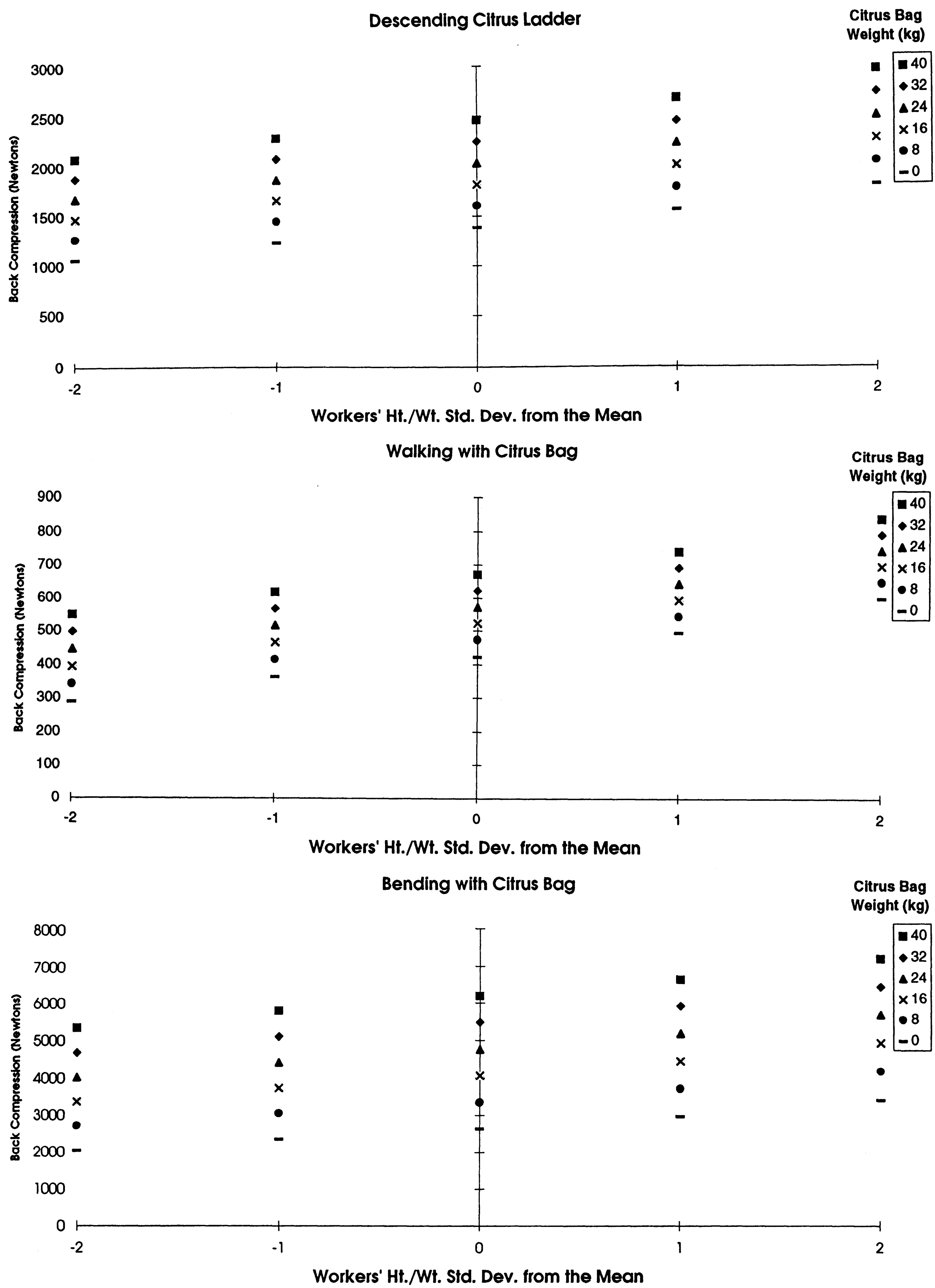

Figure 5–L5/S1 back compression force, three citrus harvesting positions.

Table 3. Abdominal pressure sensitivity analysis

Abdominal Pressure (kPa)	Citrus Harvesting Position	Citrus Bag Weight (kg)	L5/S1 Force (N)
0.0	Descending	16	2228
7.9	Descending	16	1760
13.3	Descending	16	1441
0.0	Descending	32	2659
7.9	Descending	32	2191
13.3	Descending	32	1872
0.0	Walking	16	930
7.9	Walking	16	463
13.3	Walking	16	143
0.0	Walking	32	1029
7.9	Walking	32	562
13.3	Walking	32	242
0.0	Bending	08	3749*
7.9	Bending	08	3282
13.3	Bending	08	2962
0.0	Bending	16	4463*
7.9	Bending	16	3996*
13.3	Bending	16	3676*

* L5/S1 back compression force values exceed National Institute for Occupational Safety and Health (NIOSH) back compression design limit.

to induced loading moments were abdominal pressure over the abdominal area creating an abdominal force and back muscle contraction. A large induced moment from loading on the musculoskeletal system was met with a large reaction moment from contraction of the back muscles at the L5/S1 disc. This back muscle reaction moment has a short lever arm, 5.0 cm. The back muscle contraction has to exert a large force to react to large induced moments from loading. This back muscle contraction induces a large compressive force on the L5/S1 disc.

Table 4. Height and weight sensitivity analysis (newtons)

		Height*				
	Weight*	−2	−1	0	1	2
Descending	2	2329	2411	2493	2574	2656
citrus ladder	1	2161	2238	2314	2390	2467
with 32-kg	0	2046	2119	2192	2265	2338
citrus bag	−1	1952	2202	2092	2162	2232
	−2	1825	1891	1957	2024	2089
Walking	2	686	696	706	716	726
with 32-kg	1	603	612	620	629	638
citrus bag	0	546	554	562	570	578
	−1	500	507	514	522	529
	−2	438	444	450	456	462
Bending	2	4106†	4293†	4481†	4669†	4857†
with 16-kg	1	3840†	4016†	4193†	4370†	4546†
citrus bag	0	3657†	3827†	3996†	4145†	4334†
	−1	3510†	3673†	3836†	3999†	4161†
	−2	3309	3463†	3618†	3773†	3927†

* Height and weight values are means plus or minus standard deviations for pickers (table 1).

† L5/S1 back compression force values exceed National Institute for Occupational Safety and Health (NIOSH) back compression design limit.

This analysis determined that if the loading moment created by the citrus harvesting bag and the upper body weight of the citrus picker were reduced, L5/S1 back compression force will be reduced. This loading moment on the musculoskeletal system was reduced by decreasing the citrus bag weight and/or the lever arm created by the upper body weight and citrus load.

Conclusions

The current citrus harvesting procedure and equipment exposes citrus pickers to loads in excess of National Institute for Occupational Safety and Health limits to repetitive lifting in ideal conditions. Induced force on the L5/S1 disc from these citrus loads was in excess of the back compression design limit established by the National Institute for Occupational Safety and Health (1981). Excessive back compression force values were attributed to large citrus loads, large induced moments from citrus load, and upper body weight creating a large loading moment on the L5/S1 disc. Improper lifting techniques were shown to induce high forces on the L5/S1 disc because upper body weight and citrus bag load create large loading moment at the L5/S1 disc.

Recommendations

- The best way to decrease worker injuries is to eliminate potentially hazardous or stressful situations. The current citrus harvesting bag should be reduced in weight or eliminated.
- Citrus pickers should be further trained on the proper way to lift. This education should focus on reducing loading moments on the lower back. No load should be lifted with the body and citrus load extended forward of the L5/S1 disc. This can be accomplished by lifting with the legs which prevents the body and citrus load weight from exerting large loading moments on the L5/S1 disc.
- Development of citrus harvesting aids should focus on reducing the magnitude and duration of loading on the citrus picker. This will decrease stress and fatigue, thereby creating a less hazardous working environment.
- Equipment cost must be kept low due to the efficiency of the current citrus harvesting procedure. Equipment must also be able to operate in adverse conditions including steep terrain and muddy winter conditions.

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