Ergonomic Analysis of New York Apple Harvest Work Using a Posture−Activities−Tools−Handling (PATH) Work Sampling Approach

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ABSTRACT. *Although back, neck, and shoulder strains are common among migrant and seasonal orchard workers, little data currently exist regarding the ergonomic factors contributing to this problem. We adapted Posture−Activities−Tools−Handling (PATH) instruments and methods for ergonomic job analysis of apple harvest work in three New York orchards, and used the resulting protocol to quantify hazardous activities, loads, and postures. Using a prototype developed previously, we trained twelve contract orchard observers with classroom training and supervised orchard practice. The PATH data were then collected on 14 orchard workers over four days (2,900 observations). Mean coefficients of variation ranged from a low of 0.212 (standing leg neutral) to a high of 0.603 (trunk moderate flexion). Most frequently observed activities were: picking (62.9%), placing and moving apples in the bag (8.7%), and walking (8.1%). Weight bearing (>10 lb, >4.54 kg) was observed 78.5% of the time throughout a range of activities. Apple harvest work is comparable with other ergonomically high−risk occupations. Future research should focus on low−cost interventions that reduce load and awkward postures.*

Keywords. *Apple harvesting, Ergonomics, Migrant farmworkers, Occupational health.*

Migrant and seasonal farmworkers provide much of the manual labor used in agriculture for planting, pruning, and harvesting of fruits and vegetables in the U.S. Frequent consequences of this work are musculoskeletal pain and strain, due to stooping (ground crops), reaching (orchard fruit), and carrying of heavy loads (all commodities).

In New York State and throughout much of the Northeast, migrant and seasonal workers harvest apples and other fruit from late August through October. Apples are hand−harvested by workers who carry them from the tree to a 20−bushel (0.71 m^3) bin in bushel buckets weighing as much as 42 lbs (19 kg) when full. Harvest workers carry this bucket on one side or in front, held by canvas or nylon straps fastened around either

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one shoulder or both shoulders. Unlike a number of other fruits and vegetables that can be harvested mechanically, apples are extremely delicate and must be hand picked with the utmost care. Apples will bruise if they are dropped from a few inches, reducing their market value.

Harvest work activities include climbing ladders, leaning to one side, reaching for apples, and bending forward to very gently release the apples out of the bottom of the bucket and spread them around the bin (figs. 1 and 2). Many of the awkward postures are held with full or partially full apple bags, increasing the strain potential. Therefore, it is not surprising that data collected at the Northeast Center indicate that back, neck, and shoulder strains constitute 39% of all occupational problems for which workers sought care at migrant health centers (Earle−Richardson, 2003). The frequency of back, neck, and shoulder strain among migrant and seasonal workers is documented in a number of other studies (Ag Safe, 1992; Calisto, 1999; Sakakibara et al., 1995; Villarejo and Baron, 1999; Villarejo et al., 2000; Isaacs and Bean, 1995).

Figure 1. Workers bending forward to pick apples.

Figure 2. A worker lifts a full bucket of apples over the side of the bin. The bucket will be lowered to within inches of the bottom of the bin, and then the hatch at the bottom of the bucket will be opened to release the apples.

In 1998, the Northeast Center researchers began studying hand−harvest work activity in orchards in New York and Pennsylvania, as described by Fulmer et al. (2002). Preliminary ergonomic observations produced a list of possible hazardous postures and activities likely to lead to back, neck, and shoulder strain. Shoulder hazards observed were: reaching with elbows over shoulder height, downward pressure from the bucket's strap, and carrying the ladder. Important back strain hazards identified were: holding strenuous picking postures, bending to empty the picking bucket into the bin, supporting a full load with the lower back, and carrying and setting the ladder.

Preliminary ergonomic orchard research conducted in 1998−1999 identified suspect postures and activities and generated some initial suggestions for preventive interventions. These included a padded shoulder strap, detachable hip belt, adjustable−height apple bin, and an ergonomic picking tool. Lastly, this research provided the initial development of job analysis protocol for orchard work using Posture−Activities−Tools−Handling (PATH) methodology as described by Buchholz et al. (1996).

The PATH methodology is a validated (Paquet et al., 1997) work−sampling tool for quantifying ergonomic risk factors in jobs involving non−repetitive work. The PATH tool uses the same posture codes that were developed in the Ovako Work Posture Analyzing System (OWAS) described by Karhu et al. (1977) and links the posture to tasks in its sampling protocol. A large volume of PATH data collected for a specific trade or job can yield an accurate assessment of time spent doing the various component tasks, assuming various postures, and using particular tools.

The PATH protocol has been used to evaluate ergonomic exposures in several construction trades (Buchholz et al., 1996; Paquet and Punnett, 1996; Paquet et al., 2001; Buchholz et al., 2003) as well as in non−construction sectors (Howard et al., 1998; Pan et al., 1999).

The data presented here consist of the results of a two−phase project. In phase one, the PATH instrument was modified and tested with a group of observers monitoring apple harvesters to determine the best format and best possible level of agreement between field observers. In phase two, the finalized instrument was used in the field to quantify postural and load characteristics of apple harvest work. This involved determining the proportion of time spent in hazardous postures, quantifying the extent of weight−bearing activities, and identifying areas for hazard reduction in a future intervention.

Materials and Methods

Recruiting Study Orchards and Apple Harvesters

Researchers recruited farms through the Northeast Center's orchard injury prevention training program in New York State (supported by the New York State Department of Labor), which interacts with approximately 200 orchards across the state. Two representative farms were enrolled for formal PATH data collection and a third for observer training. The two medium−sized study farms represented the two major apple−growing regions of the state, the two major ethnic groups (Mexican and Jamaican), and the two most common types of workforce (men working singly and extended family groups). Each worker on a participating farm was invited to participate and was informed that participation was voluntary. Informed consent was obtained in the worker's native language. Workers and owners were compensated for lost productivity and wages due to participation in the study.

Phase One: Training Methods

Twelve contract orchard observers were hired, most of whom were area university students. The orchard observer training was led by the ergonomist author (Fulmer) trained by the original developers of the PATH methodology. This consisted of six hours of classroom training, and a subsequent orchard practice and coaching interval, to be terminated when the following criteria were met: (1) examination of individual completed data forms revealed no clear outliers for certain individuals or postures, and (2) the ergonomist and statistician agreed that a stable level of variability between observers had been reached, and that further practice and coaching was not likely to reduce the variation further.

The orchard practice session was completed after eight hours. It consisted of an initial phase in which certain observers were discovered to be consistently different from the rest of the 14 observers (12 contract workers and 2 researchers). Following corrective training for these observers, a second session was initiated with demonstrably improved agreement. A careful review of individual data forms obtained from this second phase revealed that there were no further areas of systematic disagreement.

Minor adjustments were made to the PATH instrument during this practice as well. The high volume of observations made during this phase provided further feedback as to how it could be made easier.

Phase One: Assessment of Inter−Observer Agreement

At this point, the degree of inter−observer agreement was summarized for the most frequently assumed postures through calculation of the coefficient of variation. The six specific postures for which this was done included three arm positions, two trunk positions, and one leg position. For each observer, the proportion of observation intervals for which the worker was judged to be in each of these six postures was calculated. For example, if observer 1 observed worker A for 123 observation intervals, and noted the worker to be in the trunk neutral position for 60 of these, then observer 1 was assigned a value of 0.488 for this posture. The mean and standard deviation were then calculated separately for the seven observers watching worker A and for the seven observers watching worker B.

Phase Two: Data Collection

Phase two involved the collection of ergonomic apple harvesting data using the instrument developed and the observers trained in phase one. Data collection occurred in two New York orchards: one in the lower Hudson Valley, and the other in the western part of the state.

To do this, 14 workers from the two study orchards were observed for two days each by teams of 6 to 10 observers (table 1). Workers from the first study orchard consisted of unrelated Jamaican males traveling without families. In the second orchard, the work group was mainly one extended Mexican family.

Table 1. Apple harvest worker characteristics.

Subjects	14
Male	11
Mexican	9
Jamaican	5
Carry apple bag in front	2
on right side	4
on left side	7

The general observation scheme was for observers to work in pairs observing a single worker. One observer timed 45−second intervals, while the other completed PATH data observations (one column per 45−second interval). At the completion of five sets of observations, the observers switched roles. After 100 observations were made in this fashion, observers and workers were rotated to counterbalance the exposure of workers with timer−observer pairs. On certain days when the ratio of observers to workers was lower, observers timed their own intervals.

Observers completed one column of observations on the adapted PATH form, as shown in Appendix I. Under the Posture section, observations were divided into hands (hand 1 and hand 2 corresponding to right and left), arm/shoulder, trunk, and legs. Within these categories, one box was to be marked for every observation period, beginning with the first instant of the interval. If a certain body part was obscured (and the observer was not able to move to see it), the cell was left blank. For the Handling and Tasks sections, only boxes that applied to a given observation were completed. It should be noted that the "tools" part of the PATH scheme was omitted because the apple harvest work did not employ any hand tools.

Results

Phase One

The final data collection instrument (Appendix I) consists of a series of columns of check boxes for the presence of certain postures, handling, factors, and activities. From these, the frequencies of single postures and combinations of postures can be tabulated. The main changes made during the revision process were: (1) the order of the posture measurements were changed to flow from the top of the body (with elbows up, picking) downward, for ease of data collection; (2) the "weight−bearing" lines were changed from a multi−level set of choices to a two−level selection, "empty bag" (0 to 10 lbs, 0 to 4.54 kg), or "full/partially full, ladder carry" (>10 lbs, >4.54 kg); and (3) several of the individual line descriptions were reworded so that the distinctions between levels were more clear.

Inter−observer agreement, as indicated by a low coefficient of variation, was assessed only for those postures that occurred frequently enough to allow for stable estimation. These postures included: arm/shoulder with two elbows up, arm/shoulder with two elbows down, arm/shoulder with one elbow up, trunk neutral, trunk with moderate flexion, and standing on two legs (table 2). The coefficients of variation shown for workers A and B were based on seven observers for each. Each worker was observed for approximately 300 observation intervals.

Because of the relatively close agreement in these coefficients of variation for a given posture across the two workers (with the exception of the arm/shoulder with two elbows down position), the two values were averaged for ease of interpretation. The mean

Table 2. Coefficients of variation among observers.

	Worker A			Worker B			
Body position	Mean	SD	CV	Mean	SD	CV	Mean CV
Arm/shoulder, 2 elbows down	0.338	0.095	0.279	0.209	0.103	0.495	0.387
Arm/shoulder, 1 elbow up	0.330	0.091	0.274	0.339	0.083	0.246	0.260
Arm/shoulder, 2 elbows up	0.330	0.110	0.334	0.453	0.153	0.339	0.337
Trunk, neutral	0.698	0.162	0.232	0.726	0.154	0.212	0.222
Trunk, moderate flexion	0.255	0.140	0.550	0.166	0.109	0.655	0.603
Standing, two legs	0.560	0.107	0.191	0.477	0.111	0.232	0.212

coefficients of variation (table 2) ranged from a low of 0.212 for the "standing, two legs" position to a high of 0.603 for the "trunk, moderate flexion" position.

Phase Two

Activities − Apple workers spent nearly two−thirds of the harvest observation period (62.9%) reaching and picking apples off the branch. No other individual activity comprised more than 9% of the observation time, as shown in table 3 (activities of 1% or less are not shown).

Weight bearing − Workers were observed to bear weight (either carrying apples in buckets or carrying ladders) 78.5% of the time, irrespective of activity. Full apple bags in this study weigh up to 42 lbs (19 kg), and ladders range from 10 to 25 lbs (4.54 to 11.34 kg), depending on whether they are aluminum or wood. Carrying ladders made up a negligible fraction of this time (1.8%).

Postures and posture−weight bearing combinations − Common postures and posture−load combinations observed were: arm/shoulder with two elbows up (29.3%), arm/shoulder with two elbows up combined with bag load (23.9%), arm/shoulder with one elbow up with bag load (25.5%), trunk moderate flexion (23.4%), and trunk moderate flexion combined with bag load (18.8%). In addition, irrespective of specific activity or posture, workers were in ladders or trees 22% of the time. Refer to table 4 for the range of stances and postures observed and percentages derived.

Discussion

Weight Bearing

The fact that farmworkers were found to spend three−quarters of the observation time bearing weight has implications for musculoskeletal effects due to weight bearing.

Full apple bags are reported to weigh as much as 42 lbs (19 kg) depending on bag size and apple variety (J. Bittner, personal communication, 8 September 2003). To assess the impact of the bag's weight on back strain potential, the NIOSH lifting equation (Waters et al., 1994) was applied using factors particular to apple harvest work. According to this equation, the safe maximum bag load for 8 hours of work was estimated to be between 24 and 37.2 lbs (10.9 and 16.9 kg). (For details of the estimation, see Appendix II).

The full apple bag weight range of 38 to 42 lbs (17.2 to 19 kg) is generally above the NIOSH safe maximum bag weight range. If workers are bearing between 10 and 42 lbs (4.54 and 19 kg) for 78% of work days that average 8.5 hours and can run as long as 12 hours, they are likely to exceed this standard. While this is a rough estimate, it suggests that an intervention that reduces overall load is needed. Research by Conlan et al. (1995) in citrus orchards came to a similar conclusion, finding that a number of work activities exceeded industrial lifting limits.

Table 3. Common apple hand−harvest activities by proportion of observation interval.

Task	Activity	Time (%)
Picking task	Picking apples (grasping and pulling only)	62.9
	Placing or moving apples in bag, adjusting bag (after picking)	8.7
	Climbing ladder (up or down)	3.3
Emptying bag	Emptying bag into bin (opening bag, lifting/setting, pulling back)	7.8
Handling ladder	Carrying ladder, set down/pick up, reposition, adjust coupling	4.1
Other tasks	Walking	8.1

Table 4. Major postures observed: overall and in combination with full/partially full bag as a proportion of observation interval.

Body Posture	Time		Time Combined with Bag Load	
	%	SD	%	SD
Trunk				
Neutral (<20°)	63.1	0.167	49.4	0.148
Moderate flexion (20° to 45°)	23.4	0.132	18.8	0.119
Severe flexion (>45°)	3.5	0.037	2.4	0.027
Lateral bend or twist	6.1	0.047	5.7	0.044
Lateral bend or twist and flexion	1.9	0.023	1.6	0.024
Not observed (body part obscured)	2.0	−−	−−	−−
Arm/shoulder				
Two elbows down	39.4	0.144	29.0	0.126
One elbow up (>60°)	30	0.111	25.5	0.096
Two elbows up (>60°)	29.3	0.156	23.9	0.132
Not observed (body part obscured)	1.2	−−	−−	−−
Leg				
Standing, two legs	56.2	0.141	46	0.129
Standing, one leg	1.1	0.015	0.8	0.014
Standing, one leg or more bent	24.5	0.139	21.1	0.128
In motion	13.6	0.050	8	0.041
Climbing/descending	3.2	0.029	2.1	0.018
Kneeling (at least one leg)	0.1	0.002	0.1	0.002
Not observed (body part obscured)	1.3	−−	−−	−−

Awkward Postures

It can be concluded that workers spend considerable amounts of time in awkward postures. The greatest hazard appears to be occurring with arm posture; workers were observed with one or both elbows over the shoulder 59% of the time. These postures are cited in a number of studies as being related to musculoskeletal disorders (Pinzke, 1997; Meyers et al., 1998; Pan et al., 1999; Calisto and Kleisinger, 2001; Bjelle et al., 1979; Sakakibara et al., 1995). When all non−neutral trunk postures are combined, workers were observed in non−neutral trunk postures over one−third of the time. This represents significant stress to the back and upper body on a nearly daily basis.

The risk of musculoskeletal impacts from awkward postures is also well supported in the literature. The 1997 NIOSH literature review of the available research on musculoskeletal disorders concluded that "there is strong evidence that working groups with high levels of static contraction, prolonged static loads, or extreme working postures involving the neck/shoulder muscles are at increased risk for neck/shoulder musculoskeletal disorders" (Bernard, 1997; Punnett, 2000). Similarly, the relationship between raised arms and shoulder musculoskeletal symptoms has been demonstrated (Sakikabara et al., 1995; Bjelle et al., 1979).

Awkward Posture in Combination with Load

In addition to high proportions of time bearing weight and assuming awkward postures, significant intervals of doing both in combination were observed. For example, working with one or two elbows over the shoulder with a full or partially full bag was observed nearly 50% of the time. Similarly, non−neutral trunk postures in combination with weight bearing were observed 29% of the time. The current ergonomic literature indicates that, when combined, non−neutral postures and weight bearing are a particularly great hazard for musculoskeletal disorders (Punnett, 2000). These data indicate that posture, load, and a combination of the two are occurring frequently in this work setting.

To put these data in context, it is useful to compare them to proportions of time observed for similar stances in the construction industry presented in a PATH analysis by Buchholz et al. (1996). In four comparisons, orchard workers appear to have higher values for time spent in moderate trunk flexion (23%, versus 5% to 9% for construction workers) and time spent carrying a light to moderate load (78% versus 19% to 80% for construction workers), lower values for time spent in a flexed and twisted posture (6% versus 19% to 50% for construction workers), and about the same time spent in severe trunk flexion (4%, versus 0% to 10% for construction workers). Other PATH research on retail workers also serves to emphasize the relatively high level of ergonomic hazard experienced in apple harvest work (Pan et al., 1999). In the construction industry, the recognition of these risk factors and high rates of musculoskeletal disorders has led to a focused effort to develop a broad spectrum of ergonomic improvements (NIOSH, 2003).

These orchard postural results are also comparable to workers in nursing homes, another occupation thought to be ergonomically at high risk. In terms of shoulder posture, nursing home workers were found to have one or both elbows up about 38% of the time (Rockefeller, 2002) compared to 59% for apple workers. Nursing home workers were found to be in a neutral trunk posture about 62% of the time compared to 63% for apple workers. However, nursing home workers are handling medium loads (5 to 50 lbs) only 3% of the time, substantially less than the 78% observed in the orchard.

Application of PATH Methodology in the Orchard

Overall, the adaptation and implementation of the PATH methodology in the orchard environment was successful. However, a few limitations affect the analysis. For example, estimates of load could have been improved if the PATH instrument measured how full the bag was on more than a dichotomous (“full or partially full” vs. “empty”) scale. However, this was not possible because it was too difficult for observers to see inside the bag from certain angles to rapidly assess fullness.

In addition, the poorest level of inter−observer reliability between the 14 observers was obtained in identifying moderate vs. severe trunk flexion. The one body position of the six where the mean CV exceeds 0.39 is the trunk moderate flexion position, which has a mean CV of 0.60. Evidently, distinguishing the trunk moderate flexion position from the trunk severe flexion position is very difficult for observers in the field.

While the coefficient of variation outcome used to quantify the agreement among the 14 observers in the present study is not directly comparable to the inter−observer agreement (between two observers) used by Buchholz et al. (1996), it is noteworthy that the researchers in that study also found a wide variation in agreement for different postures (arms: 0.78 vs. neck: 0.29), with agreement for the neck substantially below the researchers’ criterion level of agreement of 0.80. This may indicate a limitation of field observation method as compared to the more time−intensive and expensive video−based observation method.

Conclusion

Taken together, the above data suggest that apple harvest workers are at significant risk for back, neck, and shoulder strain, and that interventions that reduce load on these areas or that reduce the time spent in awkward postures should be developed and tested. Recently, a number of simple ergonomic interventions have been developed for other crops such as blueberries and wine grapes, as well as for for nursery work (Baron et al., 2001).

Currently, several orchard interventions are under development. Areas of exploration include ways to transfer load off the upper body, and a means of dispersing some of the load and pressure that comes from the shoulder strap to the neck and shoulders. Equipment changes that lead directly to altered postures are more problematic in this environment. No interventions that alter posture have yet been identified that do not inherently slow down the harvest process, placing worker income at risk.

Despite the increased mechanization of agriculture, hand−harvest labor will continue to play an important role in industries such as apples, since the delicacy of the product makes machine harvest impractical. Given this reality, agricultural health and safety research must continue to explore how to reduce the chronic pain and strain that has come to be thought of as an inevitable part of this work. The identification of key musculoskeletal strain risk factors within apple harvest work and the initial quantification of these hazards are the first steps toward reducing this hazard.

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Appendix I: Orchard PATH Assessment Instrument

Variable	Value	1[a]	2	3	4	5	6	7	8	9	10
Location of worker	On ground										
	On ladder or in tree	1									
I. POSTURE											
1. Hands											
Hand 1[b]	Gross grasp										
	Empty										
	Pinch grip										
	Other										
Hand 2	Gross grasp	1									
	Empty										
	Pinch grip										
	Other										
2. Arm/Shoulder	Both elbows down	1									
	1 elbow up (>60 degrees)										
	2 elbows up (>60 degrees)										
3. Trunk	No flexion, neutral (<20 degrees)										
	Moderate flexion (20 − 45 degrees)	1									
	Severe flexion (>45 degrees)										
	Lateral bend and/or twist										
	Lateral bend and /or twist and flexion										
4. Leg	Stand (neutral)	1									
	One leg										
	One or more leg bent (>35 degrees)										
	Walking (in motion)										
	Climb/descend ladder (in motion)										
	Kneel (at least one leg)										
	Sit										
	Crawl										
	Squat										
II. HANDLING											
1. Weight[c]	0 − 10 lbs. (0 − 4.54 kg) (empty bag)										
	>10 lbs. (>4.54 kg) (full/partially full bag, or ladder carry)										
2. Carry position	Hands close to body										
(bag or ladder in hand)	Hands far from body										
3. Hanging bag position	Hanging to side (to right)										
(bag supported by strap)	Hanging to side (to left)										
	Hanging in front	1									

Appendix I: Orchard PATH Assessment Instrument (cont'd)

Variable	Value	1[a]	2	3	4	5	6	7	8	9	10
Location of worker	On ground										
	On ladder or in tree	1									
III. TASKS											
1. Picking task	Picking apple from branch/reaching	1									
	Transferring and placing apples										
	Adjusting bag										
	Climb/descend ladder/tree										
2. Emptying bag	Opening bag/closing bag										
	Lifting/setting full bag into bin										
	Setting apples/pulling back										
3. Handling ladder	Carry ladder										
	Set down / pick up ladder										
	Reposition ladder										
4. Other tasks	Walking										
	In−between										
	Communicating										
	Reaching (not part of picking task)										
	Opening bag										

Notes:

[a] Sample column completed, corresponding to the worker in the foreground of figure 1.

[b] "Hand 1" left blank because worker's left hand is not visible in figure 1.

[c] "Weight" left blank because it cannot be determined from figure 1.

Appendix II: The Revised NIOSH Lifting Equation

An assessment of limits on the total workload can be made using the revised NIOSH lifting equation. This calculation is used to assess tool effects on load lifting capacity. The product of the NIOSH equation is the "recommended weight limit" or RWL. The RWL is defined as the load weight that most healthy workers could sustain for a period of up to eight hours without increased risk of lower back pain. The RWL is calculated by the formula: RWL = LC × HM × VM × DM × AM × FM × CM. The formula terms are defined in the following table.

Terms of the revised NIOSH lifting equation for recommended weight limit.

Formula terms are defined as:	Study values are defined as:
LC = load constant: the maximum recommended weight for lifting (51 lbs) under optimal conditions.	LC = 51
HM = horizontal multiplier: the horizontal distance of the load from the spine. HM = 10/H in inches, where H = horizontal distance.	HM = 1 because half the diameter of the apple bag (where the bag is gripped when the lift is made) is less than or equal to 10 inches.
VM = vertical multiplier: the vertical distance of the lift. VM = 1−0.0075|V−30|, where V = vertical distance.	VM_{max} = 1; VM_{min} = 0.925. VM ranges from 1, when the bag is low/just above the knuckle level (regardless of the assumption of size and basing the calculation on the 30−inch knuckle height of the average worker) to about a 10−inch deviation from optimum height when the bag is at elbow height, making VM = 0.925.
DM = distance multiplier: the total distance the load is moved. DM = [0.82 + (1.8/D)], where D = distance load is moved.	DM_{min} = 1; DM_{max} =0.86. DM minimum will be 1 when the bin is full enough to preclude bending. When the bin is empty, the destination will be about 4 inches from the ground, and the DM will be at a maximum measured from elbow height of a tall person (47 − 4 inches), or DM = 0.86.
AM = asymmetric multiplier: the angle between the sagital plane and the plane of asymmetry. AM = [1−(0.0032A)], where A = angle length.	AM = 1 or 0.81. AM will be 1 when bag is in front and the bin is in front, but either easily can be 60° and AM = 0.81.
FM = frequency multiplier: number of lifts per minute weighted by vertical distance.	FM = 0.81. Assuming long duration (up to eight hours) and frequency restrictions, FM has to be determined using the average time of cycle (ATC = 3:24), with one lift per cycle, to compute F = 1 lift/3.4 min = 0.39, so from the revised NIOSH lifting equation, FM is found to be = 0.81 for work lasting up to eight hours per day with any vertical distance. Note that many pickers reported working more than eight hours per day, nullifying the revised NIOSH lifting equation.
CM = coupling multiplier: the quality of the coupling between the load and the hands. CM is assigned a multiplier from a qualitative ranking of good, fair, or poor.	CM = 0.90. CM is poor because the bag sags, because it requires the use of the hands in awkward positions, and because it has no handles.

Plugging the study−defined values into the revised NIOSH lifting equation with each factor minimized (best case) looks like this:

$$\begin{aligned} RWL &= LC \times HM \times VM \times DM \times AM \times FM \times CM \\ &= 51 \times 1 \times 0.925 \times 0.86 \times 0.81 \times 0.81 \times 0.90 \\ &= 37.2 \end{aligned}$$

or with each factor maximized (worst case):

$$\begin{aligned} RWL &= LC \times HM \times VM \times DM \times AM \times FM \times CM \\ &= 51 \times 1 \times 1 \times 1 \times 1 \times 0.81 \times 0.90 \\ &= 24.0 \end{aligned}$$

The reported weight of a full bag in the observed orchard (James Bittner, personal communication, September 8, 2003) is 42 lbs (19 kg), which is substantially over the recommended weight limit for this task. Furthermore, the RWL is not meant for jobs where duration of lifting frequency is beyond eight hours/day. Because time is a critical factor in harvesting fruit, the farmworkers usually work more than eight hours per day.