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An ergonomic intervention to reduce back strain among apple harvest workers in New York State

Giulia Earle-Richardson[a,*], Paul Jenkins[b], Scott Fulmer[c], Christine Mason[a], Patrick Burdick[b], John May[a]

[a]*New York Center for Agricultural Medicine and Health, Bassett Healthcare, 1 Atwell Road, Cooperstown 13326 NY, USA*
[b]*Bassett Research Institute, Cooperstown, NY, USA*
[c]*University of Massachusetts, Lowell, MA, USA*

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Abstract

The impact of modifications to the apple picking bucket on common picking postures, self-reported comfort, ease of use, and speed of harvest were measured. Fourteen apple pickers wore an intervention hip belt, were interviewed and measured using posture-activities-tools-handling methodology. The use of hip belt did not significantly alter time spent in various postures. 78.6% of interviewed workers preferred the modified bag, 71.4% noted a difference in the back, neck, or shoulder, while 64.3% said regular use of modified bag would slow their work. Major themes in worker comments are discussed. The hip belt modification to apple harvest bag seems generally acceptable to workers, but needs further development to overcome unintended effects. Although work sampling demonstrates that the bag does not affect work practices, workers appear somewhat concerned that productivity will be negatively impacted. Further training of workers in the use and potential benefits of bag are needed.

Keywords: Ergonomic improvements; Musculoskeletal disorders; Muscle strain; Fruit harvest; Migrant and seasonal farmworkers; Agricultural health

1. Introduction

Throughout the US, migrant and seasonal farm workers hand harvest a wide variety of ground, bush and orchard crops for which mechanized harvest is not technically or economically feasible. This harvest work involves long hours of reaching or stooping and carrying heavy loads, often under extreme weather conditions. Although ergonomic research in hand-harvest labor is increasing (Meyers et al., 1998; Sakakibara et al., 1995; Calisto et al., 1997; Miles and Steinke, 1996; Baron et al., 2001), the health and safety hazards associated with this work have not been as thoroughly studied as in many other industries.

In New York State, apples are hand harvested by workers who carry them from the tree to 20-bushel bins. The buckets used to carry the apples can weigh as much as 40 pounds when full. Fig. 1 shows a worker using a traditional apple bucket. Harvest work activities include climbing ladders, picking apples, and carrying full apple bags down the ladder to empty them into the apple bin, which is usually located between five and twenty yards from the worker. These activities require the worker to assume a number of awkward postures, ranging from leaning far to one side while standing on a ladder, to stooping down to release the apples out of the bottom of the apple bag through a drawstring opening, to holding both hands over the head for prolonged periods. Fig. 2 illustrates an apple harvest worker leaning during

*Corresponding author. Tel.: +1 607 547 6023; fax: +1 607 547 6087.
E-mail address: gearlerichardson@nycamh.com (G. Earle-Richardson).

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Fig. 1. Apple harvest worker carrying full bucket of apples over one shoulder.

Fig. 2. Apple harvest worker leaning to pick.

picking. Many of these postures are assumed while the apple bag is full or partially full, which increases the likelihood of muscle and joint strain injuries. The postures associated with these activities have been 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).

Previous research by the New York Center for Agricultural Medicine and Health (NYCAMH) suggests that back, neck and shoulder strain is a common problem among orchard workers (Earle-Richardson et al., 2003). This is consistent with other similar studies (Sakakibara et al., 1995; Calisto et al., 1997). Further research (Earle-Richardson et al., 2004) found that workers spend three-quarters of the time with a full or partially full bag and significant amounts of time in awkward trunk, arm or leg postures. This research also identified significant intervals of doing both of these in combination. Other studies have found proportions of apple hand harvest time spent with hands over the shoulder in a range from 40% to 50% (Calisto and Kleisinger, 2001; Sakakibara et al., 1995).

The identification of high proportions of working time spent with heavy loads and in awkward postures underscores the need for the development of load or posture-modifying interventions. Once developed, such interventions must be evaluated according to a number of criteria before producing and testing on a large-scale. Specifically, it must be determined whether the intervention is likely to be effective in the orchard environment and is acceptable to workers as well as to the orchard enterprises.

In this study, a community ergonomic work team made up of research staff, farm workers, orchard owners and other agricultural community members developed two ergonomic modifications to the apple-harvesting bag. One of these alterations was then evaluated by working apple harvest workers for overall acceptability, comfort and impact on picking speed.

2. Methods

2.1. Development of the ergonomic intervention

During 2001–2002, researchers held seven group meetings with orchard owners and managers, farm workers, and other apple industry representatives. When individual orchard owners were unable to attend these meetings, an interviewer was sent to the farm to obtain their input.

The goal of these meetings was to identify several intervention concepts and collaboratively select one to test in the orchard. This ergonomic team process is consistent with methods used in a number of agricultural ergonomic studies (Miles and Steinke, 1996; Baron et al., 2001; Ehlers and Palermo, 1999; Meyers et al., 1997; Zalk, 2000).

The meetings and interviews included an introduction to ergonomic principles, a presentation of the ergonomic observations made in the orchard, and a facilitated discussion of possible equipment modifications. At each meeting, ideas proposed to date were presented, and new ideas solicited. Facilitation included providing opportunities for each participant to voice his opinion, and adoption of a consensus statement at the end.

Ideas discussed at these meetings covered a range of possible intervention targets: the apple bins, harvest ladders, worker harvest equipment and harvest practices. They were evaluated on their potential efficacy, cost, acceptability to the worker, likely impact on harvest speed, and potential for unintended consequences. The two most popular intervention ideas were: modifications to the shoulder straps to reduce compression and surface friction and a hip belt to displace the weight on the shoulders.

Fig. 4. Ergonomic hip belt attached to bucket.

Fig. 5. Apple harvest worker wearing hip belt intervention.

2.2. Modified shoulder straps

The most commonly observed shoulder strap is made of 2-in. wide canvass, approximately 3 m in length, which can be arranged in a double loop over one shoulder, or looped once over each shoulder, crossing in the back. The intervention design adds a wider padded section to the strap where it lies on the shoulder, and incorporates an elasticized suspension into the strap in two places to minimize the impact of sudden downward forces.

Implementation of this intervention for evaluation purposes was limited by two factors. First, there appeared to be a variety of apple bag straps in use by workers, some with padding, some without. This made the operational definition of a control condition difficult. Furthermore, researchers were not able to devise a means of measuring dispersion of load and reduction of surface pressure through simple field methods. Therefore, this intervention seemed the less promising of the two and was not selected for the current analysis.

2.3. The hip belt

The hip belt is made of soft padded neoprene and attaches to the apple bag with a small, metal hook. Figs. 3–4 illustrate the hip belt. Fig. 5 shows a worker using the hip belt. The bag may be removed and reattached to the belt at will. This intervention redistributes weight from the upper back, neck and shoulders to the hips. This intervention idea was based on earlier mail bag research done by Page (1985), demonstrating that wearing one strap over the shoulder and one strap around the waist while carrying the load in front is effective at reducing load on the lower back.

Fig. 3. Ergonomic hip belt.

Since no hip belt of any kind is currently used in the orchards under study, ‘‘usual equipment’’ was a simple choice for a control condition. This was in marked contrast to the shoulder strap intervention, for which there was not simply definable control condition.

2.4. PATH work sampling data collection

The goal of this data collection was to measure the proportion of time spent in different work postures, engaging in different activities, and using tools, under intervention and control conditions. PATH methodology and instruments employed for this data collection are described elsewhere (Earle-Richardson et al., 2004). Briefly, PATH work sampling records posture, work activity, tools and materials handling at regular intervals over the work cycle. This provides quantified job activity estimates and time spent in various postures for non-mechanized work with no set task time or cycle (Buchholz et al., 1996).

After obtaining informed consent, fourteen workers from two volunteer orchards were observed for two days each by teams of from 6 to 10 PATH observers. Working in pairs, one observer timed 45-s intervals, while the other made PATH postural and work activity observations. All workers were observed both when using the intervention and also when using their usual equipment, which was defined as the control condition. The order in which the conditions were assigned to the subjects was counterbalanced to eliminate order effects. After 100 observations were made in any given condition, observers and workers were rotated to counterbalance the exposure of workers with timer–observer pairs. Timers and observers rotated such that all observers took measurements for all workers.

For each worker, the proportion of observation intervals spent in a given posture or activity was calculated for both hip belt and control conditions. These proportions were then compared across the two conditions for each posture using paired t-test analysis. The per-comparison alpha of 0.05 was not adjusted for multiple comparisons. These analyses were weighted to reflect any slight variations in the number of observations made on each worker.

2.5. Orchard trial and worker interview

After each employee's first use of the intervention, they were interviewed as to their opinion of the usefulness and comfort of the modified equipment. The actual questions asked are shown in Tables 3–5. These questions had been previously selected by the principal investigator based on extensive conversation with apple harvest workers and pre-tested with several workers to assure clarity. Free-text commentary was solicited after every survey question. Responses were tabulated for quantitative data, and common themes identified from commentary sections.

3. Results

3.1. Subjects

Fourteen workers from the two study orchards were observed over two days each by teams of 6–10 observers. One study orchard was comprised of unrelated Jamaican males traveling without families, while the other work group was mainly one extended Mexican family. Table 1 shows selected subject characteristics.

3.2. Orchard observation results

3.2.1. Worker postures

Table 2 shows the proportion of observation intervals spent in twelve postures in both control and the hip belt conditions. In all, there were 2900 observations of workers in each condition.

No significant differences were found in these proportions between conditions for any of the twelve postures. In either condition, workers were in non-neutral trunk stances roughly one-third of the time, non-neutral arm posture 60% of the time, and non-neutral leg positions about 45% of the time.

3.2.2. Correct use of the hip belt

During the first two days of observation, it was noted that a number of workers were wearing the hip belt but not engaging the hook, which is necessary to displace the load. In order to quantify this behavior, a category denoting whether or not the bag was properly hooked during each observation interval was added to the PATH data collection instrument. From this, the hook was observed to be engaged appropriately 62% of the time.

3.2.3. Orchard worker interview results

Tables 3–5 identify major themes with each set of survey questions summarized. Briefly, free text responses among workers were both positive and negative. On the positive side, there was general enthusiasm for the hip belt, a perception of the hip belt as both a support for the back (even when detached from the bag) and a means of displacing some of the bag weight.

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

Table 2
Orchard observation time spent in various postures in the control and hip belt conditions, $n = 14$

Body posture	Control		Intervention		Difference score	
	% time	s.d.	% time	s.d	I–eΔ%	*P*
Trunk neutral	63.1	16.9	62.6	17.0	−1.0	0.82
Trunk moderate flexion (>20′)	23.4	13.3	23.1	10.8	−0.31	0.91
Trunk severe flexion (>45′)	3.5	3.7	4.6	4.5	1.3	0.24
Trunk lateral bend or twist	6.1	4.7	6.9	5.2	0.83	0.45
Trunk lateral bend or twist and flexion	1.9	2.3	2.0	2.6	0.31	0.61
Arm/Shoulder 2 elbows down	39.3	14.5	36.1	16.1	3.4	0.28
Arm/Shoulder 1 elbow up (>60′)	30	11.2	30.6	10.1	0.45	0.82
Arm/Shoulder 2 elbows up (>60′)	29.3	15.8	33.0	14.3	4.0	0.12
Leg—Standing, 2 legs	56.2	14.3	55.2	17.8	−1.3	0.75
Leg—Standing, 1 leg	1.1	1.6	2.4	3.6	1.3	0.10
Leg—Standing, 1 leg or more bent	24.5	14.0	24.9	14.6	0.76	0.81
Leg—Walking	13.6	5.0	14.2	5.2	0.69	0.64

Table 3
Orchard worker survey responses and narration themes: overall assessment, $n = 14$

Question	Yes	No	Same/not sure
Do you think the equipment given to you is better than what you usually use?	71.4	14.3	14.3
If this equipment were available to you would you use it?	78.6	21.4	

Descriptive themes from worker comments

Positive
Enthusiasm for using hip belt
Hip belt has greater comfort
Hip belt "feels good around the waist"
Hip belt takes weight off the shoulder (also lighter on the arms)
Using the belt kept weight steady
Hip belt "helps you work better"

Negative
Hip belt is awkward, sometimes worker misses hooking it back
The hook gets in the way of swinging the bag back when empty
Hard to lift the bag up and out when emptying bag
The worker used hook once, would not use it again
The extra hook can get caught on things
Bag has a steel center (for attaching to hook) that hurts worker
Hip belt good for some kinds of picking, not others
There are situations when belt does not work or is problematic like up in tree; a limb might hit it
Bag with hip belt bothers worker's knee
Bag with hip belt is "nice but not better"

Negative themes included dissatisfaction that the bag was no longer moveable from side to side when empty, reservations about the belt hook attachment, and a more general concern about the intervention slowing work down.

4. Discussion

The following discussion of worker assessment of the hip belt intervention is organized around three key acceptance factors as described by Rogers (1995), as part of diffusion of innovation theory: (1) perceived advantage, (2) compatibility with current worker needs, practice and values, and (3) innovation complexity. The consideration of these principles in the context of agricultural ergonomics has been previously undertaken by Miles and Steinke (1996).

4.1. Perceived advantage

Over three-quarters of workers interviewed said they would use the modified bag in the future, and a substantial portion of the positive commentary indicated that upper back relief was the reason (Tables 3–4). From this it can be concluded that there is substantial

Table 4
Orchard worker survey responses and narration themes: hip belt comfort, $n = 14$

Question	Yes	No
Is the equipment comfortable?	92.9	7.1
Does your neck, shoulder or back feel any different after using it?	71.4	28.6
Themes related to comfort		
Bag with hip belt is comfortable		
The belt adds comfort		
The hip belt provides more comfort due to reduced weight on shoulders		
Worker "does not work with it comfortable"		
Belt holds waist firm		
Really likes the belt but not the hook		
Hook bar would have to come off, then worker would really like it		
Workers waist feels better when he uses it		
Less weight on workers shoulder when he uses belt		
The belt helps sometimes, but other times it gets moved into a place where it does not		
It helps a lot on the lower back (waist), and the worker does not get tired in shoulder		
Effect on back neck and shoulder is due to how it holds the bag from moving while working		
Worker does not get tired the same when using belt		
At beginning uncomfortable but after getting used to it, its comfortable		

Table 5
Worker estimated picking speed, $n = 14$

Question	Yes	No	Same/not sure
Does using this equipment slow you down?	42.9	50	7.14
Do you think it would slow you down if you used it everyday?	64.3	35.7	—
Themes related to whether it slows workers down			
Slowed worker at first, then he "got into it" does not really slow him down now			
Remembering to lift off hook slowed worker down a little			
Makes worker walk slower; feet get stuck			
The hook is a disadvantage			
The hip belt slows worker down because you have to arrange it			
It can unhook at get stuck on tree branches			

acceptance of the bag, and that this is at least partially due to a perceived advantage in terms of reducing load on the upper back.

However, there were some definite perceived disadvantages as well. The main negative feedback related to the hip belt hook, which protrudes from the belt when not holding the bag. Concerns about catching the hook on branches, and over the difficulty of detaching it, suggest that future development of the intervention must include an improved attachment device.

A secondary concern was the inability to move the bag from side to side when empty. Workers frequently move the bag far to one side when climbing ladders and when leaning to pick. A different attachment mechanism which does not protrude and which also can slide around the belt when emptying the bag would address many of the worker concerns.

Finally, the observed workers were noted to have a wide range of heights, weights, and body types. This variation appears to affect the way the hip belt is worn, and may affect the benefit conferred by its use. For example, a person with a large waist to hip ratio might experience difficulty resting the hip belt on the hips, since they would not protrude the way a person whose hips are larger than their waist. Another example are people with shorter arms, who wear the bag high on the chest so that their hands reach the bottom of the bucket for carefully placing the apples. This arrangement may make it more difficult to attach the bucket to the hip belt, placed around the hips.

4.2. Compatibility with current worker practice and values

A major consideration for worker acceptance is that the intervention allows the worker to maintain his current level of picking speed, which is directly related to income for piece rate workers.

Study results were somewhat contradictory on the innovation's effect on speed. Worker interview data were equivocal: half reported that the intervention did not slow down their work during the trial, whereas two-thirds expected that regular use of the intervention would slow them down. It is noteworthy that no changes in work postures or activities were observed with intervention use. Since the intervention does not appear to change work practices, it seems unlikely that it would affect picking speed, since picking speed is a component of work activity.

At this point the intervention's effect on worker speed cannot be conclusively determined. Direct measurement of picking speed over longer work intervals and after an orientation period is needed before this critical question can be answered.

A number of comments were made which were positive about the belt but negative about the hook or about having the hook attached, suggesting that the belt was popular *by itself*, apart from its role as a means of weight redistribution. Further conversation with workers revealed that some thought of the hip belt as conferring a supportive benefit like the perceived benefit of a lifting back-belt.

This perceived consistency with a back-belt benefit might have both a positive and a negative consequence. On the positive side, workers who saw this similarity were positive about the intervention, so the association promoted adoption. On the negative side, some workers were apparently in favor of the intervention for the wrong reason, which could lead to inappropriate use (not engaging the hook when necessary, not adjusting the shoulder straps correctly), thereby depriving themselves of the benefit.

Future development and dissemination of the belt should emphasize a more developed educational component so that workers understand that since the benefit comes from weight displacement, they must hook the belt to the bag to gain the intended benefit. It also suggests that future development of the design should incorporate a feature where having the belt hooked to the bag is the default (removal for unloading only).

4.3. *Innovation complexity*

It became apparent that a certain amount of adjustment of belt and shoulder straps were required until the belt provided the proper weight support. In the short time that workers were trying out the intervention, it was possible to adjust the intervention for them and observe that it remained in proper adjustment. However, in the future when workers use the intervention for longer periods of time without supervision, there is the potential for not receiving the benefit of the intervention due to improper adjustment of the belt and straps. For example, the intervention will not displace the weight on the shoulder if the belt is too loose, if the belt is placed too high or low to reach the hook on the bucket, or if the shoulder straps are too long. Some consideration should be given to design changes that would make the belt and straps more likely to stay at one adjustment point.

5. Limitations

As a pilot study, these results must be viewed as a small part of a much larger process of identifying methods of reducing chronic back, neck and shoulder strain among an important agricultural workforce. As with all pilot research, sample sizes were small, trial periods were short, and endpoints were, by necessity, intermediate to the final health outcomes (Robson et al., 2001).

6. Conclusions

From these analyses, it can be concluded that the hip belt intervention to displace some of the apple bag load was acceptable to a majority of study subjects, although further research into the matter of picking speed is also needed. Redesign of the hip belt-bag attachment mechanism is needed, so that it is easier to hook, so the bag can move around the worker when empty, and so that there are no extra protrusions to catch on branches. Lastly, a more fully developed orientation and training for bag users is needed, to assure that a clear understanding of the mechanism of weight transfer is understood, and so that bag adjustments are not time-consuming.

When these modifications are complete, large-scale testing of the impact of the intervention on back, neck and shoulder pain and strain should be undertaken.

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