An Ergonomic Assessment of the Long Handle Blueberry Harvesting Rake

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Background *Previous work shows the superiority of the long-handled blueberry harvesting rake (LHR) for worker preference and productivity compared to the short-handle rake (SHR).*
Methods *Post-shift interviews on occurrence, location, and severity of pain, and video-based observation of body postures enabled ergonomic assessment of Maine workers harvesting blueberries. Workers randomly crossed between LHR and SHR on consecutive work days. Wilcoxon tests compared proportions of specific body postures between LHR and SHR.*
Results *Subjects used SHR for shorter work periods than LHR. Thirty workers provided interviews for both one LHR and one SHR shift. Assessment of these matched pairs suggested a trend toward less frequent overall pain ($P = 0.07$) and back pain ($P = 0.11$) with the LHR versus the SHR. Video tape analysis included 17 sets of observations (8 SHR and 9 LHR) on 12 individuals. Posture assessment showed more severe forward bend and squatting with the SHR and more moderate/neutral postures with the LHR.*
Conclusion *Harvesting with the traditional SHR is likely to be associated with increased frequency of pain in general, and mid-low back pain in particular, when compared to the newer LHR. This may well relate to the work postures associated with each rake.* Am. J. Ind. Med. 55:1051–1059, 2012. *© 2012 Wiley Periodicals, Inc.*

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INTRODUCTION

Epidemiological studies have identified musculoskeletal disorders (MSDs), occupational injuries, chemical exposure, and skin and eye problems as the leading threats to farmworker health [Villarejo and Baron, 1999; Hanson and Donohoe, 2003; Villarejo and McCurdy, 2008]. Among these, MSDs are the single most common and costly non-fatal agricultural occupational injuries [Bobick and Myers, 1994; Kirkhorn and Earle-Richardson, 2006; Fathallah et al., 2008; Villarejo and McCurdy, 2008]. These injuries to the muscles, tendons, ligaments, joints, nerves, spinal discs, cartilage, blood vessels, or related soft tissue are caused or aggravated by labor demanding repetitive exertion, in particular those tasks that require force to be applied in awkward motions or postures [NIOSH, 2004]. The work performed in agriculture often requires stoop labor, repetitive lifting, and rapid, repetitive wrist and hand movements, and carrying heavy loads—all recognized as risk factors for MSD. Furthermore, workers

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are often paid on a piece-rate strategy, which provides an incentive to work at high speed and to skip recommended breaks.

In Maine, some 60,000 acres of wild blueberries are grown annually. The 88 million pounds of blueberries harvested each year make this state the world's leading producer of wild blueberries [University of Maine Extension, 2010]. During the harvest, which extends over a 3- to 4-week period falling between late July and early September, blueberries are raked from low-lying, scrubby bushes standing 16 inches from the ground. A substantial amount of this work is done manually because of uneven terrain, financial and social considerations. Workers systematically comb through acres of low-lying brush, bending at the waist and utilizing cyclical scooping or sweeping motions to load hand-held metal rakes. In the only previous report of ergonomic analyses of blueberry harvest work, Estill and Tanaka described use of the traditional short handle rake with repetitive and forceful adduction/abduction of the wrist, prolonged trunk flexion, and repeated cranking motions involving the upper extremity. The cycle rate of raking with a short center handle rake averaged 32 strokes, or lifts, per minute [Estill and Tanaka, 1998]. Conservatively this can translate into 1,200 cycles per hour, repeated over the course of shifts ranging from 3 to 12 hr in duration. A single worker could perform in excess of 10,000 forceful strokes in 1 day of harvesting.

In addition to the hand/wrist stresses, these workers spend a substantial portion of each day in a forward-flexed posture with severe flexion of the lumbar and thoracic spine and extension of the cervical spine while manipulating a blueberry-laden rake. Frequently they assume a lunge forward posture, sometimes partially leaning forward with an elbow on the ipsilateral knee (Fig. 1). Thus the blueberry harvester using a short center handle rake experiences weeks of highly repetitive hand, wrist and arm labor performed in a predominantly forward stooped or squatting posture with one arm.

FIGURE 1. Photo of raking posture with the short center single handle rake.

Not surprisingly, the questionnaires accompanying Estill's ergonomic observations showed a substantial rate (36/134 workers—27%) of back pain, often of moderate to severe intensity. The second most frequent complaint involved hand/wrist pain (27/134 workers—20%) [Estill and Tanaka, 1998].

In recent years, a community-based project attempted to address the high prevalence of work-related MSDs detected among the region's wild blueberry harvesters by modifying the design of the traditional short-handled blueberry harvesting rake [Hawkes et al., 2007; May et al., 2008]. A long-handled modification of this rake, which utilizes both arms in the work, was found to be preferred by workers because of both greater comfort and increased productivity [May et al., 2008] (Fig. 2).

Subsequently, the long double-handle rake has become the dominant design (Fig. 3) used for blueberry harvest work [Hubbard, 2011], however it has not been previously ergonomically evaluated. During the course of the previous productivity evaluation, the harvest work with each of the rake designs was video-recorded. Ergonomic questionnaire information was also collected from a cohort of workers using both handle designs. This report describes the findings from an ergonomic assessment of blueberry harvesters randomly allocated to the long-handled rakes (LHR) versus the traditional short, single-handled rakes (SHR). Because the majority of work-related symptoms related to leg/torso/spine postures, these were the main focus of this observational study.

MATERIALS AND METHODS

Forty-eight adult workers harvesting berries for two of the leading blueberry producers in Washington County, Maine were recruited to test different rake types. These workers were randomized to test the several widths of LHR versus SHR while harvesting. The design of this trial has been previously described in considerable detail [May et al., 2008]. Briefly, it consisted of a two-factor design with two rake head widths (70- and 80-tine) and four rake-handle types (single short center handle and 25, 36, and 41 cm. double handle extensions) for a total of eight test rake configurations or "treatments." In light of expected limits on workers' willingness to participate, each subject was assigned to only four of the eight treatments (i.e., in "incomplete blocks"). Using random permutations, constraints were placed on the randomization process to assure that all eight levels of the treatment received equal exposure.

Prior to the test period, each subject completed at least three days of work with the usual equipment in order to acclimate to raking. This prerequisite was intended to

FIGURE 2. Photos of the traditional short-handle blueberry rake (left) and long-handled rake (right). [Color figure can be seen in the online version of this article, available at http://wileyonlinelibrary.com/journal/ajim]

minimize variation in the subjects' responses over the test period attributable to opening season "warm up." The trial took place on consecutive workdays in which the workers used their own rakes on day one to establish a "baseline." For the next four consecutive days of raking, each subject was randomly assigned one of the eight test rake designs (varying handle lengths and tine widths) and the test rake was provided prior to the morning shift. The order of exposure to each specific handle length was random. Initially, the workers were asked to use the assigned rake for the duration of the morning shift. Resistance to this approach forced researchers to allow rakers to switch back to their own equipment after harvesting at least one box of blueberries (see Table I).

Throughout the morning shift, two research assistants collected video footage of those subjects who were sufficiently accessible for detailed video recording (Sony DCR-DVD 403 NTSC, San Diego, CA). The camera was positioned as close to 90° to the direction of the raking as possible, though these angles were not precise. Some workers preferred not to be videotaped. Except for those cases in which the subject refused to complete more than one box of blueberries using the test rake, the researchers filmed each worker continuously for the duration of three completed boxes (approximately 25 min). Although components of this work are highly repetitive, the work is complex and involves considerable variation in posture and activities. During the observation period, workers typically raked, cleaned twigs from rakes, emptied rakes into boxes, carried boxes, walked to new locations, or chatted briefly with co-workers.

At the conclusion of the morning shift, a brief interview was conducted in English or Spanish using a previously validated questionnaire [Faucett et al., 2001]. This interview detailed the type of rake used for the preceding shift, time worked, boxes harvested, conditions encountered, force required, pain experienced and rake preference. Following the interviews these data were entered into an Access database.

FIGURE 3. Photo of raking posture and use of both arms with the long double-handle rake.

Ergonomic Assessment Methodology

The ergonomic analyses relied upon (1) workers' reports of work intensity and pain experienced and (2) observational methodology derived from the posture activity tools handling (PATH) technique described by Buchholz et al. [1996]. While this timed work-sampling observational method has been used extensively for analysis of non-repetitive work in construction [Paquet et al., 2001; Buchholz et al., 2003], it is quite suitable for assessment of postures with the more repetitive nature of blueberry harvest tasks. This approach relies upon detailed observational data being recorded in each of the PATH categories at regular short intervals. This is facilitated by preparation of an itemized worksheet based upon preliminary review of the tasks involved in the work to be analyzed.

Preliminary observations of the harvest images confirmed fears that hand/wrist analyses were not possible because the video data did not show the posture and motions

TABLE I. Allocation of Subjects to Eight Test Conditions and Mean Hours Spent Raking in Each Condition

Handle length	0 (SHR)		10 (LHR)		14 (LHR)		16 (LHR)	
Tine width	70	80	70	80	70	80	70	80
# Subjects	22	23	25	22	24	22	25	24
Mean (SD) hours used	1.4 (1.7)	1.7 (1.8)	2.8 (1.8)	2.4 (1.7)	3.3 (1.8)	3.6 (1.7)	2.7 (2.1)	3.1 (2.1)
Declined[a]	2 (9%)	1 (4%)					2 (8%)	

[a]With completely missing data, those reporting "0" hr of use, and those simply refusing.

of these joints in sufficient detail. In addition to evaluating the posture of the legs, torso, and spine, the blueberry harvest checklist allowed observations of the positions of the arm, elbow, and head. This was done in consultation with an experienced ergonomist who identified a series of potentially problematic body postures to be evaluated, including but not limited to: thrusting or twisting of the head/neck, lunging or squatting, trunk flexion or twisting, arm, and elbow flexion or extension.

Prior to any posture measurements, a random sample of 20 still frame images was taken from video recordings of raking work. Researchers reviewed sample images until there was agreement on how various joints would be graded. For the actual measurements, a still frame of each video was printed at 30-s intervals. Each of two trained researchers independently assessed the postures shown on these still frames using a hand-held transparent ("universal") goniometer to measure body angles. In cases where video detail was insufficient for accurate measurement of a particular joint, the observer noted this on the worksheet.

Data Analysis

Video taped observations

Kappa statistics (which adjust for chance agreement) were calculated to determine the level of inter-observer agreement on analyses of 233 still frame images for each of the body postures assessed using the ergonomic checklist. Only postures exhibiting Kappa scores interpretable as "substantial agreement" or "near-perfect agreement" (a Kappa score 0.61 or greater) were considered for further analyses [Viera and Garrett, 2005]. Postures that were noted in less than six of the still frames by both observers were not considered further. Video-taped workers with fewer than six still-frame observations were also eliminated from analysis.

Observations of rakers using handle extensions of any length (25, 36, and 41 cm.) were collapsed into one "long-handle" category. Previous analyses have demonstrated that rake width is not a significant factor for worker pain and that there was no difference between any of the extended handle lengths [May et al., 2008]. The proportion of observations that a subject was in each posture was calculated. For example, if a subject had 30 observations (still frames) using the SHR and a squatting leg posture was present in ten of these, the proportion of squat would be 0.33. Because all subjects were not observed in both SHR and LHR conditions, the medians of these proportions were compared as for non-paired samples using Wilcoxon rank-sum tests.

Post-shift questionnaire data

Questionnaire data collected after each work shift enabled investigators to test for differences between SHR and LHR in mean hours using the rake, pain experience (yes vs. no), location of pain (back vs. other/no pain), and severity of back pain (moderate/severe vs. mild/none).

To make these comparisons the subject's survey data from the day using the short handled rake was matched with the data from the day using the longest long handled rake. If two like handle lengths were used on more than 1 day, rakes with matching tine widths were selected. Subjects not exposed to both conditions were excluded from these analyses.

The paired *t*-test was used to test if the mean hours worked differed significantly between the SHR and LHR. McNemar's test was used to test for differences in general pain, back pain, and severity of back pain.

Relationships between pain and demographic factors (age, gender, BMI, total height in centimeters, and weight in kilograms) were investigated. On a given day, a subject could report locations and corresponding severity of pain for up to six separate body parts. Pain for that day was defined as the sum total of pain severity across all body parts noted. To calculate this sum, the following values were assigned: 0, no pain reported; 1, mild pain; 2, moderate pain; and 3, severe pain.

To assign one "mean overall pain severity" to each subject, the pain sums were averaged across the days of participation. This mean pain severity was tested for correlation with age, BMI, height, and weight using Pearson's correlation and was tested for a relationship with gender using the Wilcoxon rank-sum test. All data analysis was carried out using SAS 9.1 statistical package (SAS Institute, Cary, NC).

This project was approved and monitored by the Mary Imogene Bassett Hospital Institutional Review Board. Subjects were provided information in either English or Spanish. Subjects gave consent for participation in both the questionnaire and video components of this study. As specified by the IRB, consents were signed unless the subject felt that signing the consent added to the risk of their participation. In these cases verbal consents were accepted.

RESULTS

Although 48 subjects agreed to participate, one submitted no data and was dropped. Demographic characteristics of the remaining 47 are summarized in Table II. Each of these 47 subjects worked from one to five shifts for a total of 180 shifts—41 of these with the SHR (Fig. 4).

Post-Shift Interviews

The percentage of workers reporting general pain was higher for the SHR than the LHR (53.7% and 30.2%, respectively). Back-specific pain was also more prevalent (36.6% for SHR vs. 23.7% for LHR—Table III).

These two prevalences (general and back-specific pain) were contrasted using the 30 matched pairs that were formed as described in the methods. As shown in Table IV, McNemar's test for discordant pairs showed trends favoring the LHR over the SHR that bordered on statistical significance for general pain ($P = 0.07$) and back pain ($P = 0.11$). On average, workers used the SHR for less than half the time that they used the LHR ($P = 0.0004$; Table IV).

No statistically significant relationships were identified between mean pain severity and any of the demographic variables tested. Therefore, these demographic factors were not considered in subsequent analyses.

TABLE II. Demographic Characteristics of Subjects Included in Blueberry Rake Intervention Trial

Total subjects	**47**
Gender	
Male	43 (91.5%)
Female	4 (8.5%)
Age (years)	
Mean (SD)	32.4 (11.3)
BMI (kg/m^2)	
Mean (SD)	25.6 (4.1)
BMI category	
Underweight	2 (4.8%)
Normal	15 (35.7%)
Overweight	21 (50.0%)
Obese	4 (9.5%)
Height (cm)	
Mean (SD)	168.4 (10.9)
Weight (kg)	
Mean (SD)	73.8 (13.5)
Years of raking experience	
Mean (SD)	7.0 (6.5)

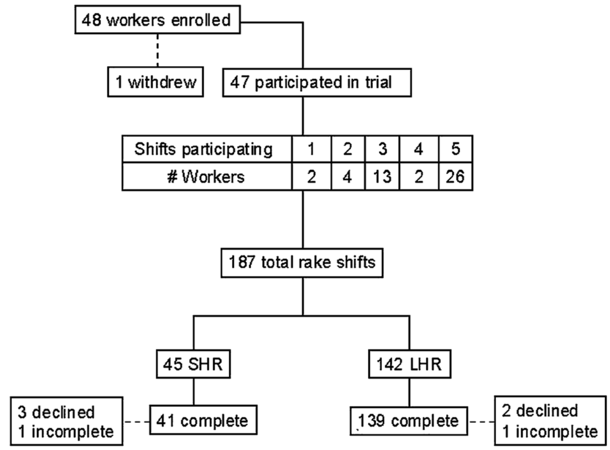

FIGURE 4. Participation in the post-shift questionnaire phase.

Time-Sampled Video Data

Due to both subject refusals and logistical difficulties, only 21 (9 LHR and 12 SHR) sets of video observation were captured on 16 rakers (13 males and 3 females). Four sets of SHR observations (all male) were dropped because the total number of suitable observations (still frames) for each was less than six. Thus, the analyses below relate to observations on nine males and three females using nine LHR and eight SHR rakes (Fig. 5). Although five subjects were viewed under more than one condition, there was no pair-matching of these data.

Hand and wrist postures could not be seen in sufficient detail for accurate measurement and had to be excluded. There remained 23 items to be captured at each still frame. Five of these 23 items (''arm angle not sure,'' ''head not sure,'' ''right elbow not sure,'' ''left elbow not sure,'' and ''picture not suitable'') were provided so the observer could note that the posture was indeterminable and were not intended for further analyses.

Assessment of inter-observer agreement of the postures captured in the still frames showed ''substantial'' or ''near-perfect'' agreement ($\kappa \geq 0.61$) for 19 of the 23 items (Table V). The four showing less than ''substantial'' agreement were dropped from further analyses. Of the remaining 19, five related to the posture being

TABLE III. Post-Shift Reports of Pain After Using Short or Long Handle Rake Treatment Among all Workers

	Short handle		Long handle	
Number of worker shifts	45		142	
Shifts declined to use rake	3	6.7%	2	1.4%
Pain data missing	1		1	
Number of shifts analyzed	41		139	
Experienced pain	22/41	53.7%	42/139	30.2%
Primary pain location[a] (among those reporting pain)				
Back	15	36.6%	33	23.7%
Wrist/forearm	2	4.9%	1	0.7%
Arm/shoulder	2	4.9%	4	2.9%
Legs	2	4.9%	2	1.4%
Neck	—	—	1	0.7%
Not specified	1	2.4%	1	0.7%

[a]Primary pain location definition: if subject reported more than one location of pain on a given shift, the pain location was taken from the first location with the highest severity rating. For example, if the subject reported mild back pain, moderate wrist pain and moderate shoulder pain, the pain location was given as wrist.

indeterminable. Thus a total of 14 separate types of posture observations (five descriptors of leg/torso/spine and nine others) could be analyzed for LHR–SHR differences. After establishing this high level of agreement between the two observers, it was deemed appropriate to use the results for only one observer in the subsequent analyses. Of the 443 still frames captured by this observer, 327 (73.8%) occurred in male workers, and 288 (65%) were with LHR.

TABLE IV. Analyses of Paired Reports of Post-Shift Pain ($n = 30$ Matched Pairs)*

Short handle	Long handle	Mean difference (long–short)	*P*-value
Mean hours worked (SD)			
1.46 (1.60)	3.49 (1.97)	2.04 (2.78)	0.0004

Short handle	Long handle	Number of pairs	*P*-value
Pain experienced			
Yes	No	10	
No	Yes	3	0.07
Yes	Yes	7	
No	No	10	
Back pain experienced			
Yes	No	9	
No	Yes	3	0.11
Yes	Yes	6	
No	No	12	
Back pain severity[a]			
Moderate/severe	None/mild	6	0.40
None/mild	Moderate/severe	3	
Moderate/severe	Moderate/severe	3	
None/mild	None/mild	15	

*Data shown are for the 30 subjects with matched pairs of short and long handled shifts, obtained from post-shift questionnaires.
[a]Number of pairs do not add to 30 because three individuals did not specify the level of back pain severity (all reported back pain with short handled rakes with no specification of severity).

The median proportion of worker observations in each joint position is reported in Table VI. Positions of the leg and spine that might be expected to increase the risk of back pain (squatting ($P = 0.05$), severe forward flexion ($P = 0.01$)) are significantly more common with the SHR. Conversely, postures more likely to reduce the risk of back pain (standing ($P = 0.01$), moderate forward flexion ($P = 0.01$)) are more common with the LHR.

DISCUSSION

One of Maine's leading rake producers recently observed that the long handle rake "has virtually obsoleted

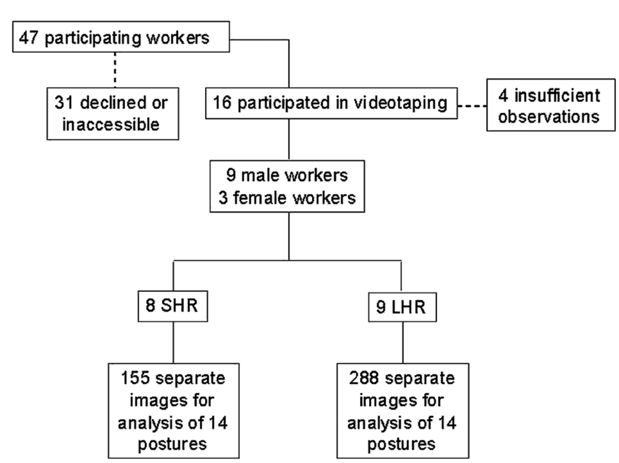

FIGURE 5. Participation in the work observation phase.

TABLE V. Analysis of Inter-Observer Agreement on 233 Still Frame Images

Posture	Observed agreement	Kappa	Interpretation of Kappa
Standing	0.84	0.68	Substantial agreement
Walking	0.92	0.44	Moderate agreement
Lunging	0.94	0.72	Substantial agreement
Squatting	0.91	0.78	Substantial agreement
Moderate fwd bend (20–45°)	0.89	0.67	Substantial agreement
Severe fwd bend (>45°)	0.87	0.64	Substantial agreement
Lateral bend (>20°)	0.96	0.42	Moderate agreement
Trunk not sure	0.94	0.42	Moderate agreement
Both arms neutral	0.96	0.82	High level agreement
Right arm (>60°)	0.92	0.70	Substantial agreement
Left arm (>60°)	0.95	0.60	Moderate agreement
Two arms (>60°)	0.94	0.85	High Level agreement
Arm angle not sure	0.91	0.81	High Level agreement
Head neutral (0–20°)	0.92	0.67	Substantial agreement
Head backward (>10°)	0.99	0.80	Substantial agreement
Head not sure	0.93	0.76	Substantial agreement
Right elbow neutral (60–150°)	0.92	0.78	Substantial agreement
Right elbow extended (>150°)	0.92	0.82	High level agreement
Right elbow not sure	0.87	0.73	Substantial agreement
Left elbow neutral (60–150°)	0.90	0.71	Substantial agreement
Left elbow extended (>150°)	0.92	0.79	Substantial agreement
Left elbow not sure	0.88	0.75	Substantial agreement
Picture not suitable	0.96	0.88	High level agreement

TABLE VI. Proportions of Observations in Target Postures by Handle Type

	Short handle	Long handle	
Posture	Median proportion	Median proportion	*P*-value
Legs			
Lunge	0.16	0.06	0.13
Squat	0.57	0.17	0.05
Stand	0.21	0.69	0.01
Trunk			
Moderate fwd bend	0.00	0.22	0.01
Severe fwd bend	1.00	0.73	0.01
Head/neck			
Neutral	0.38	0.21	0.28
Extended	0.06	0.00	0.13
Arm			
Right arm (>60°)	0.11	0.06	0.24
Both arms neutral	0.11	0.31	0.14
Both arms (>60°)	0.44	0.20	0.25
Elbow			
Right extended	0.29	0.21	0.16
Right neutral	0.27	0.41	0.37
Left extended	0.40	0.21	0.08
Left neutral	0.23	0.35	0.02

[*sic*] the center single handle rake for production rakers" [Hubbard, 2011]. In recent years the demand for the long handle rake has increased tremendously. Based upon previous findings, this likely relates to the combination of increased productivity and greater worker comfort associated with the long handle configuration [May et al., 2008]. This is despite some increase in the weight of the LHR. By adding 25–40 cm, handle material, the weight of the rake increases by roughly a pound over the current weight of 7 lb (for 70 tine) to 8 lb (for 80 tine) steel rakes.

Previous studies of blueberry rakers using short handle rakes have documented frequent complaints of back pain and hand/wrist pain [Tanaka et al., 1994; Millard et al., 1996; Estill and Tanaka, 1998]. This study attempted to assess in greater depth the ergonomics of work with both short single-handle and long double-handle rakes. In assessing both self-reported pain data and video-observed work postures a number of findings emerged. Back pain was a commonly reported problem with both rake designs but was reported more frequently with the SHR. Additionally, the time the workers were willing to use the SHR was less than half of that of the LHR. Despite working for longer periods with the LHR, reports of pain (both in general and in the back specifically) were considerably more common with the SHR. There may also be an advantage in terms of pain severity for the LHR, but the numbers here are quite small.

The results of the video work observation analyses of back postures are certainly of interest in light of the above noted subjective pain data. The findings of significantly *less* time spent squatting and in severe spinal flexion, and of significantly *more* time spent standing and in moderate spinal flexion, all suggest that the postures of the legs and spine are improved when the worker switched from a short handle rake to the long handle rake. Further review of Table VI shows non-significant trends suggesting that the long handle rake may also be associated with less frequent lunging forward and less frequent neck hyperextension with head backward postures.

We have attempted to use our work observations with other readily available ergonomic tools in the assessment of blueberry harvesting. Because the postures associated with this work are so extreme, these approaches can only indicate that harvesting is high risk/very high risk regardless of the type of rake used and are of limited use in differentiating between them. An example of this limitation is seen in the ‘‘rapid entire body assessment (REBA)’’ approach [Hignett and McAtamney, 2000], which assigns the same score for a neck extension of any severity greater than 20° and the same score for any trunk flexion beyond 60°. In contrast, the ‘‘posture’’ component of PATH used in this study quantified the proportion of time in these extreme postures and thus helped demonstrate the differences between the SHR and the LHR.

There are certainly challenges with regard to these data. Key among these is the limited number of observations. The study design fell victim to the realities of fieldwork done by immigrant workers. Worker unwillingness to use the SHR for long periods of time resulted in some of the biases previously noted. A shortened season, early departure of some participants, and differing work pace between some of the crews resulted in fewer observations than had been planned. Our choice of incomplete block design proved unfortunate, resulting in pain data from 17 of our 47 surviving participants being unusable for paired comparisons because these were not randomized to assignments that included at least one SHR and one LHR shift. As a result some of the potentially important reductions in both the prevalence and severity of pain could not be declared statistically significant.

Few would argue that videotaping with a single camera in a blueberry field represents state of the art ergonomic assessment for the complex, three-dimensional motions of the upper extremity and shoulder [Vieira and Kumar, 2004]. For this study, subjects were working in field (literally) conditions, with variations in their positions, ambient lighting, and distance from the camera. Subsequent measurements relied upon manual universal goniometers rather than the more accurate electronic software. Forces were not quantitated and bony landmarks were not marked.

Alternative approaches would have offered some advantages, but also disadvantages. Certainly direct quantitative biomechanical measures using electrogoniometers worn by the workers would add a level of precision not possible with our approach. However, in addition to the greater expense, electrogoniometers present a higher likelihood of interfering with farmworkers while they perform their tasks. The result in this work setting would likely have been sharply lower worker participation rates. Attempts to replicate this work in a laboratory with video techniques appropriate for the complex motions of shoulder arm and wrist would also have produced higher quality measurements, though with the loss of real working conditions. Methods relying upon observation of actual work are more likely to validly reflect work postures [Pinzke, 1996]. Although there were some advantages of our in-the-field video observation approach, there can be little debate that there were also significant limitations related to the ergonomic assessment technique.

Despite challenges related to technique and to worker participation, this article presents the only available ergonomic data on the long handle blueberry rake. The observations relate directly to the actual field use of this tool, by the actual population of workers at risk for ergonomic problems. Finally, the findings of this work are entirely congruent with the previous evaluation work on the long handle rake [May et al., 2008]. The post-shift interview findings and the videotaped work observations independently suggest an ergonomic advantage for the LHR. Our findings are also supported by the current natural experiment in which the LHR is rapidly replacing the SHR in response to consumer demand. Further work specifically designed to measure changes in hand, wrist and forearm motions would considerably enhance understanding of the benefits of this long handle design.

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