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Signature Page

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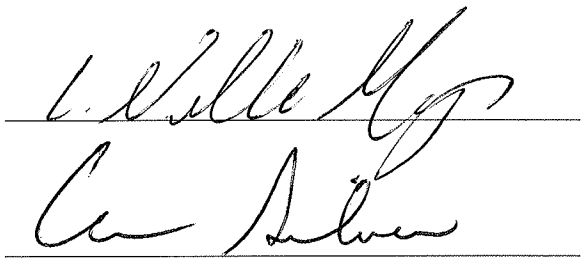

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ABSTRACT

This project tested the hypothesis that non-experts' rankings of ergonomic stressors differ from those of health professionals. Tennessee ranks fifth in the production of tomatoes, an industry in which stoop labor, hand harvesting, and packing predominate. Specific parts of tomato workers' bodies are at risk of ergonomic injury, such as shoulders (loads), backs (stoop labor), lower extremities (posture), and upper extremities (repetitive motion). Of equal importance is our expectation that the scores assigned by non-experts will correlate with those of experts, leading to a community consensus for action and practical intervention research. Video footage of harvesting and sorting was analyzed using the Rapid Entire Body Assessment method, revealing movements and postures likely to be injurious. A panel of 13 health professionals ("experts") and industry personnel ("non-experts") were assembled to rate job task video segments in tomato harvesting and packing using the REBA method. Analysis of variance (ANOVA) was used to analyze the extent to which raters agree on the major body parts at risk of cumulative trauma disorders. Agreement and variation among professional groups, as well as intra-rater variability, were assessed . The possibility of achieving consensus among various professional groups with respect to the most dangerous tasks is discussed.

INTRODUCTION

Reducing the incidence and prevalence of musculoskeletal disorders (MSD) associated with work practices in production agriculture (Chapman and Meyers, 2001; Davis and Kotowski, 2007) will require a multi-pronged effort. Risk factors can be evaluated using observation-based exposure assessment tools familiar to university-based investigators (Van der Beek and Frings-Dresen, 1998; David 2005). Research on alternative methods to accomplish tasks performed by agricultural laborers can be carried out in a dialogue with workers and supervisors, informed by awareness of sociocultural and economic issues underpinning the organization of work, such as crew hierarchies and piece-rate pay. Continuing education of primary care providers is likely to be helpful in establishing MSD as serious clinical entities, disabusing employers and workers of the popular perception that MSD are just another of life's "hard knocks." A participatory, interactive, long-term approach that achieves buy-in from these key stakeholders

across an agricultural region may ultimately yield workable solutions to ergonomic problems.

Little is known about rates of MSD in the tomato industry in the United States, despite the large production volume and economic importance of this crop. Case reports of "tomato trainer's shoulder" due to awkward and repetitive motions in tying staked plants, spotlight a dangerous task (Palmer 1996), albeit one that is performed early in the growing season by relatively few workers. By contrast, highly repetitive manual sorting work is performed by large numbers of workers. In Italy's highly mechanized tomato industry, sorting is believed to account for the fact that MSDs exceed the number of injuries caused by machinery. On the Occupational Repetitive Action (OCRA) Index, values greater than 3.5 denote unacceptable risks; Cecchini and co-workers (2010) calculated a score of 20 for sorting tomatoes.

In our earliest survey of occupational health concerns among tomato workers in east Tennessee, MSD were top-ranked (Figure 1). Clinicians providing care to tomato workers at summer health screenings lent confirmation by voicing concern to a medical school faculty member about excessive requests for prescription painkillers. In 2008, ETSU catalyzed a partnership between the national Migrant Clinicians' Network (MCN) and Rural Medical Services (RMS), a federally-funded "330" migrant health center which serves southeast Tennessee (Andino et al, 2010). Nested within a two-semester course in which interprofessional teams of health science students and faculty work with off-campus organizations, the partnership has carried out an array of assessments and pilot interventions with workers who harvest tomatoes in the fields by hand, as well as packinghouse workers who do most of the sorting (Silver et al, in press).

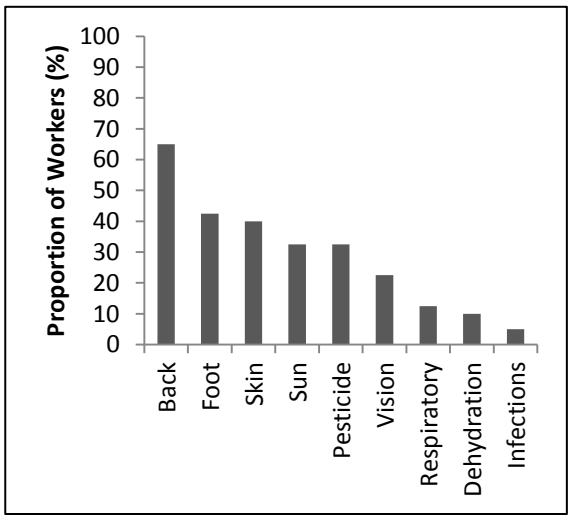

Figure 1. Proportion of tomato workers reporting concern about a variety of occupational exposures and health outcomes; results of initial opinion survey of workers on a tomato farm (N=40).

Predominating the east Tennessee tomato crop are indeterminate varieties which ripen throughout the growing season, militating against the use of mechanical equipment for harvesting. A migrant and seasonal workforce of several thousand is employed from April to September. Family-owned and slow to change, approximately 300 tomato farms in the region are served by extension offices in each of the 24

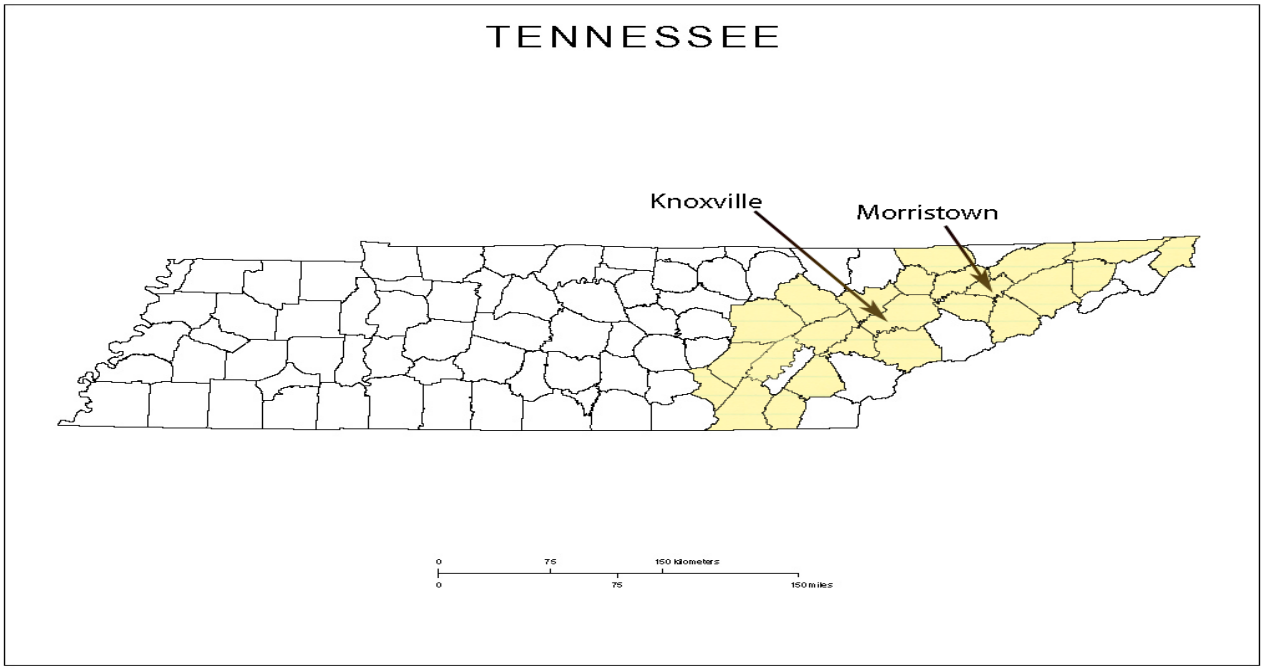

Figure 2. East Tennessee counties with commercial tomato production. (At least 10 acres or five farms in tomato production according to the Census of Agriculture [National Agricultural Statistics Service, 2007] and modified by personal communication with Dr. Annette Wszelaki, University of Tennessee).

counties where the industry is concentrated (Figure 2).

This setting provides an opportunity to develop an understanding of the ergonomic stressors of tomato workers using a "bottom up" approach with participation by individuals and regional organizations from the agricultural and health sectors. As a problem-solving tool, "participatory ergonomics" is of increasing interest to funding agencies, employers, and occupational health specialists (Baron et al, 2001). Straightforward and requiring no prior background in the field, the Rapid Entire Body Assessment (REBA) method, an observation-based exposure assessment tool (Hignett and McAtamney, 2000), can be applied after a half day of training.

Here, in one of the first formal studies of U.S. tomato worker ergonomics, a panel drawn from the agricultural and health sectors in the community applied REBA to rate ergonomic risk factors for three tomato worker tasks. With physicians, tomato workers, extension agents and other professionals, this panel study was designed to elicit the views of professionals and laypeople with complementary areas of expertise, an approach taken in other occupational exposure assessment expert panel studies (Järvholm and Sandén (1997); De Cock et al, 1996; Segnan et al, 1996; Goldberg et al, 1986). It is the first study to evaluate REBA for

its sensitivity to raters' professional backgrounds.

METHODS

Video Footage. A bilingual health outreach worker from RMS accompanied a student researcher (L.Y.) into a field of indeterminate tomatoes in August 2011. After informed consent was obtained (see below), the researcher used a hand-held video recorder to shoot 30 to 45 minute segments of workers, who are paid piece-rate, harvesting tomatoes. Select still photographs were also obtained. # male and # female workers gave consent and were videotaped. The tasks captured were stoop labor, carrying a filled bucket to the nearest truck, and tossing it up to the truck bed. Similarly, on a visit to a packinghouse, video footage was obtained of workers sorting tomatoes and stacking filled boxes as they came off the line.

For the expert panel, video excerpts of these tasks, up to two minutes in length, were selected by the researcher, along with the PI (K.S.) and project ergonomist (N.F.), with an eye toward representativeness. Marbling of workers' faces in the video segments was applied by an audiovisual technician to protect workers' identities. A master DVD in five parts, each corresponding to one of the five aforementioned tasks, was prepared. Each part was configured to loop continuously, to allow panelists ample time to view and score each task. Copiess of the DVD were made and played on the laptop computers at the expert panel session.

For the intra-rate reliability follow-up assignment, an analogous set of video segments was created of # tasks to be scored. These video segments were burned onto DVDs for distribution to each panelist at the conclusion of the panel session. The only difference between the video footage on the distributed DVD and that used in the panel session is that different individual workers were videotaped performing the tasks.

Recruitment of Panelists. Individuals who had not discussed ergonomics with ETSU were recruited into one of four classes of panelists, via e-mail and flier, through the regional contacts of the university researchers and community partners. A $100 stipend was offered, contingent upon attending the one-day REBA training and panel evaluation and returning the follow-up assignment (see below). The panel was held in the private meeting room of a popular Mexican restaurant in Morristown, TN, "the heart" of tomato country (Lewis 2007). Participants completed a brief demographic questionnaire, linked by code to their REBA score sheets. Three Spanish-speaking tomato workers, four physicians, and three agricultural extension agents were recruited. Rounding out the 13-member panel were two ES&H professionals and one nurse.

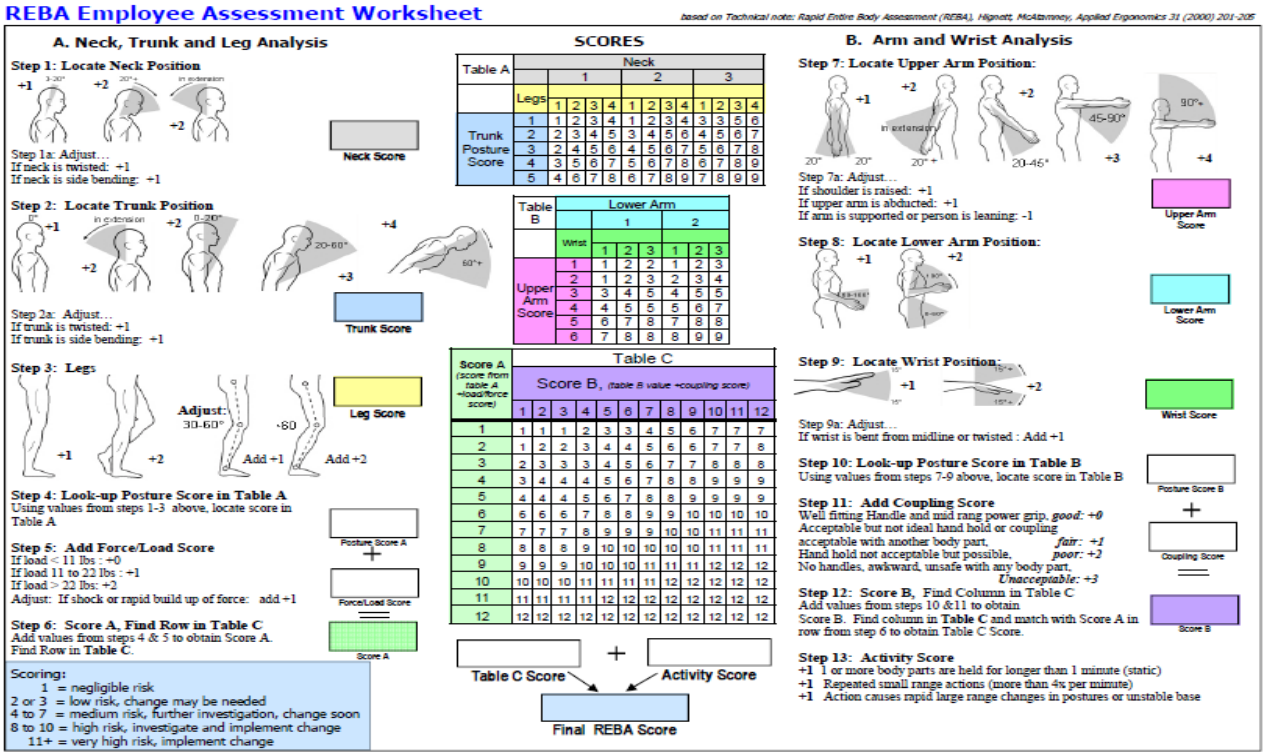

Figure 3. REBA score sheet. Hignett, S. and L. McAtammey (2000)

REBA Training and Panel Evaluation. A morning training session in the REBA scoring method, using stock video footage of other industries, was conducted by the project's ergonomist whose university-based research focuses on ergonomics (N.F.). After a complimentary lunch, panelists returned to the meeting room which had been rearranged with individual laptop computers equipped with DVD's with the video footage of tomato workers' tasks. Instructed to "work alone" without discussing the task with their fellow panelists, each panelist completed a REBA score sheet (Figure 3) for each of the three job tasks. Proctors ensured that individuals did not influence each other's scoring. All score sheets were collected. As a condition of receipt of stipends, panelists performed a second rating solo, using similar but not identical video footage on DVD, for the analysis of intra-rater variation.

Informed Consent. Human subject protection protocols for both the REBA panelists and the workers whose tasks were reviewed and approved by the ETSU Institutional Review Board. Those candidate panelists who were reached via email or phone at least five days prior to the REBA panel session were provided with the informed consent (IC) form in advance. Additional copies of the IC form were made available in the morning as the REBA panel convened. The PI briefly described the IC process, the study objectives and methods, and then invited questions. The three tomato

workers whose native language is Spanish were recruited to participate by RMS's outreach staff. To facilitate their participation, we translated the IC form into Spanish and provided it to RMS two weeks in advance. At their offices near east Tennessee's tomato farms, RMS outreach workers discussed the objectives and methods with the tomato workers, who then brought their signed IC forms to the REBA panel.

The workers whose job tasks were videotaped and photographed were likely to include individuals of limited literacy. ETSU's IRB approved a consent procedure whereby RMS's bilingual outreach worker (accompanying the student researcher) explained the study and read the IC form verbatim to potential volunteers. Individuals signed their names to the IC form that had just been read to them.

REBA panelists were mailed $100 stipend checks upon returning the results of their solo REBA scoring, in follow-up to the panel day. However, to pay stipends to the three Spanish-speaking tomato workers, whose documented immigration status was unknown, a single check of $300 was issued to RMS, who in turn issued $100 payments to each of the workers. Also, as state employees, the cooperative extension agents directed payment to their respective agencies. For the field harvest and packinghouse workers who volunteered to have their tasks videotaped, cash payments of $25 were made on the days of the field visits upon completion of the filming.

TABLE 1. Demographic characteristics of REBA panelists

Sample Characteristics	(n = 13)
Modal Ethnicity	White (13)
Mean Age	35.6 years (13)
Gender	
Female	61.5% (8)
Male	38.5% (5)
Ethnicity	
White	76.9% (10)
Latino/Hispanic	23.1% (3)
Education	
Some High School	7.7% (1)
Some College	7.7% (1)
College Graduate	15.4% (2)
Some Graduate School	7.7% (1)
Graduate Degree	61.5% (8)
Occupation	
Cooperative Extension	23.1% (3)
Crop Production	23.1% (3)
Environment/Safety	15.4% (2)
Medicine	30.8% (4)
Nursing	7.7% (1)
Experience in Current Occupation (years)	
1-10	61.5% (8)
11-25	30.8% (4)
26+	7.7% (1)

Statistical Methods. Interrater agreement analysis was performed using MiniTab statistical software. Task rankings were compiled from the REBA score sheets which were outlined in a spreadsheet based on the training session, morning group and homework solo. The correlation among rater scores was measured by examining Spearman's correlation, r-square value. Two-way ANOVA tests, with α=0.05,

were conducted to examine the value of interaction among interrater agreement. To visually analyze the interaction between the raters and the tasks, an interaction plot was prepared and analyzed. A dotplot was also composed to observe the differences among professional rankings for the four tasks.

Table 2: Two-way ANOVA: score versus prof, task for Morning Assessment

Source	DF	SS	MS	F	P
prof	3	36.229	12.0764	6.04	0.002
task	3	207.063	69.0208	34.51	0.000
Interaction	9	38.187	4.2431	2.12	0.057
Error	32	64.000	2.0000		
Total	47	345.479			

S = 1.414 R-Sq = 81.48% R-Sq(adj) = 72.79%

Table 3: Two-way ANOVA: score versus prof, task for Off-site Assessment

Source	DF	SS	MS	F	P
prof	3	6.833	2.2778	0.64	0.598
task	3	241.500	80.5000	22.47	0.000
Interaction	9	11.000	1.2222	0.34	0.954
Error	32	114.667	3.5833		
Total	47	374.000			

S = 1.893 R-Sq = 69.34% R-Sq(adj) = 54.97%

RESULTS

Demographic Description of Panelists. As shown in Table 1, the 13 panelists represented several occupations involved in the tomato industry, as well as health personnel concerned with evaluating risks or treating the injured. Educational attainments ranged from "some high school" to graduate degrees, with the latter predominating. Three Latino tomato workers provided a degree of ethnic diversity. Consistent with the mean age of 35.6 years, a majority of panelists (61.5%) had been in their current occupations no more than ten years.

Interrater REBA Scoring of Four Tasks. Interrater correlation suggests that there was a moderately strong correlation, $r^2 = 0.81$, of expert agreement. There was an interaction of borderline statistical significance ($p = 0.057$) between the profession and the tasks. Based on $p<0.001$ for task and $p = 0.002$ for profession, significant differences were found among tasks and among professions (Table 2).

In the morning session, the expert panelists assigned the highest risk rankings to picking and packing. Sorting and hoisting to the truck received the lowest scores (Figure 4). The interrater correlation was highest for picking and lowest for sorting tomatoes. Additionally, the order in which the professions ranked the tasks remained the same for both picking and sorting tasks. According to Figure 4, there is an interaction between the worker and the agricultural extension agents for how the truck was ranked. A consensus exists among the physicians, agricultural extension agents, ES&H professionals and one nurse for packing. The workers, however, assigned a lower ergonomic risk score to packing. On average, all four tasks were ranked highest among the workers and lowest among the physicians for ergonomic risk (Figure 5).

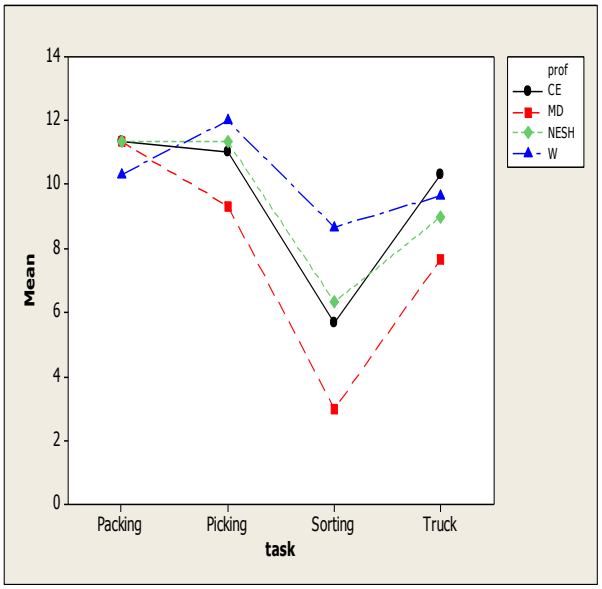

Figure 4: Data Mean Interaction Plot for Profession Score of Morning Assessment

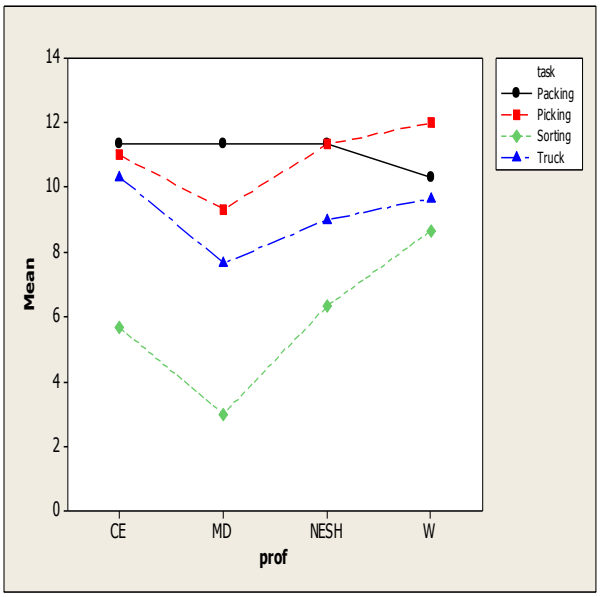

Figure 5: Data Mean Interaction Plot for Task Score of Morning Assessment

In the offsite assessments, an r^2 value of 0.69 suggests that expert agreement of task rankings were moderately correlated. There was no interaction, p = 0.954, between the profession and tasks in the way they ordered their scores (Table 3). As with the morning session it was

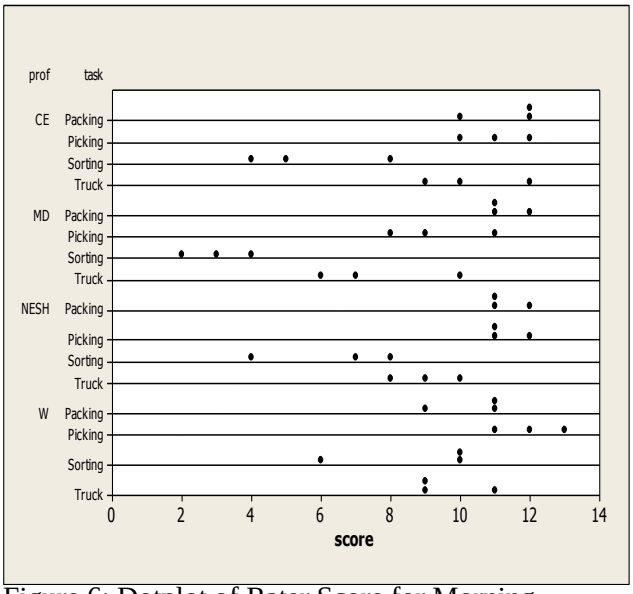

Figure 6: Dotplot of Rater Score for Morning Assessment

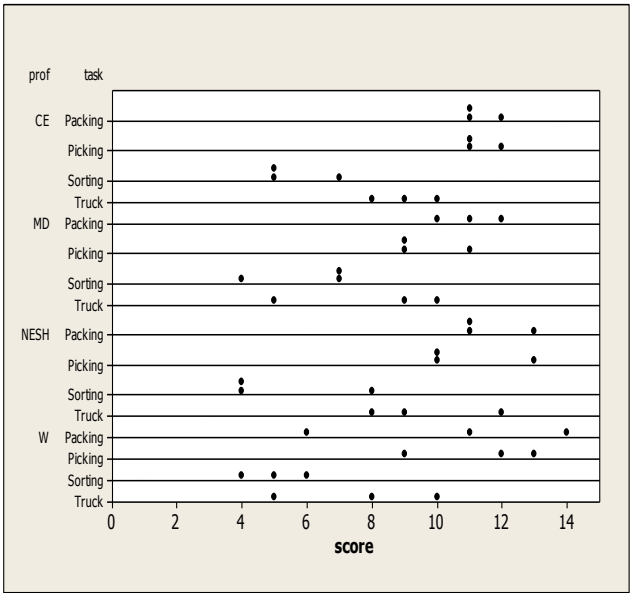

Figure 7: Dotplot of Rater Score for Off-site Assessment

found that there was a significant difference among the tasks, giving that p = 0.000. However, there was no significant difference found between the professions, given p = 0.598, illustrating that the they were in agreement for which tasks were the most difficult and

ergonomically challenging and likewise which were the least demanding.

Intrarater Variability Using REBA. Twelve panelists performed the requested tasks and sent in the results promptly. For one panelist, the results were not received until after analysis had begun. This 13th panelist was one of the four recruited medical doctors; therefore, analyses were conducted with only the first 12 panelists (n =12), excluding the late participant.

Dotplots were constructed to analyze intrarater variations among how the tasks were ranked. Figure 6, from the initial morning session, illustrates that the tasks were judged differently by each profession and differently within each profession (workers, physicians, agricultural extension agents, ES&H professionals, and one nurse). This can be confirmed by analyzing the professions p value of 0.002 from the two-way ANOVA. In contrast, the dotplot constructed from the off-site assessment (Figure 7), demonstrates that the tasks were comparably rated by each profession. There was no significant difference among how the professionals scored each task (p=0.100).

Therefore, upon a second exposure to the rating system, during the off-site assessment, the experts began to see the tasks in the same manner and come to a consensus about the ergonomic significance of each task. This may indicate that the panelists understood the REBA assessment tool better after a second exposure.

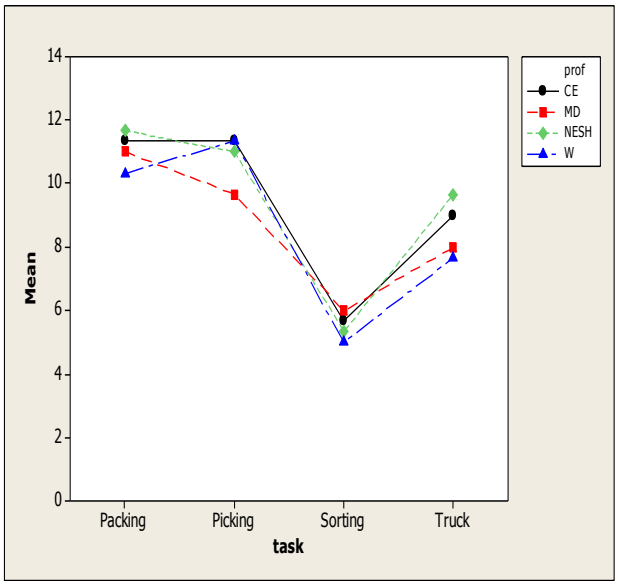

Figure 8: Data Mean Interaction Plot for Profession Score of Off-site Assessment

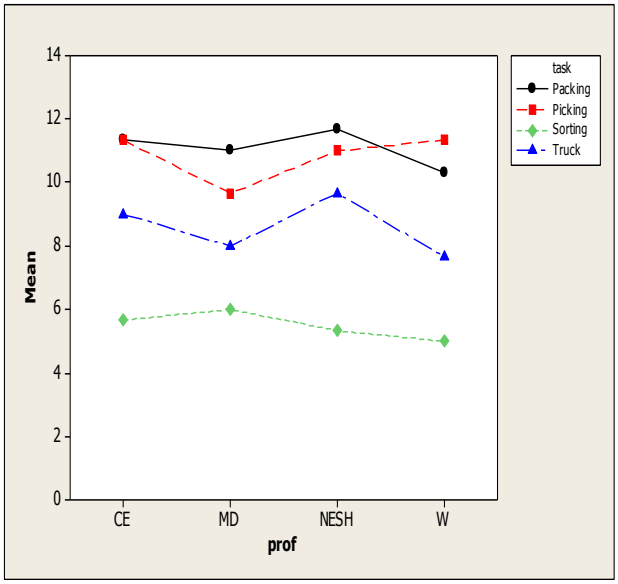

Figure 9: Data Mean Interaction Plot for Task Score of Off-site Assessment

Interpretation of Results. There was a general consensus that sorting was the least ergonomically demanding task (Figure 8). The expert panel agreed that both picking and packing were almost comparable in terms of ergonomic risk. Based on the mean values for

picking (10.8), and packing (11.0), it is clear the panel viewed both tasks as approaching "very high risk," according to REBA. There were no observable significant variations of the order in which the panelists ranked which takes were the most challenging and which were not, between the initial morning session and the subsequent off-site assessment (Figure 5, 9).

DISCUSSION

Stoop labor in the manual harvesting of field crops is a recognized source of musculoskeletal damage to farmworkers around the world, as well as in parts of the United States where it has not been replaced by mechanization. Here, ergonomic hazards in the east Tennessee tomato industry were the focus of a pilot participatory study involving extension agents, tomato workers, and health and environmental professionals. Interventions to remedy the recognized, but seemingly intractable, hazards of manual harvesting and packing will require ongoing cooperation of these diverse sectors of the industry and community.

Agreement among professions suggests that packing was observed to be the most ergonomically hazardous task. According to REBA, a mean score of 11 for packing correlates indicates a "very high" risk. The comparable order in which the tasks were ranked from the morning to the off-site assessment was very similar, with little variation. On average, the three tomato workers on the panel scored tasks as higher risk in comparison to medical doctors whose scores were consistently the lowest. Upon conducting a second assessment, the professions began to rank each task in a similar manner, resulting in concordant scores.

The REBA tool is one of the simpler observation based exposure assessment tools (David, 2005), useful in categorizing body postures and force, leading to numerical action levels to prioritize the need for interventions. An important process lesson from the current study is that persons of widely disparate educational and socioeconomic backgrounds, from farmworkers to physicians, can be trained in half a day to use REBA in a manner that appears to be reliable and reproducible. Missing from the current study and perhaps the wider literature is a similarly simple tool for identifying strategies to modify work practices, tools and machinery.

Here, the REBA assessment tool has proven to be teachable and reproducible in half a day for a panel of participants of varying educational and socioeconomic backgrounds. It may therefore be useful as a tool for conducting initial assessments using the increasingly popular approach of "participatory ergonomics." Obvious next steps beyond this pilot study would entail disseminating the following key finding to panel participants: while there appears to be a consensus that packing is the most ergonomically hazardous task, picking is

rated almost as hazardous. A truly participatory approach would invite the panelists to direct the next stage of inquiry: whether further analysis is warranted or to suggest specific technologies and modifications in work practices and work organization to mitigate risks. REBA may continue to be useful for "before" and "after" assessments of proposed and pilot modifications to jobs and tasks.

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