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Ergonomic Evaluation of Checkstand Designs in the Retail Food Industry: A Report Based on Expert Assessment

Katharyn A. Grant,[A] Daniel J. Habes[A] Sherry L. Baron,[B] Marie Haring Sweeney,[B] Laurie A. Piacitelli,[B] Vern Putz-Anderson,[A] and Lawrence J. Fine[B]
Divisions of [A]Biomedical and Behavioral Science, and [B]Surveillance, Hazard Evaluation and Field Studies, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, M.S. C-24, Cincinnati, Ohio 45226

Increasing evidence suggests that musculoskeletal disorders are common in the U.S. retail food industry. Cashiers who use electronic scanners appear to be at especially high risk for upper extremity cumulative trauma disorders (CTDs). One potential source of biomechanical stress is the checkstand design. Checkstand design can greatly influence the cashier's posture and movement patterns during grocery checking tasks. It is hypothesized that designs which expose cashiers to stressful postures and unnatural movements may be associated with increased musculoskeletal complaints.

The National Institute for Occupational Safety and Health (NIOSH) is conducting an industrywide study to evaluate the prevalence and possible causes of musculoskeletal disorders among retail food workers. An objective of this research is to evaluate the relationship between CTDs and different checkstand designs. This article describes initial activities to identify ergonomic stressors associated with five common checkstand types found in the United States. A panel of ergonomic experts was convened to rate the degree of biomechanical stress placed on specific body areas (neck, shoulders, elbows, hand/wrist, and back) by 13 different checkstand configurations. The panel reviewed cashier work activities recorded on videotape, and design specifications collected during site visits to different grocery stores. The experts agreed that certain checkstand features are more likely to impose substantial biomechanical stresses on cashiers than others. NIOSH investigators will use the experts' assessments as a basis for future studies in this industry. **Grant, K.A.; Habes, D.J.; Baron, S.L.; Haring Sweeney, M.; Piacitelli, L.A.; Putz-Anderson, V.; Fine, L.J.: Ergonomic Evaluation of Checkstand Designs in the Retail Food Industry: A Report Based on Expert Assessment. Appl. Occup. Environ. Hyg. 8(11):929–936; 1993.**

Introduction

The retail food industry is the third largest employer in the United States, employing approximately 3.5 million workers.[1] Of these, approximately 1 million are grocery store cashiers. In recent years, evidence of a relationship between musculoskeletal disorders and the work activities of grocery checkers has gained increasing attention. Several studies conducted in the United States and Europe have found high prevalence rates of upper extremity cumulative trauma disorders (CTDs) among cashiers who use electronic scanners for totaling customer orders.[2–5]

The National Institute for Occupational Safety and Health (NIOSH) is conducting an industrywide study to evaluate the prevalence and possible causes of musculoskeletal disorders among retail food workers. An objective of this research is to evaluate the relationship between CTDs and different checkstand designs. Checkstand design can greatly influence the cashier's posture and movements during checking tasks. The NIOSH study will test the hypothesis that workstations which expose cashiers to stressful postures and awkward movements are associated with an increased incidence of musculoskeletal complaints.

To select populations for inclusion in this study, NIOSH investigators have been working to identify biomechanical stressors associated with different checkstand designs in the United States. These activities and some preliminary findings are described in the following sections.

Methods

Data Collection

Based on data provided by the Food Marketing Institute, 13 checkstands were selected for evaluation by NIOSH investigators. A brief description of each checkstand is found in Table I. The sample included all major checkstand types, and three scanner/scale designs found commonly in the retail food industry.[6]

Checkstand types included the following:

Side

The cashier and customer face each other from opposite sides of the scanner or take-away belt. An input belt brings groceries to the scanner. The keyboard and cash drawer are placed on a stand to one side of the cashier, at a 90° angle with respect to the flow of groceries across the scanner. An example of this design is shown in Figure 1.

Front

The cashier and customer face each other from opposite sides of the scanner. An input belt brings groceries to the scanner. The keyboard is located in front of the cashier, above or to the side of the scanner. The cash drawer may be located below or to one side of the scanner. An example of this configuration is shown in Figure 2.

Right Hand Take-away (RHT)

The cashier stands directly in front of the input belt, facing the flow of groceries. The scanner is located between the cashier and the input belt. The customer stands to the cashier's left. After grocery items are scanned, the cashier places items on a take-away belt located on the cashier's right side. The layout of this checkstand is shown in Figure 3.

Over-the-Counter (OTC)

The cashier and customer face each other from opposite sides of the scanner. The grocery cart is positioned directly in front of the scanner, generally to the right side of the cashier. The cashier unloads groceries directly from the cart for scanning. The keyboard and cash drawer may be located in front of or to one side of the cashier. An example of this checkstand type is shown in Figure 4.

Over-the-End (OTE)

The cashier stands directly in front of the input belt, facing the flow of groceries. The scanner and a bag stand are placed between the cashier and input belt. The customer stands to one side of the input belt. After scanning the grocery item, the cashier places items directly into a bag. The layout of this checkstand is shown in Figure 5.

Scanner/scale arrangements included the following: (1) vertical beam scanner, scale as a separate unit (Figure 6); (2)

TABLE I. Checkstand Descriptions

Checkstand	Type	Scanner Orientation	Scale	Scanner Height (Inches)	Take-away Conveyor
A	Front	Vertical beam	None*	36	Yes
B	Side	Vertical beam	In scan unit	36	Yes
C	OTC (front)	Horizontal beam	In scan unit	31	Yes
D	Front	Vertical beam	Separate unit	37	Yes
E	RHT	Vertical beam	Separate unit	34	Yes
F	OTC (front)	Vertical beam	None*	32	Yes
G	OTC (side)	Vertical beam	Separate	28	No
H	Side	Vertical beam	None*	34	Yes
I	Side	Vertical beam	Separate	36	No
J	RHT	Vertical beam	In scan unit	34	Yes
K	Front	Vertical beam	In scan unit	36	Yes
L	Front	Horizontal beam	In scan unit	36	Yes
M	OTE	Vertical beam	Separate	34	No

*Store policy required items to be weighed in the produce department.
OTC = Over-the-counter; RHT = right hand take-away; OTE = over-the-end.

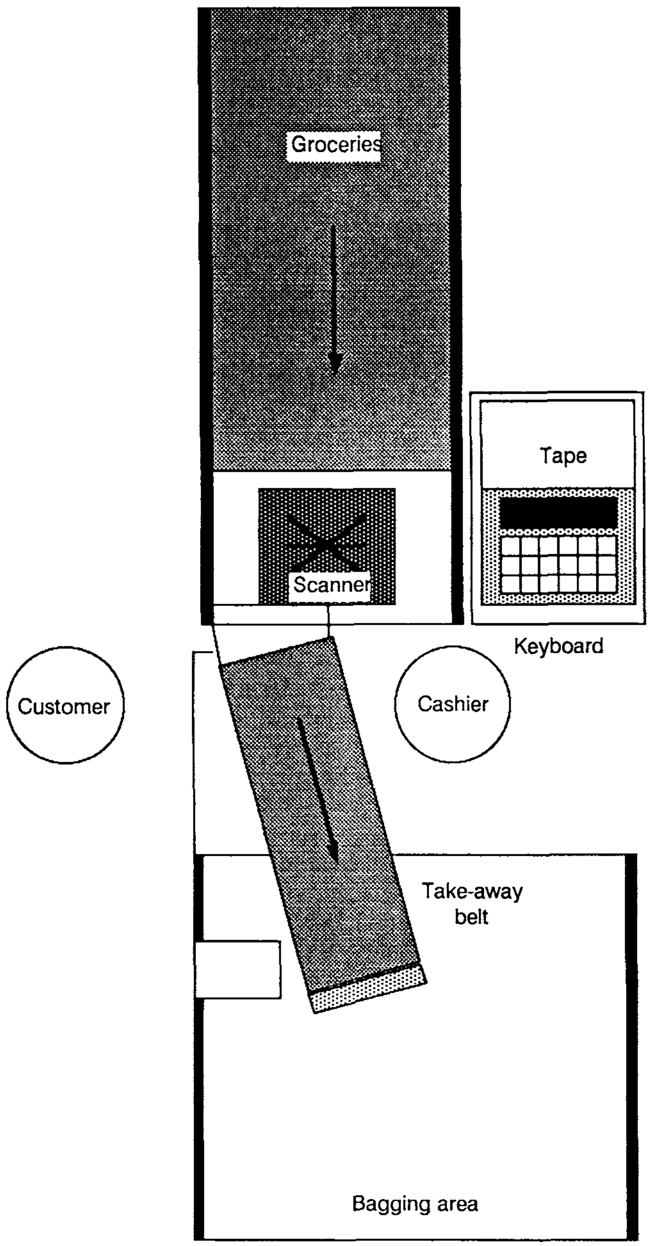

FIGURE 1. Side-facing checkstand.

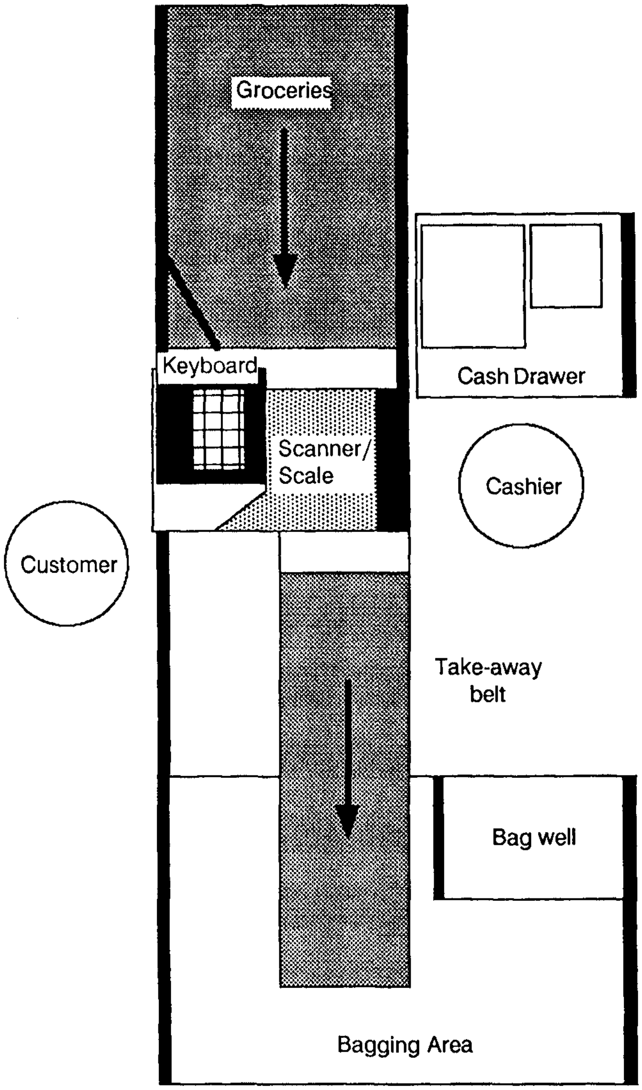

FIGURE 2. Front-facing checkstand.

vertical beam scanner/scale (single unit); (3) horizontal beam scanner/scale (single unit).

Checkstands also differed in the availability and location of certain components (e.g., conveyor belts and bag stands).

Site visits to 13 grocery stores were conducted to collect data for evaluation purposes. Checkstand dimensions (heights, widths, reach distances, etc.) were measured, and checkstands were photographed from several angles. The presence and location of checkstand components were recorded on a checklist specifically designed for this study. The work activities of at least three cashiers at each checkstand configuration were recorded on videotape. To provide a basis for comparing different designs and the motion patterns associated with different checkstand features, a "standard cart" containing 20 common grocery items of varying size and shape was assembled (Table II). The cart included both heavy and light items, and items that required use of the scale. The movements required to scan, weigh, and bag these items at each checkstand configuration were also filmed.

Ergonomic Evaluation

Based on observations of grocery checking activities at the work site, the grocery checker's job was divided into the following work tasks: (1) scanning grocery items; (2) weighing produce; (3) entering amounts into a keyboard; (4) collecting payment (tender collection); and (5) bagging grocery items.

Expert opinion is one of the oldest and most extensively employed workload evaluation techniques.[7] Experts in the field of industrial ergonomics are frequently called upon to evaluate jobs and identify ergonomic stressors that may cause fatigue, discomfort, or injury. Keyserling and Wittig[8] indicate that experts can achieve strong consensus when rating the level of ergonomic stress associated with different job tasks. The information collected by NIOSH investigators was provided to a panel of six "experts," each with previous experience in workstation design, evaluation of ergonomic hazards, and the retail food industry. A brief description of each of the experts is provided below.

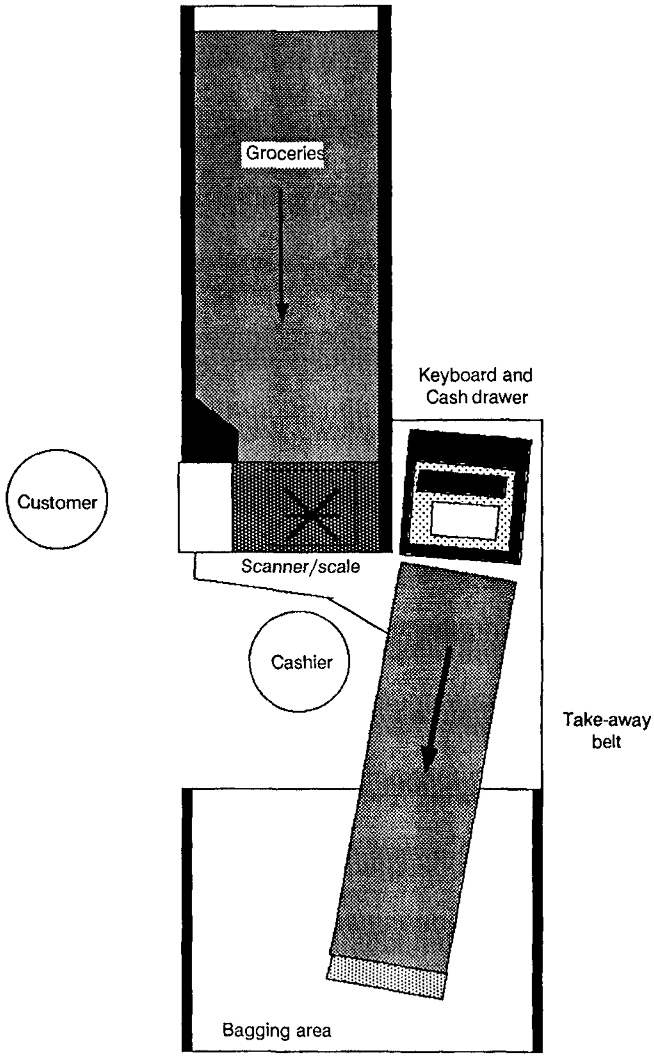

FIGURE 3. Right hand take-away checkstand.

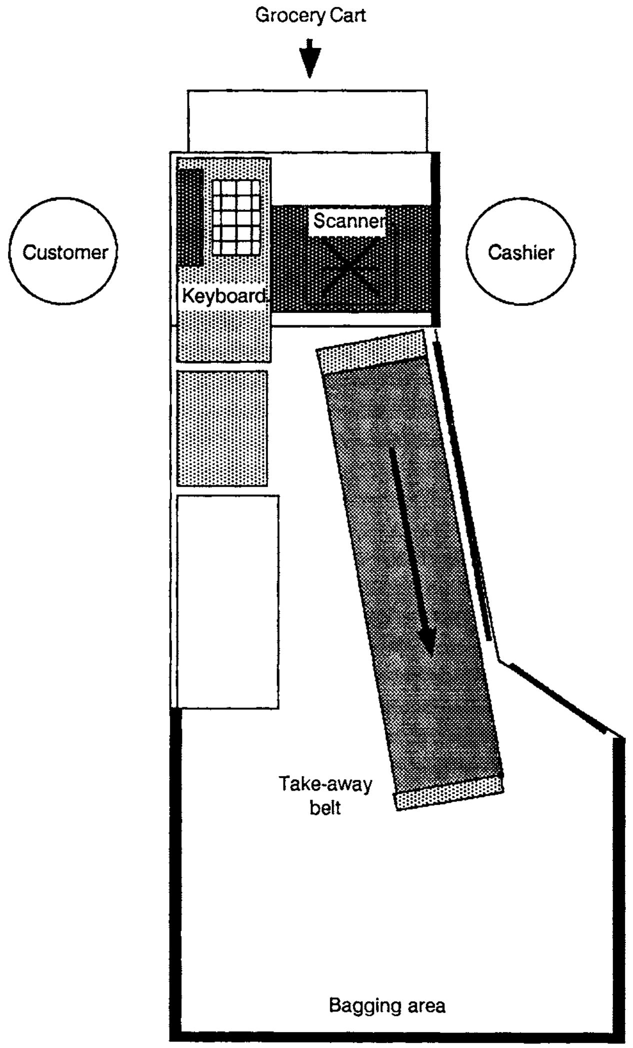

FIGURE 4. Over-the-counter checkstand.

Expert 1 has conducted detailed biomechanical studies of wrist and trunk motion among grocery cashiers using various checkstand designs.

Expert 2 has performed ergonomic evaluations in a variety of industries and has authored several papers describing risk factors for musculoskeletal disorders.

Expert 3 is an experienced work physiologist and author of a well-known series of textbooks on ergonomic design.

Expert 4 has performed laboratory studies of checkstand/ scanner designs using psychophysical evaluation methods.

Expert 5 has developed new checkstand designs and implemented changes to existing models in a large supermarket chain in the Northeast.

Expert 6 is the national occupational safety and health director of a union representing cashiers and other workers in the retail food industry.

To facilitate discussion, the experts were asked to rate the biomechanical stress placed on eight specific body areas by the checkstand features during different work activities. A 5-point Likert-type rating scale (1 = insignificant stress, 5 = high stress) was used.[9] These body areas were the neck, the shoulders (left and right), the elbows (left and right), the hand/wrist complex (left and right), and the lower back.

A modification of the Delphi technique was used to arrive at consensus opinions and to identify the design elements that presented the most and least stress to the targeted body parts.[10] After panel members were provided an opportunity to review the data and record their ratings independently, the experts were convened to discuss the criteria used in their analyses and the rationale for their evaluations. The experts were allowed to change their ratings during the discussion. The discussion was recorded, and prediscussion and postdiscussion ratings were provided to NIOSH investigators for evaluation. Nonparametric test procedures (the Friedman test and the Chi-square test for differences in probabilities) were applied to the rating data to identify differences between checkstand types.[11]

Results

Ratings collected from the experts prior to the discussion indicated good consensus among experts about the desirability of certain checkstand features from the standpoint of minimizing biomechanical stress. Discussions between experts also indicated agreement concerning the criteria that should be used to evaluate checkstand design for musculoskeletal stressors. The ratings and the opinions expressed by the experts lead to several preliminary conclusions and recommendations which are described below.

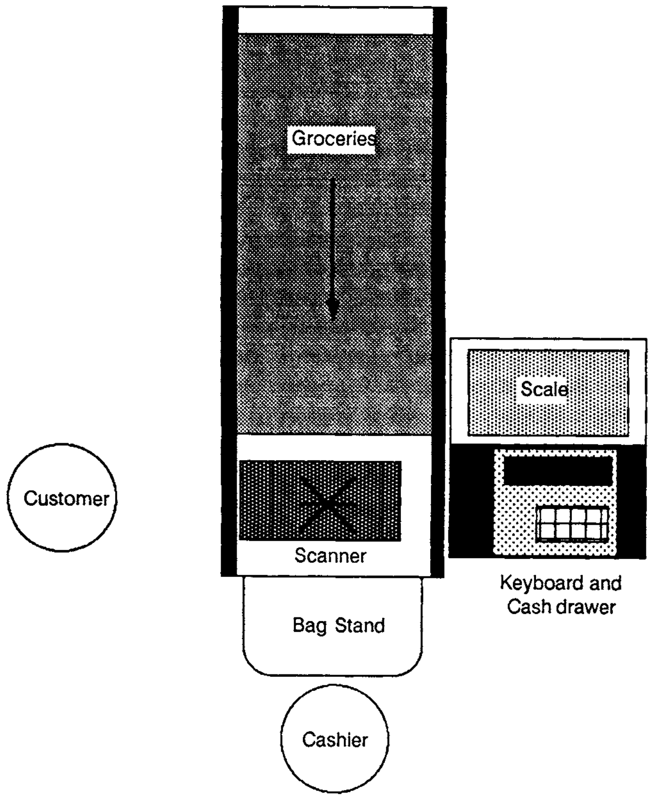

FIGURE 5. Over-the-end checkstand.

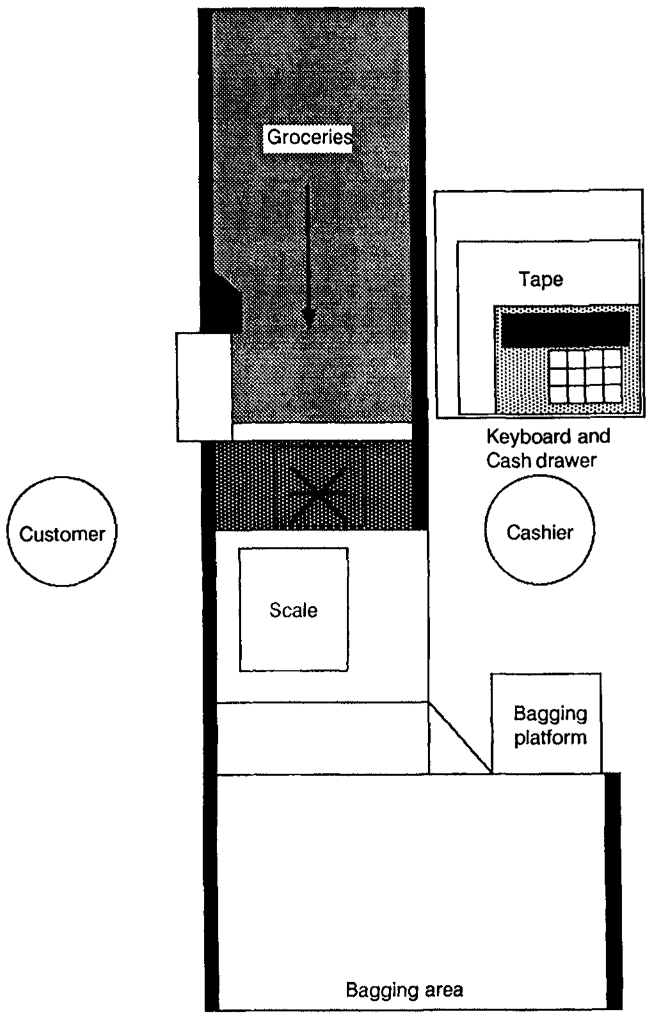

FIGURE 6. Side-facing checkstand with no take-away conveyor belt.

According to data provided by NCR, scanning and tendering tasks occupy the greatest percentage of the cashier's time.[12] Therefore, experts agreed that checkstand components used in the execution of these tasks are most critical in determining the overall stress presented to the cashier by the checkstand design. For this reason, the front checkstand configuration was selected nearly unanimously as the type that presented the least biomechanical stress to the cashier (Tables III and IV). Because the scanner and keyboard are located directly in front of the cashier, most panelists felt that the front design provided the best potential for minimizing reach and potential muscle fatigue during scanning and key entry tasks.

Although not expressly indicated in the ratings, experts voiced a preference for designs that allow symmetric distribution of stresses, or load-sharing by several muscle groups, over designs that concentrate stress on one side or area of the body. For example, checkstands that allow the checker to use both hands for scanning and bagging groceries were judged superior to designs in which one hand is used principally for scanning. The OTE design was judged favorably by the panel *on this point,* since this design allows the checker to stand in front of the scanner and pick up grocery items with both hands. In contrast, the experts criticized the right hand take-away design because this design forces the cashier to adopt a specific movement pattern during scanning. The RHT design forces cashiers to reach forward with the left hand to scan groceries, while using the right hand to transfer items to the take-away belt (backward reach).

Checkstands that provide groceries to the cashier on an input belt were preferred to checkstands that require the cashier to unload groceries from a cart (OTC checkstands). According to the experts, the OTC checkstands put greater stress on the cashier's shoulders and back, since the design causes cashiers to lift, rather than slide, groceries across the scanner (see Table V). Problems associated with OTC checkstands include the following: (1) The cashier must make long reaches to retrieve items from the back of the grocery cart; (2) Lifts are often required to retrieve large or heavy items (e.g., detergent boxes, cases of soft drinks) from the bottom of the grocery cart; and (3) Asymmetric push/pull forces are sometimes required to align carts with the end of the checkstand. A study by Herrin[13] has since shown that the force required to reposition a moderately loaded grocery cart can result in excessive shoulder and elbow loading.

In discussions, experts identified the height of the scanner as a critical design feature that influences the stress on the lower back and shoulders during the scanning task. Scanners that are "too high" can cause fatiguing static shoulder abduction. Scanners that are "too low" may require the cashier to bend over for prolonged periods of time, putting stress on the lower back. Among the checkstands included in this evaluation, scanner height ranged from 28 to 36 inches above the floor. A scanner height 31 to 34 inches above the floor was judged to be most desirable.

The distance between the scanner and the input and take-away conveyor belts was identified by the experts as a factor that influences the reach required during scanning

TABLE II. Standard Cart Items

Small can (10.5-oz soup)
Small can (10-oz vegetable)
Small can (12-oz frozen juice)
Large can (46-oz juice)
Small box (16-oz spaghetti)
Small box (10-oz frozen vegetable)
Large box (15-oz cereal)
Small glass jar (18-oz jelly)
Large glass jar (30-oz sauce)
Small flexible (16-oz candy)
Large flexible (20-oz bread)
Large flexible (paper towels, single roll)
Meat (1.5-lb ground beef)
Bag (4 pears)
Six pack (soda)
Large bottle (2-L soda)
Small, irregular (bunch bananas)
Large, irregular (1-gal milk)
Large, irregular (diapers, 40 pack)

TABLE III. Expert Ratings: Biomechanical Stress During Scanning*

Checkstand	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Sum of Ranks
Front	20.8 (1)	17.5 (1)	23 (2.5)	18.8 (1)	19 (1)	11.3 (1)	7.5^{A}
Side	30 (3)	22 (2)	22.5 (1)	23.5 (3)	25.5 (3.5)	19.5 (2)	14.5^{B}
OTC	28.3 (2)	25 (3)	25.3 (4)	25 (4)	25.3 (2)	21.7 (3)	$18^{B,C}$
RHT	33.5 (4)	29 (4)	25.5 (5)	21.5 (2)	25.5 (3.5)	31.5 (5)	$23.5^{C,D}$
OTE	36 (5)	34 (5)	23 (2.5)	35 (5)	28 (5)	22 (4)	26.5^{D}

*Rating value is equal to the average "whole-body" stress score (sum of eight body-part scores) associated with each checkstand type (all scores based on prediscussion rating values).
Numbers in parentheses represent rank relative to other checkstand types (1 = least stress, 5 = most stress).
Test for rating differences between checkstands:
Friedman's test statistic (T) = 15.25, $0.001 < p < 0.005$.
Checkstand types are significantly different if sum of ranks differ by > 7.49 (indicated by different superscript letters).
OTC = Over-the-counter; RHT = right hand take-away; OTE = over-the-end.

tasks. According to the experts, the input conveyor should bring grocery items directly to the edge of the scanner. Similarly, the take-away conveyor should begin directly after the scanner, and extend to the back edge of the bagging platform. An example of a checkstand that incorporates these features is shown in Figure 2. According to the experts, checkstands that lack take-away conveyor belts (Figure 6) force operators to push items into the bagging area as they accumulate. A poorly placed conveyor can also cause longer reaches during bagging.

Similarly, experts indicated that the width of the input conveyor belt should be minimized to reduce the cashier's reach to items on the far side of the belt. The use of a "diversion" bar to direct groceries on the conveyor closer to the cashier for pickup was considered a good design feature. This feature is illustrated in Figure 2. NIOSH investigators have previously noted that using barriers to reduce reach distance has been shown effective in reducing discomfort among grocery express checkstand workers.[14]

Scanner designs that allow the cashier to slide items easily across the scanner were judged superior to designs that require operators to pick up and lift grocery items across the scanner (Table VI). The scanners that allow "sliding" require fewer gripping postures and less manual force application than scanners which do not. Frequent and highly forceful hand exertions have been linked to the development of tendinitis, tenosynovitis, and carpal tunnel syndrome.[15] The experts noted that one disadvantage of the vertical beam scanner/scale with the "starburst" cover (Figures 1, 3, 5, and 6) is that items must be lifted across the scanner. The horizontal beam scanner/scale (Figures 2 and 4) not only allows the cashier to easily move items through the beam, but also avoids contact between the scanner and the grocery item. Frequent contact between grocery items and the scanner can smudge or damage the scanner glass, resulting in increased "rescan" rates.

Checkstands that incorporate a combined scanner/scale were judged superior to checkstands where the scanner and scale exist as separate components (Tables VII and VIII). According to experts, these designs are less likely to require extended reaches and lifts during weighing tasks, reducing the risk of back and shoulder strain.

Checkstands that provide an easily accessible bag stand at a height 13 to 17 inches lower than the top surface of the checkstand (approximately 20 inches above the floor) were preferred. The experts agreed that lifting groceries into a paper bag positioned on top of the checkstand (top of bag is 45 to 53 inches above floor) is stressful to the shoulders and elbows (Tables IX and X). Although none of the checkstands included in the evaluation incorporated this feature, experts also agreed that a height-adjustable bag stand would be desirable.

Finally, experts agreed that the location of the bag stand should not increase the reach distance to the checkstand. A

TABLE IV. Expert Ratings: Biomechanical Stress During Tendering*

Checkstand	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Sum of Ranks
Front	20 (2.5)	11.3 (1)	12.7 (1)	12.3 (2)	17 (2)	19.3 (2)	10.5^{A}
Side	19.3 (1)	12.8 (2)	14.5 (2)	11 (1)	13.8 (1)	18.5 (1)	8^{A}
OTC	28.3 (4)	16.3 (3)	21.7 (4)	14.3 (3)	20.3 (4)	19.7 (3)	22^{B}
RHT	20 (2.5)	14 (4)	18 (3)	15 (4)	20 (3)	21.5 (4)	19.5^{B}
OTE	NR	NR	NR	NR	NR	NR	

*Rating value is equal to the average "whole-body" stress score (sum of eight body-part scores) associated with each checkstand type (all scores based on prediscussion rating values).
Numbers in parentheses represent rank relative to other checkstand types (1 = least stress, 4 = most stress).
Test for rating differences between checkstands:
Friedman's test statistic (T) = 14.1, $0.001 < p < 0.005$.
Checkstand types are significantly different if sum of ranks differ by > 4.82 (indicated by different superscript letters).
NR = OTE checkstand was not rated by the experts.
See Table III for abbreviations.

TABLE V. Expert Ratings: Back Stress During Scanning*

Checkstand	Rating Values 1-2	3	4-5	Totals
Front	13	10	0	23[A]
Side	4	7	7	18
OTC	0	2	16	18
RHT	0	3	9	12
OTE	0	2	4	6

*Chi-square test for differences in ratings between checkstand types: $\chi^2_{(8)} = 45.2$, $p < 0.001$.
[A]One reviewer did not provide a rating for checkstand L.
Abbreviations as in Table III.

TABLE VI. Expert Ratings: Hand/Wrist Stress During Scanning*

Scanner Type	Rating Values 1-2	3	4-5	Totals
Horizontal Beam[A]	19	4	1	24
Vertical Beam[B]	23	20	5	48

*Chi-square test for differences in ratings between checkstand types: $\chi^2_{(2)} = 6.43$, $p < 0.05$. Controlled for checkstand type (front and OTC only)
[A]Checkstands C and L.
[B]Checkstands A, D, F, and K.

TABLE VII. Expert Ratings: Back Stress During Weighing*

Scale Type	Rating Values 1-2	3	4-5	Totals
Separate scale[A]	16	2	12	30
Combined scanner/scale[B]	25	1	3	29[C]

*Chi-square test for differences in ratings between checkstand types: $\chi^2_{(2)} = 7.69$, $p < 0.025$.
[A]Checkstands D, E, M, I, and G.
[B]Checkstands B, C, J, K, and L.
[C]One rater did not provide a rating for checkstand C.

TABLE VIII. Expert Ratings: Right Shoulder Stress During Weighing*

Scale Type	Rating Values 1-2	3	4-5	Totals
Separate scale[A]	9	1	19	29[C]
Combined scanner/scale[B]	23	7	0	30

*Chi-square test for differences in rating distributions between checkstand types: $\chi^2_{(2)} = 29.69$, $p < 0.001$.
[A]Checkstands D, E, M, I, and G.
[B]Checkstands B, C, J, K, and L.
[C]One rater did not provide a rating for checkstand M.

TABLE IX. Expert Ratings: Right Shoulder Stress During Bagging*

Location of Bag	Rating Values 1-2	3	4-5	Totals
Countertop[A]	2	2	25	29[C]
Bagging platform[B]	9	11	12	32[D]

*Chi-square test for differences in rating distributions between checkstand types: $\chi^2_{(2)} = 19.6$, $p < 0.001$.
[A]Checkstands A, B, C, D, and G.
[B]Checkstands E, H, I, K, L, and M.
[C]One rater did not provide a rating for checkstand G.
[D]One rater did not provide a rating for checkstand H. One rater did not provide a rating for checkstand K or M. One rater did not provide a rating for checkstand K.

TABLE X. Expert Ratings: Right Elbow Stress During Bagging*

Location of Bag	Rating Values 1-2	3	4-5	Totals
Countertop[A]	3	9	17	29[C]
Bagging platform[B]	8	13	11	32[D]

*Chi-square test for differences in rating distributions between checkstand types: $\chi^2_{(2)} = 6.83$, $p < 0.05$.
[A]Checkstands A, B, C, D, and G.
[B]Checkstands E, H, I, K, L, and M.
[C]One rater did not provide a rating for checkstand G.
[D]One rater did not provide a rating for checkstand H. One rater did not provide a rating for checkstand K or M. One rater did not provide a rating for checkstand K.

disadvantage of the OTE checkstand is that the bag stand is positioned between the cashier and the groceries/scanner. The location of the bag stand increases the reach required to retrieve groceries from the input conveyor, putting additional stress on the cashier's back, shoulders, and elbows. Experts also found this to be a problem with bag stands located in areas adjacent to the scanner (see Figure 6). Bag stands that allow cashiers to stand to one side of the bag (often located in the back of the checkstand) were preferred.

Discussion

The criteria suggested by the expert panel for evaluating checkstand design are consistent with basic biomechanical principles and previous research which suggest that workstations resulting in awkward postures, long reaches, and frequent lifts are more stressful to the musculoskeletal system than those that do not.[16] However, empirical evidence is limited to indicate that different checkstands actually expose cashiers to significantly different levels of biomechanical stress. Further research is also needed to characterize the relationship between checkstand design and patterns of musculoskeletal disease in grocery checkers.

Follow-up studies are planned to examine these issues. Based on the ratings of the expert panel, certain checkstand configurations and cashier groups will be selected for future ergonomic and epidemiologic investigations. The purpose of ergonomic studies will be to quantify exposures to ergonomic stressors associated with different checkstand designs. Epidemiologic investigations will evaluate the relationship between checkstand design and musculoskeletal disorders in cashiers. In both studies, workers using checkstands with highly rated components will be compared to workers using checkstands with lower rated features. Hopefully, these studies will lead to the identification and development of intervention strategies to reduce the incidence of work related musculoskeletal disorders in the retail food industry.

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Disclaimer

All references to preferred design characteristics represent the opinion of outside experts and not necessarily those of the National Institute for Occupational Safety and Health.

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