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An analysis of scanning postures among grocery cashiers and its relationship to checkstand design

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Mounting evidence suggests that musculoskeletal disorders are prevalent among US retail food workers. Cashiers who use electronic scanners appear to be at especially high risk for upper extremity musculoskeletal disorders. Checkstand design has been implicated as a contributor to musculoskeletal injury among cashiers because workstation design can significantly impact working posture. The present study examines working posture among two groups of cashiers to determine if checkstand design is associated with substantial differences in posture and movement during scanning. The work activities of twenty grocery cashiers using one of two checkstand designs (front-facing and right-hand takeaway) were examined. Videotapes of cashiers performing scanning tasks were observed and associated postures and movements were visually coded. The right-hand takeaway design was associated with a significantly higher percentage of non-neutral trunk postures than the front-facing design. However, there were no significant differences in shoulder posture, grasp, or scanning motion associated with checkstand/scanner design. Factors that appeared to affect cashier work posture during scanning included stature, order size, and product type. Although improving the checkstand design may reduce the occurrence of certain awkward postures and static muscle loading conditions among cashiers, the success of these interventions is likely to be limited unless follow-up programmes are instituted to ensure that cashiers are able to use these designs effectively. Furthermore, fundamental changes in cashier work may be required to fully eliminate hazards for musculoskeletal disorders from this job.

Introduction

An association between stressful working postures and the development of musculoskeletal disorders in the trunk and upper extremities is widely acknowledged in the ergonomic literature. It is well established that postures that overload muscles and tendons, load joints in an uneven manner, or require prolonged static muscle contraction can result in transient fatigue and discomfort (Corlett and Bishop 1976, van Wely 1970). More recently, Westgaard *et al.* (1986) linked repeated exposures to low levels of static muscle load, combined with moderate flexion or extension of the joints, to considerable levels of lost work time. There is also evidence that a dose-response relationship may exist between non-neutral arm and shoulder postures, and the development of soft-tissue disorders in industrial workers (Hagberg 1984, Kilbom *et al.* 1986, Aaras *et al.* 1988).

In recent years, musculoskeletal disorders among grocery cashiers have received increasing attention within the retail food industry. Various authors indicate that 37-56% of grocery cashiers experience regular pain in the back or upper extremities (Buckle *et al.* 1986, Margolis and Kraus 1987, Ryan 1989, Baron *et al.* 1991). Although the aetiology of musculoskeletal disorders is complex and not completely understood, the following

work-related factors may contribute to an increased rate of musculoskeletal complaints among cashiers:

- complex and repetitive hand and arm movements (Harber *et al.* 1992);
- static working postures (Ohara *et al.* 1976, Elias *et al.* 1981);
- high working speeds (Lannersten and Harms-Ringdahl 1990);
- boredom and job dissatisfaction (Wilson and Grey 1984).

According to several studies, complaints among grocery cashiers have increased dramatically since the introduction of the laser scanning workstation on a mass scale (Wicksell and Gorne 1986, Margolis and Kraus 1987, Baron *et al.* 1991). These same studies indicate that cashiers who use laser scanners may be at increased risk for upper extremity musculoskeletal disorders. Although the grocery cashier's job encompasses several tasks (tendering money, bagging, etc.), scanning occupies approximately 40% of the cashier's work time (Hoffman and Cramer 1987). There is some agreement that checkstand components that are used during scanning (e.g. the scanner and scale) can significantly influence the cashier's workload (Grant *et al.* 1993). Therefore, initial efforts to address ergonomic hazards in the retail food industry have focused on identifying deficiencies in the design of the scanner and the supermarket checkstand. Several researchers have recommended improvements in the design of the checkstand. Some of these recommendations are listed in figure 1.

In 1991, the National Institute for Occupational Safety and Health (NOSH) initiated an industry-wide study to evaluate the prevalence and possible causes of musculoskeletal disorders among retail food workers. A proposed objective of this research is to evaluate the relationship between work-related musculoskeletal disorders (WMDs) and different checkstand designs. As reported by Grant *et al.* (1993), an 'expert panel' was convened to evaluate the biomechanical stress associated with thirteen common checkstand configurations found in the USA. The panel members agreed that certain checkstand features are more likely to impose substantial biomechanical stresses on cashiers than others. Specifically, the 'front-facing' checkstand with a vertical (mount)

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- Work surface height should be at or just below elbow height (van der Doelen and MacDonald 1985).
 - The cashier should face the customer (Rodrigues 1989).
 - The flow of groceries across the scanner should be parallel to the cashier's shoulders to reduce wrist deviation. The design should allow use of both hands during scanning (Stoffman *et al.* 1986, Rodrigues 1989, Grant *et al.* 1993).
 - Groceries should be presented to the cashier on a conveyor. Conveyors should extend from the scanner to the back of the checkstand (Rodrigues 1989, Grant *et al.* 1993).
 - Conveyor width should be minimized to reduce reach (Grant *et al.* 1993).
 - The scanner and scale should be located in front of the cashier. The scale should be flush mount with the conveyor (Rodrigues 1989, Baron *et al.* 1991, Grant *et al.* 1993).
 - The keyboard should be located in front of the cashier, above the scanner. Keyboard height should be adjustable (Baron *et al.* 1991).
 - The cash drawer should be located to the side of the cashier, no more than 18 in away (Stoffman *et al.* 1986, Baron *et al.* 1991).
 - The checkstand should provide the cashier with an opportunity to sit or stand (Elias *et al.* 1981, Stoffman *et al.* 1986, Margolis and Kraus 1987, Ryan 1989, Baron *et al.* 1991). Foot rests and anti-fatigue mats should be provided (Wells *et al.* 1990).
 - Tops of bags should be flush with the checkstand surface. Adjustable bagging platforms should be provided (Schmidt *et al.* 1988, Wells *et al.* 1990, Grant *et al.* 1993).
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Figure 1. Recommendations for checkstand design.

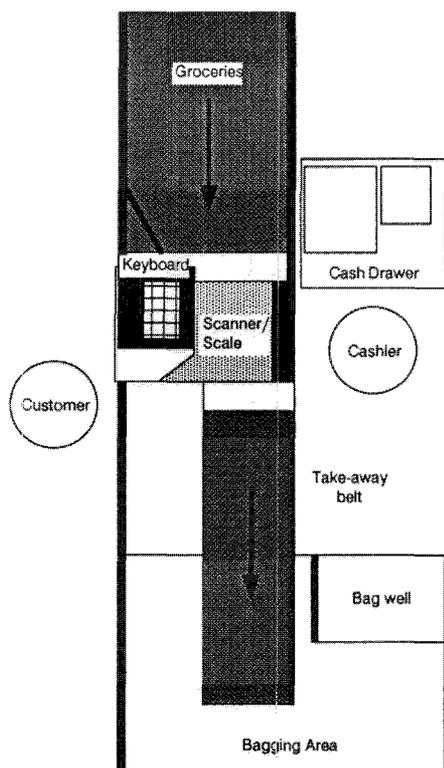


Figure 2. Front-facing checkstand design. Scale 0.75 ft to 1 inch.

scanner/scale was favoured by most panellists as the 'best' design for minimizing postural stress during scanning tasks (figure 2). In the front-facing design, frequently used equipment, such as the scanner, scale, and keyboard, is located directly in front of the cashier. According to the panel members, the vertical scanner allows the cashier to push or drag items across the scanner with fewer gripping postures and less manual force application than horizontal scanner designs. The right-hand takeaway design was identified by panellists as an example of a less optimal design (figure 3). Panel members agreed that the location of the scanner (between the cashier and the grocery items on a conveyor belt) promotes excessive bending and reaching during scanning. The horizontal scanner (particularly those designed with a cover over the scanner glass) also encourages the cashier to lift items across the scanner, thereby increasing manual force demands during scanning.

None the less, there is little empirical evidence to suggest that different checkstands *actually* impose different levels of biomechanical stress on cashiers. Further investigations are needed because there is substantial interest in this topic among retailers and labour representatives. This paper describes the results of a study of scanning postures among grocery store cashiers using two different checkstand designs. The objective of this study was to determine if hypothesized improvements in checkstand design effectively reduce cashiers' exposures to biomechanical stresses during grocery scanning tasks.

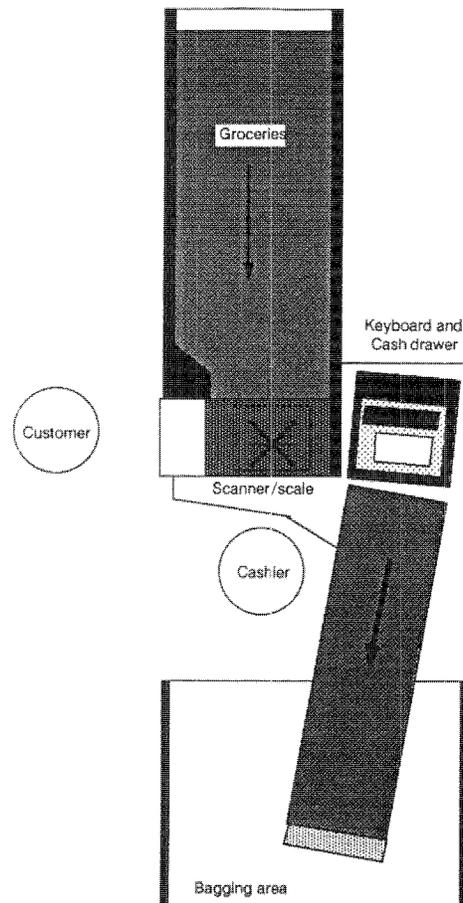


Figure 3. Right-hand takeaway checkstand design. Scale 0.75 ft to 1 inch.

2. Methods

2.1. Subjects

Data for this evaluation was collected at four medium-sized retail supermarkets (8–12 lanes), located in the North-east or Mid-west USA. Two stores employed the front checkstand with a vertical scanner/scale, while the other two stores used a right-hand takeaway checkstand with a horizontal scanner/scale.

Twenty cashiers (ten cashiers working at each type of checkstand) were selected for inclusion in this study. All cashiers were right-handed and had a minimum of six months' experience working as a grocery store cashier. Cashiers ranged in age from 17 years to approximately 50 years. As near as possible, groups were matched in terms of age and gender (eight women, two men in the front-facing group, six women and four men in the right-hand takeaway group).

2.2. Work sampling

Site visits to each of the four stores were conducted on a Friday, between the hours of 09:00 and 19:00, during the months of July–September. After giving voluntary consent to participate in the study, cashiers were told that they would be observed and videotaped

periodically throughout the workday. The investigators made no attempts to interfere with the work habits of the cashier or the actions of the customers.

It was hypothesized that cashier work style might be influenced by fatigue, customer demands, level of store activity, etc. hence cashiers were videotaped once every hour for 15 min for the duration of their workshift (generally 3–6 h). Depending on the length of the workshift, 45–90 min of videotape was collected for each cashier. The number of items scanned by each cashier during each 15 min period ranged from 48 to 199 (mean = 107.3). To minimize parallax errors, the cashier's work postures were recorded from positions perpendicular to the frontal and sagittal planes, at a distance of approximately 4 m. The videotapes were reviewed by trained observers in analyses described below.

2.3. Posture classification system

Numerous investigators have suggested ways to classify upper extremity and trunk postures during work tasks (Corlett *et al.* 1979, Armstrong *et al.* 1982, Keyserling 1986, Kilbom and Persson 1987, Stetson *et al.* 1991, Harber *et al.* 1992). Based on existing methods, an observational system for the analysis of upper extremity and trunk postures during grocery scanning activities was developed. The system focused on scanning postures that are likely to be affected by checkstand design, and which can be accurately identified through observation. Descriptions of the postures, the rationale for evaluation, and decision rules for coding are provided below.

2.3.1. *Initial reach*: The location of key components (scanner, keyboard, conveyor belts, etc.) can affect the reach required by the cashier to retrieve items for scanning. A realistic goal in workstation design is to enable a working posture in which the elbows are not elevated above mid-torso height and the shoulders are neither flexed nor abducted $> 60^\circ$ (Armstrong *et al.* 1986). Similarly, the workstation layout should allow the trunk to be maintained in an upright, neutral posture, neither flexed, bent nor twisted by $> 20^\circ$ (Keyserling 1986).

In this study, the cashier's posture was evaluated at the instant that the cashier's hand made initial contact with each grocery item. Observers noted each of the following:

- Hand used to grasp each item (left, right or both).
- Elbow extension—coded 'yes' if the elbow was fully extended (0°) at the time of initial grasp (figure 4(a)).
- Shoulder abduction/flexion—coded 'yes' if the shoulder was flexed or abducted more than 60° at the time of initial grasp (figure 4(a) and (b)).
- Trunk posture—coded 'yes' if flexed $> 20^\circ$ at the time of initial contact with the grocery item (figure 4(c)).

2.3.2. *Grasp*: Pinch grips have long been associated with an increased load on the finger flexor tendons (Armstrong *et al.* 1982). The grasp used by the cashier to pick up each grocery item was coded as either a pinch grip or power grip. Grasp was coded as a pinch grip if the object was held between the fingers and the thumb with no contact between the object and the base of the thumb or palm (Eastman Kodak 1983). Grasp was coded as a power grip if the object was held pressed against the palm, allowing use of the aggregate power of the hand and arm during handling.

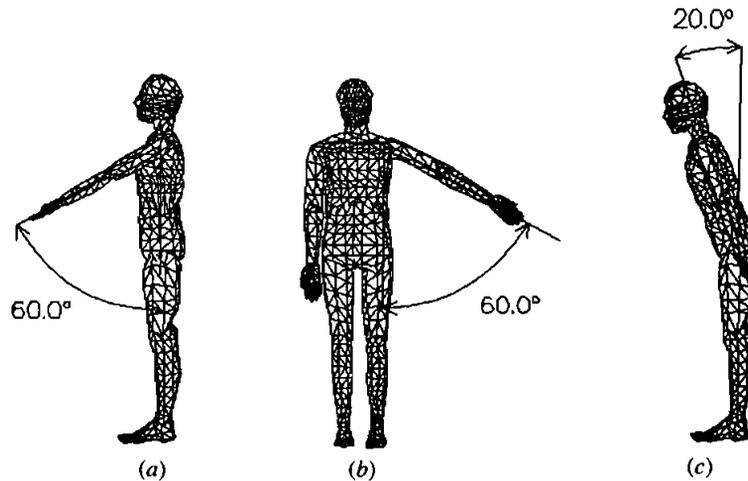


Figure 4. Postures coded during analysis of scanning tasks: (a) shoulder flexion with elbow extension; (b) shoulder abduction; and (c) trunk flexion.

2.3.3. *Motion across scanner*: A perceived advantage of the vertical mount scanner/scale is that the cashier is able to slide rather than lift items across the scanner, thereby avoiding forceful exertions with the hands and fingers (Anon, 1988, Grant *et al.* 1993). For each item, the rater noted whether the object was 'lifted' across the scanner, with the full weight supported by the arm, or 'dragged' across the scanning surface (Harber *et al.* 1992). A third category 'half lift/half drag' was defined for instances where the cashier lifted the object to the scanner, but then dragged it across the surface of the scanner to the adjoining conveyor, or vice versa.

2.4. Data analysis

Videotape segments were reviewed by the investigators, and the motions and postures used by the cashier to scan grocery items during each segment were visually coded. Each cashier was observed scanning a minimum of 220 items (mean = 274). According to Barnes (1980), 'if workers perform a specific activity (i.e. assume a given posture or use a specific motion pattern) at least 20% of the time, at least 220 observations are needed to allow investigators to quantitatively estimate the frequency of occurrence with 95% confidence and a relative accuracy of $\pm 25\%$ '. Coding was performed principally by one investigator (K.G.); however, 25% of the tape was reanalysed independently by a second investigator (blind to the study hypothesis) to ensure that rater bias toward a particular checkstand design did not affect the results. In addition, the principal rater reanalysed several segments of tape 2–3 months after the original analysis was completed. The ratings from the two analyses were compared to determine if rating stability was maintained across repeated observations.

The relative frequency (percentage score) of each motion and posture was calculated for each cashier, using the total number of items scanned as the denominator. Mean percentages of awkward postures and grasping/scanning motions were calculated for each checkstand group. To obtain homogeneity of variance, arc sine transformations were applied to the data (Myers 1979). Hotelling's T^2 test was used to determine if statistically significant differences existed between checkstands when percentages of awkward postures and scanning motions were compared simultaneously. *Post hoc t*-tests were performed to identify which of the dependent variables showed significant differences between the checkstand groups. All computations were performed using SAS Release 6.04 (1988).

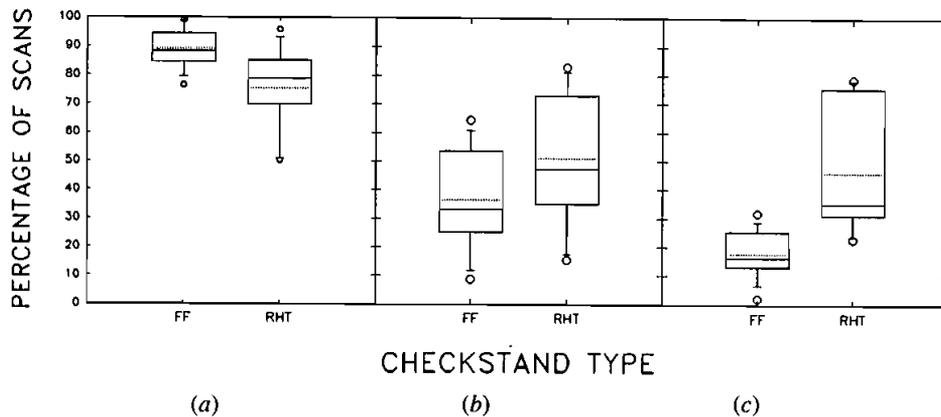


Figure 5. Percentages of (a) scans involving transfer of items between hands, (b) awkward shoulder postures during scanning, and (c) awkward trunk postures during scanning bottom and top edges of each box represent sample 25th and 75th percentiles. The solid horizontal line in the middle box represents the sample median; the dashed horizontal line represents the sample mean. Vertical lines extend to the sample 5th and 95th percentiles. Circles represent extreme values of the sample. FF, front-facing checkstand; and RHT, right-hand takeaway checkstand.

3. Results

Multivariate analysis (Hotelling's T^2 test) indicated that the two groups of cashiers (front-facing and right-hand takeaway) differ significantly in their postures and motion patterns during grocery scanning, $F(8, 11) = 130.05$, $p < 0.001$. Differences between groups in reaching and scanning motions, and shoulder, trunk and grasping postures are described below.

3.1. Initial reach

Checkstand design had a large influence on both initial reach and the motion pattern used for scanning. Cashiers using the front-facing checkstand almost always used the right hand to reach for and grasp grocery items for scanning (mean relative frequency = 97.4%), whereas cashiers using the right-hand takeaway generally used the left hand to reach for grocery items (mean relative frequency = 89.7%). All cashiers tended to transfer items from one hand to the other during the scan (mean relative frequency = 75.6% for right-hand takeaway users and 89.2% for front-facing users; figure 5 (a); however, as these percentages indicate, cashiers using the right-hand takeaway design were significantly more likely to use only one hand during the scan, $t(18) = 2.62$, $p = 0.017$. This occurred because the right-hand takeaway design allows users to adopt a 'swimming motion' while scanning, i.e. to alternately reach forward with the right and left hands to grasp and scan items in rapid succession. Although this method reduces scanning time, Marras *et al.* (1991) suggest that one-handed scans may result in higher wrist accelerations and finger tendon forces.

3.2. Shoulder posture

The relative frequencies of awkward shoulder postures (flexions or abductions of 60° or more during initial reach) associated with each checkstand design are shown in figure 5 (b).

Although the percentage of awkward shoulder postures observed among cashiers using the front-facing checkstand (mean frequency = 34.8%) was smaller than the percentage observed among cashiers using the right-hand takeaway design (mean relative frequency = 51.1%), the difference between checkstand groups was not statistically significant

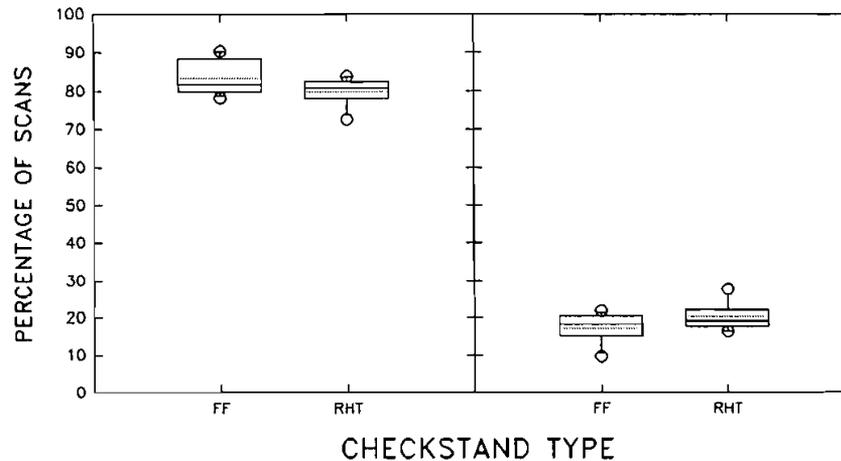


Figure 6. Percentages of pinch (left) and power (right) grasp use. FF, front-facing checkstand; and RHT, right-hand takeaway checkstand.

($t(18) = 1.53$, $p = 0.133$). The relative frequency of awkward shoulder postures varied widely among cashiers. The percentage of scans involving awkward shoulder postures ranged from 8.7 to 64.5% among cashiers using the front-facing checkstand, and from 15.6 to 83.0% among cashiers using the right-hand takeaway design.

3.3. Trunk posture

The relative frequencies of awkward trunk postures associated with front-facing and right-hand takeaway checkstands are shown in figure 5(c).

As predicted by the expert panel (Grant *et al.* 1993), the right-hand takeaway design was associated with a substantially larger proportion of awkward trunk postures than the front-facing checkstand design (mean frequency = 46.3 versus 17.7%). A *T*-test indicated that the difference in frequency of awkward trunk postures between the two groups of cashiers was statistically significant ($t(18) = 3.85$, $p = 0.001$). As indicated by the box plot, there was also substantial variation in the frequency of awkward trunk postures among cashiers using the right-hand takeaway design. Observed percentages of awkward trunk postures ranged from 23.0 to 78.0% among cashiers using this design.

3.4. Grasp

The relative frequencies of grasp types used by cashiers during scanning are shown in figure 6.

Grasp type was unaffected by checkstand/scanner design. The mean relative frequency of pinch grips among front-facing checkstand users was 82.9 compared with 79.8% for right-hand takeaway users ($t(18) = 1.80$, $p = 0.089$). Pinch grips were used three to four times more often than power grips. Deviations from the mean within groups were small.

3.5. Motion across scanner

The relative frequencies of scanning motions (drag versus lift) associated with each checkstand design are shown in figure 7.

The proportion of 'drags' was slightly greater among cashiers using the vertical scanner/front-facing design (22.6 versus 12.4%); however, the difference between this group and the horizontal scanner/right-hand takeaway group was not statistically significant

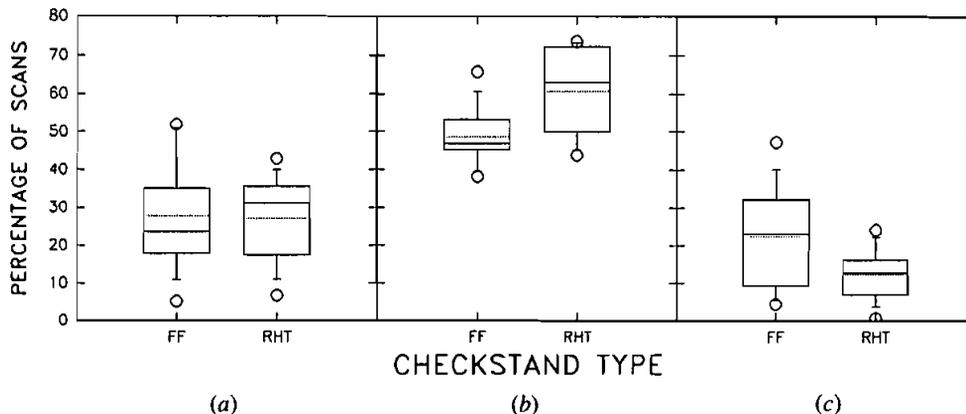


Figure 7. Percentages of motions used in scanning. (a) Lift; (b) half lift/half drag; and (c) drag. FF, front-facing checkstand; and RHT, right-hand takeaway checkstand.

($t(18) = 1.99, p = 0.062$). There was no difference in the frequency of lifts between groups ($t(18) = 0.05, p = 0.958$). In both groups, cashiers overwhelmingly tended to lift items at least once during the scan, accounting for the large proportion of lifts and half-lifts observed. This tendency was aggravated by large customer orders. As order size increased, the takeaway conveyor in both designs became less effective at clearing items away from the scanner, often forcing cashiers to lift items to a vacant spot at the back of the checkstand after they were scanned.

3.6. Intra- and inter-rater reliability

Analysis of intra and inter-rater reliability indicated good consistency in ratings of all postures, although agreement between raters varied somewhat with the posture being assessed. Raters were highly consistent in their codings of shoulder postures and motion patterns during scanning. Raters were less consistent in their codings of grasp type, which was more difficult to identify from the videotape. In some cases, the correlation coefficient was somewhat smaller than expected because observed frequencies varied little between checkers (e.g. use of pinch grip). Restrictions in the range of the observed variables

Table 1. Intra- and inter-rater variability by posture.

Posture	Intra-rater reliability coefficient†	Mean intra-rater CV†	Intra-rater reliability coefficient‡	Mean intra-rater CV‡
Right-hand grasp	0.999	0.036	0.999	0.067
Pinch grasp	0.399	0.075	0.508	0.268
Shoulder posture	0.832	0.085	0.888	0.089
Trunk posture	0.767	0.230	0.739	0.343
Elbow extension	0.950	0.147	0.948	0.107
Drag across scanner	0.972	0.216	0.849	0.270
Use of two hands during scan	0.970	0.032	0.594	0.066

† Based on ratings of four cashiers (repeated after a 2-month interval).

‡ Based on ratings of 10 cashiers (five/checkstand type).

CV, coefficient of variation.

generally result in a lower correlation than would be obtained if the range were not so restricted (Edwards 1976). Reliability coefficients of variation (CV) are listed in table 1.

In summary, because of the level of agreement, the presented data can be assumed to primarily reflect variations in work postures and methods, rather than random variations or bias introduced by the observer over time.

4. Discussion

This study represents a first attempt to examine the relationship between checkstand design and postural risk factors for musculoskeletal disorders among grocery cashiers *in a field setting*. Although a relatively small sample (ten cashiers/checkstand) was selected to represent the population of grocery cashiers using the front-facing and right-hand takeaway checkstand designs, the results of this study have several important implications.

First, the results indicate that the front-facing checkstand dramatically reduces the cashier's exposure to awkward trunk postures during scanning. Awkward trunk postures may pose a risk for low-back pain, which is reported to be a significant problem among grocery cashiers (Buckle *et al.* 1986, Ryan 1989, Ayoub 1990). Although cashiers are exposed to additional risk factors for back pain (e.g. prolonged standing and lifting), there is some evidence that redesigning checkstands to reduce trunk flexion can lessen musculoskeletal discomfort (Orgel *et al.* 1992).

Otherwise, there was little indication that checkstand/scanner design had a substantial effect on posture during grocery scanning tasks. Whereas experts predicted that the front-facing checkstand would reduce awkward reaching (Grant *et al.* 1993), in this study there were few observable differences in the shoulder postures of cashiers using the front-facing and right-hand takeaway designs. Similarly, there appeared to be little relationship between scanner design and the gripping postures/movement patterns observed during scanning. Factors that *did* appear to influence the cashier's work posture included the size and shape of grocery items and their order/manner of presentation to the cashier on the conveyor belt (factors not related to checkstand design). Cashiers tended to use pinch grips to handle small boxes, flexible plastic bags, and most cans—items that comprise approximately 75% of all scannable grocery products (Hoffman and Cramer 1987). Power grips were used to handle two-litre bottles, items with handles and some produce items. Cashiers also attempted to scan larger, more durable items first to prevent more delicate objects from being crushed during bagging. Therefore, cashiers were frequently observed reaching over items to the front of the conveyor belt. These practices mitigated many of the advantages of the front-facing layout.

Although the study did not set out to examine sources of variability within checkstand groups, it was obvious that individual differences among cashiers also played a major role in determining work posture. This observation underscores the difficulty in designing a single workstation to fit an entire population. Furthermore, it was hypothesized that prior experience in using a laser scanner may have influenced scanning motion. Early scanner designs were characterized by narrow 'read' zones (which required the cashier to carefully orient the UPC label) and horizontally-oriented scan windows that were easily damaged or scratched. Cashiers accustomed to using these models may have been more likely to lift items past the vertical scanner than novice cashiers with recent training in scanner use, although this hypothesis was not examined in this study. If this is true, it is possible that work posture could be improved if cashiers are provided with better training in work technique. Specifically, some of the benefits of the vertical scanner may be more fully realized if cashiers are instructed about the enhanced 'read' capabilities of the scanner and are taught to drag items past the scan area.

Importantly, awkward postures are only one of several ergonomic risk factors that may contribute to musculoskeletal disorders among cashiers. Repetitive handling of merchandise is a substantial source of physical stress to the cashier, wholly unrelated to checkstand design. Unfortunately, the retail food industry is currently moving in directions that will reduce overall transaction time, thereby increasing handling rates (Hoffman 1992). Even if the checkstand design permits the cashier to adopt the best possible working posture, it is not clear that musculoskeletal disorders will be avoided if workload is maintained at a high level (Orgel *et al.* 1992). Furthermore, the contribution of task and organizational factors such as work scheduling, lack of worker autonomy and feedback, stress of dealing with the public, etc., to the development of musculoskeletal disorders has been largely unexplored in the retail food industry. These components have been associated with musculoskeletal disorders in other industries, and they could play a role in the retail food industry as well (Wilson and Grey 1984, Linton and Kamwendo 1989, Hales *et al.* 1992). Unfortunately, these elements are often the most difficult aspect of the work environment to evaluate, and interventions aimed at reducing their influence on musculoskeletal disorder risk are a challenge to identify and implement.

In summary, the results of this study support expert opinion and indicate that the front-facing checkstand with vertical scanner does reduce the occurrence of awkward trunk postures among cashiers. However, checkstand design had very limited effects on the occurrence of awkward upper extremity postures examined in this study. This finding was unexpected, given that the checkstands examined in this study are thought to represent the ends of the spectrum in terms of sound ergonomic design. While retailers are encouraged to develop and implement workstations that will eliminate excessive reaching, stooping and bending, the success of these interventions is likely to be limited unless cashiers are provided with adequate training and follow-up programmes are instituted to ensure that cashiers are able to use these designs effectively. Furthermore, future efforts at managing musculoskeletal disorders in the retail food industry must certainly address a broader range of task-related and organizational issues (e.g. development of means that will eliminate manual scanning by cashiers). In the absence of these measures, it is believed that further refinements in checkstand design will have only marginal effects on the biomechanical stress associated with grocery checking tasks.

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