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Effects of sitting versus standing and scanner type on cashiers

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In the retail supermarket industry where cashiers perform repetitive, light manual material-handling tasks when scanning and handling products, reports of musculoskeletal disorders and discomfort are high. Ergonomics tradeoffs exist between sitting and standing postures, which are further confounded by the checkstand design and point-of-sale technology, such as the scanner. A laboratory experiment study was conducted to understand the effects of working position (sitting versus standing) and scanner type (bi-optic versus single window) on muscle activity, upper limb and spinal posture, and subjective preference of cashiers. Ten cashiers from a Dutch retailer participated in the study. Cashiers exhibited lower muscle activity in the neck and shoulders when standing and using a bi-optic scanner. Shoulder abduction was also less for standing conditions. In addition, all cashiers preferred using the bi-optic scanner with mixed preferences for sitting (n = 6) and standing (n = 4). Static loading of the muscles was relatively high compared with benchmarks, suggesting that during the task of scanning, cashiers may not have adequate recovery time to prevent fatigue. It is recommended that retailers integrate bi-optic scanners into standing checkstands to minimize postural stress, fatigue and discomfort in cashiers.

1. Introduction

Supermarket checkout work varies throughout the world. One major difference in such work is created by the workstation design and the average posture adopted while working. Checkstands in North America, Asia and Australia are typically designed to accommodate standing postures, whereas seated checkstands are the norm in many European countries and in South America. Despite differences in the average working posture of cashiers, no geographical area or checkstand design is exempt from reports of musculoskeletal disorders (MSD) or discomfort complaints.

The literature reports that MSD problems exist both in Europe among seated cashiers (Sällström and Schmidt 1984, Buckle 1987, Krueger *et al.* 1988, Hinnen *et al.* 1992) and in North America among standing cashiers (Margolis and Kraus 1987, Morgenstern and Kraus 1988, Ryan 1989, Wells *et al.* 1990, Baron *et al.* 1991, Harber *et al.* 1992, 1993, Osorio *et al.* 1994). Although comprehensive information

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on the severity and costs of MSD among cashiers globally does not exist, various government agencies do provide statistics on the prevalence of MSD associated with checkout work. The UK Health and Safety Executive (HSE 1996) reported that a percentage of cashiers who experienced work loss in 1 year was due to problems associated with the low back (32%), wrist (28%), neck (21%) and shoulder (21%). In the USA, the grocery industry is ranked fourth highest in number of cases of disorders associated with repeated trauma (BLS 1996).

Researchers suggest that the following occupational risks may contribute to MSD: shoulder load, static tension of the neck, shoulder, and arm muscles, highly repetitive contractions in the shoulder muscles, work at or above shoulder level, repetitive grasping, extreme deviations of the wrists, and repetitive lifting of loads (Bjelle *et al.* 1979, 1981, Luopajärvi *et al.* 1979, Hagberg and Wegman 1987). Grocery scanning is often described as a light and repetitive manual materials-handling (MMH) task because it involves exerting low force to move products repeatedly from one side of a checkout to the other. The largest component of a cashier's job, an average 45–50% of customer transaction time, is spent scanning or handling products (Lehman 1998).

For MMH tasks with light loads, the ergonomics literature discusses tradeoffs between standing and seated postures. Generally, the literature discourages a static work posture (either standing or sitting) and states that changes in work posture are important in reducing fatigue (Kroemer and Robinette 1969, Magora 1972). A standing posture provides a more stable condition for the low back by preserving the natural lordosis of the lumbar spine (Andersson 1979). Standing also allows for dynamic use of the arms and trunk, which is better for handling loads, and enables one to cover larger work areas because of the ability to move. On the other hand, sitting has been shown to be less energy consuming than standing and less stressful on the lower extremity joints (Grandjean 1988, Kroemer *et al.* 1994). However, the literature cites increased risk of low back pain in seated jobs (Kroemer and Robinette 1969, Magora 1972, Kroemer *et al.* 1994) and greater disc pressure for a seated than for a standing posture (Andersson *et al.* 1974). Work in a seated position can also require greater shoulder abduction, which causes more stress on the shoulder joints and shoulder/neck. Foot and leg swelling, reduced circulation, varicose veins, and lower extremity discomfort have been shown to occur in both standing and sitting occupations (Brand *et al.* 1988, Sadick 1992, Sisto *et al.* 1995) although leg and foot activity reduce swelling (oedema) and increase circulation (Winkel and Jorgensen 1986, Noddeland and Winkel 1988).

The literature offers numerous studies that compare ergonomic aspects of different checkstand configurations. Marras *et al.* (1993, 1994, 1995), Grant *et al.* (1993), Grant and Habes (1995) and Rodrigues (1989) assessed various checkstand designs by use of instrumentation to quantify joint dynamics, expert evaluation, posture estimation and heuristic analysis. These researchers recommended a front-facing design (i.e. where the equipment is located directly in front of the cashier) which promotes sharing of the load between right and left upper extremities and minimizes twisting, lifting, forward bending and the moment arm between the load and spine. Other researchers who have studied aspects of checkout work recommend general ergonomics principles such as reducing the reach distance, minimizing lifting, reducing the work surface thickness, and using footrests and adjustable chairs (Wells *et al.* 1990, Orgel *et al.* 1991, Strausser *et al.* 1991, Wilson and Grey 1994).

A few researchers have evaluated work posture in checkout work using a variety of biomechanical and physiological measures. Lannerstern and Harms-Ringdahl (1990) investigated differences between sitting and standing in checkout work by measuring the thoracic erector spinae, infraspinatus and trapezius muscle activity and found higher levels in the seated posture. They recommended allowing cashiers to alternate between sitting and standing positions. Unfortunately, the tasks in this study were simulated using a non-functional scanner and therefore probably underestimated the true EMG amplitude. Sandsjö *et al.* (1996) reported high static loading of the trapezius during seated cashier work and concluded that the muscles did not relax during the scanning task.

Typical European supermarket retailers use single-window scanners mounted vertically. Advances have been made in scanner technology that have provided ergonomic benefits to cashiers. Bi-optic scanners consist of both horizontal and vertical windows that can read barcodes on four or five sides of a product, thereby reducing the need to reorient the barcode toward the scanner. Bi-optic scanners have been shown to reduce wrist accelerations, lifting and awkward postures compared with traditional single-window scanners (Lehman and Marras 1994, Lehman 1996, Madigan and Lehman 1996).

Guidelines for checkout ergonomics (INRS 1992, FMI 1992, 1996) and ergonomics regulations of retail workstations (BSR 1991, SZW 1994, 1998, Arbejdstilsynet 1996) are published in many countries. The guidelines and standards are useful in terms of recommending workstation design parameters; however, many standards are based on video display terminal (VDT) research. In virtually all guidelines and standards reviewed on checkout work, an assumption about work posture (standing or sitting) is made when making recommendations and requirements for the checkout. Although these standards do mention that cashiers should alternate between sitting and standing, they do not provide recommendations as to how to design the checkstand to provide the option of using both postures. Often, these publications do not address new technological advancements because they are not regularly updated.

There has been insufficient research performed to understand the effect of posture (both sitting and standing) on the entire body during checkout work. The literature contains studies that consider only one part of the body and are restricted to one work posture. Most researchers have chosen either to measure posture or muscle activity but have not taken a comprehensive view to consider both for this work task. While the benefits of bi-optic scanners to the hand and wrist have been shown, measurement of effects to the neck and shoulders has not. Because tradeoffs exist between sitting and standing, and because the type of scanner confounds the checkstand design for each posture, it is important to understand the implications of the workstation design and its components. The objective of this study was to provide a biomechanical and physiological evaluation of the cashier while working in sitting versus standing postures with different scanner types, in order to understand MSD risk potential for cashiers.

2. Methods

2.1. *Participants*

Ten female cashiers at a Dutch supermarket volunteered to participate in the laboratory study. The average (SD) age, height and weight of the participants were, respectively, 21.1 (5.2) years, 176.8 (4.9) cm and 66.8 (9.0) kg. Participants had an average of 2.8 years of cashiering experience and no history of musculoskeletal disorders. While all participants worked with vertically mounted single-window scanners in seated checkouts for most of their career, they were trained on proper scanning techniques and used the bi-optic scanner for 1 month prior to testing. Training for the bi-optic scanner included techniques such as sliding all items, no orienting of items, no flipping, twisting or rotating items, and using two hands to share the load of heavier items (Lehman 1996). The procedure was approved by the university and participants were allowed to withdraw at any time.

2.2. *Experimental design*

2.2.1. *Independent variables*: Two different scanners, vertical and bi-optic, were used for this study along with two different work postures, sit and stand. Because the scanner type affected the checkstand configuration due to its position, scanner and posture were not viewed as independent of each other. Therefore, the independent variable was called 'scan posture' and had four levels of combinations of scanner and posture: sit bi-optic, stand bi-optic, sit vertical and stand vertical. Within each testing session the four conditions were randomized.

2.2.2. *Dependent variables*: The dependent measures included muscle activity, posture and subjective preferences. Muscle activity was obtained through surface electromyography of the right and left anterior deltoid (RDELT, LDELT), descending part of the trapezius (RTRAP, LTRAP), levator scapulae (RLEV, LLEV), and the erector spinae at the level of L3 (RERES, LERES) (figure 1). Posture was collected in three planes of motion for both the right and left arms relative to the trunk (T1), the head relative to the trunk, the upper back (T1) relative to the mid-back (L1) and the lower body (L5/S1) relative to the mid back (L1) (figure 2). Roll, pitch and yaw movements were collected and interpreted as rotation, lateral/abduction, and flexion/extension movements. Subjective discomfort and preferences were obtained from each participant at the completion of each condition. Comfort was rated on a seven-point scale anchored by very comfortable (1) to very uncomfortable (7). In addition, participants were asked to explain their discomfort and to comment on their preferences.

2.3. *Task/equipment*

Cashiers scanned two similar sets of 15 grocery items that included a mix of product sizes and shapes. Products included a variety of boxes, bags, cans, bottles and flexibles, which were typical items in Dutch supermarket transactions (Lehman 1998). Product weights ranged from 100 to 1000 g with the exception of a 2- and 6-kg product in each set. The checkstand was a front-facing design with incoming and outgoing conveyor belts. Additionally, the checkstand was designed to convert to either a sitting or standing height by the removal of the floor from the sitting configuration (figure 3). For standing, the distance from the floor to the top of the checkstand was 98 cm, while for sitting it was 85 cm. These values are based on standing and sitting elbow heights for Dutch women. The chair height was adjusted by the participant to a height that was the same as her typical seated working height, which provided a 2 cm clearance between the thigh and underside of the counter. The chair was obtained from a Dutch supermarket and met ergonomics standards (padded, five wheels, lumbar backrest) as required by the SZW (1998). A footrest

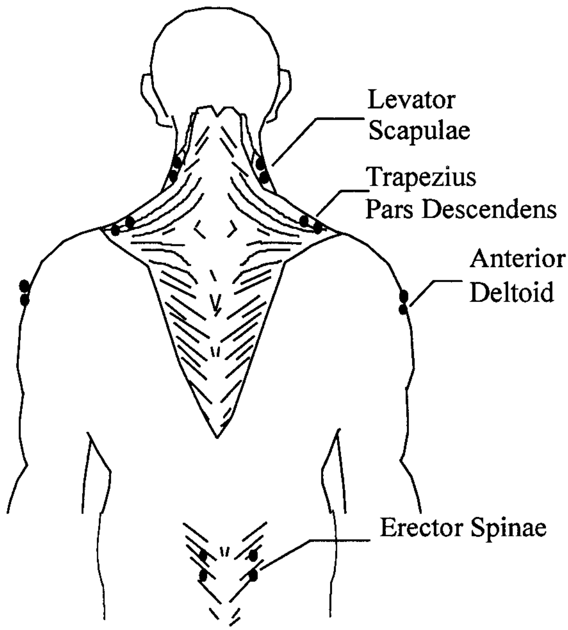

Figure 1. Electrode placement.

was also used and adjusted so that the participant's foot was properly supported. Depth of the counter was the same for both seated conditions, ~13 cm. The vertical scanner was mounted slightly to the left of the participant's mid-sagittal plane, which is typical of European checkstands. The bi-optic scanner was centred directly in front of the cashier.

The scanners used in the test included both a bi-optic and vertical window scanner. The bi-optic scanner was the NCR 7875 scanner, which has the ability to read bar codes from five sides (figure 4). The single window vertical scanner was the NCR 7880 scanner (figure 5). Both scanners were fully operational for the experiment. No other peripheral equipment (keyboard, cash box, printer, etc.) was operating for the test. Each participant was tested in a single session that lasted 5 h.

2.4. *Apparatus*

Myoelectric activity was collected via 18 bipotential skin electrodes with a diameter of 11 mm (SensorMedics, Yorba Linda, CA, USA). The RMS signal was collected and then normalized to the maximal voluntary contraction of the participant. The signal was filtered from both high- and low-pass frequencies between 20 and 1000 Hz. An A/D converter allowed the data to be stored on a PC. The posture data were collected through an Optotrak (Northern Digital, Canada) system that quantified movement in the three planes of motion. A sampling rate of 100 Hz with a spatial accuracy of <0.2 mm in x, y and z dimensions was used. Infrared markers were placed on the participant and tracked by three cameras from the Optotrak system. The three cameras were mounted high on a wall behind the checkstand in order to view all infrared markers.

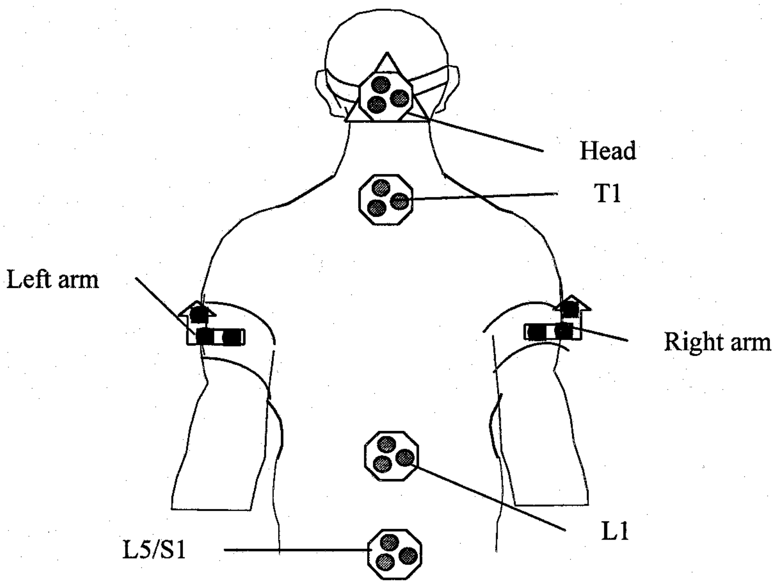

Figure 2. Rigid body placement.

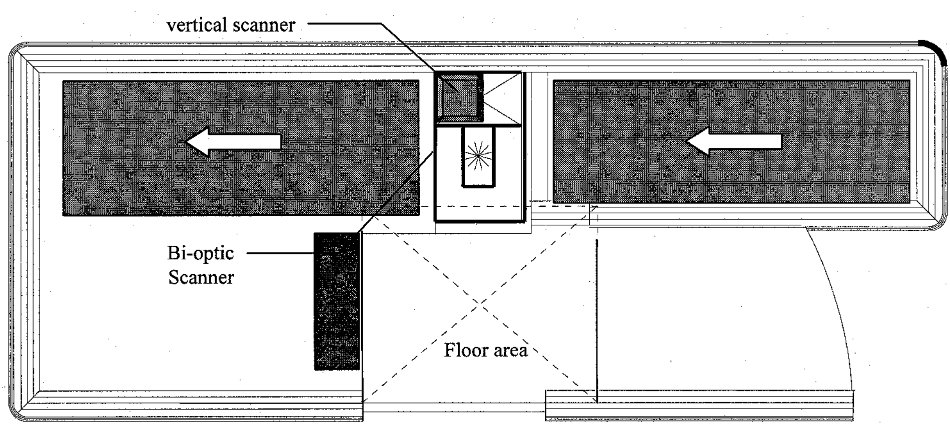

Figure 3. Front-facing checkstand design with interchangeable housing for vertical scanner and bi-optic scanner. Item flow proceeds from right (incoming) to left (outgoing) conveyor belts.

2.5. *Procedure*

The testing procedure for each participant occurred as follows: overview information, anthropometric measurement, electrode preparation and placement, maximum voluntary contractions, rigid body placement, testing conditions, and subjective questioning. The participant's skin was prepared for electrode placement (Marras 1990), and surface electrodes were placed over the belly of the following muscles bilaterally: anterior deltoid, 2 cm below and 1 cm medial to acromion (Hagberg 1981); trapezius pars descendes, 2 cm lateral to half the distance between

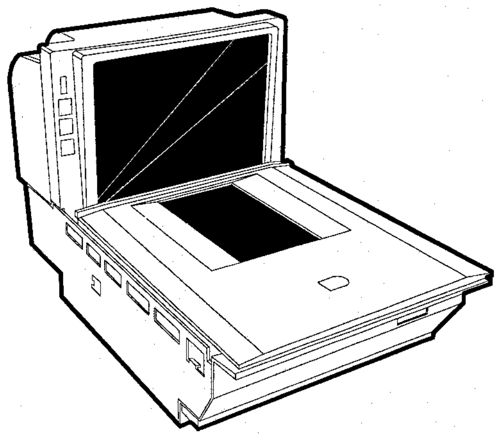

Figure 4. Bi-optic scanner.

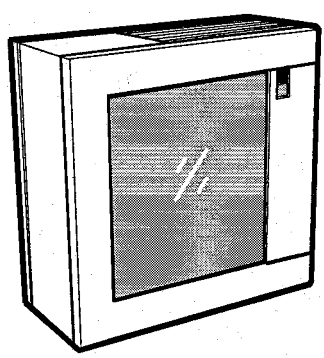

Figure 5. Single-window vertical scanner.

C7 and acromion (Hägg *et al.* 1987, Sommerich *et al.* 1998); levator scapulae, at base of neck (Schüldt *et al.* 1986); erector spinae, 3 cm lateral to the spine at level of L3 (Mirka and Marras 1993) (figure 1). Two ground electrodes were placed on the participant's clavicle and spinous process of the L1 vertebra.

After a brief warm-up and stretching exercizes, a series of six types of isometric exertions were performed to elicit the maximum muscle activity from each muscle. Participants were instructed to concentrate on using only the muscles of interest for each exertion. The first exertion, which generated a maximum force from the trapezius, involved abducting the arm in a 90° posture with resistance from a strap placed proximal to the elbow (with the elbow angle also at 90°) (Hägg *et al.* 1987). This exercize was performed individually on both the right and left arms of the participant. In order to generate a maximum exertion from each deltoid muscle, the arm was fully extended at 90° shoulder flexion with resistance placed proximal to the elbow. The participant was instructed to perform maximum anterior shoulder flexion while keeping the arm straight (Christensen 1986). For the levator scapulae, participants exerted maximal shoulder elevation by pulling up on two inextensible straps that were secured to the platform on which the participant stood (Turville *et* *al.* 1998). For the erector spinae, the participant used an apparatus that allowed her to hang her torso over a cushion while supporting her body weight through resistance of the bent lower legs. The participant then performed a dynamic contraction through her full range of motion, but was limited to a posture of $\sim 5^\circ$ of spinal extension by a strap placed around the shoulder blades which provided resistance (McGill 1992).

After the voluntary maximal exertions, the rigid bodies for the posture analysis were securely placed on the participant. A rigid body consisted of three infrared markers that were previously calibrated to establish its location in three-dimensional space, which were affixed to a thin piece of aluminium, so that no movement of markers occurred relative to each other. Rigid bodies were placed on the left and right arms by means of a lightweight cuff (figure 6). For the head, a headpiece with the rigid body was placed around the participant's head at the level of the temples. The T1, L1 and L5/S1 rigid bodies were affixed directly on the skin with tape (figures 2 and 6). Then the participant was taken to the checkstand and neutral trials were collected with the participant standing (or sitting) still in an upright, neutral posture. This neutral posture was assumed to be '0' such that all subsequent postures were reported as deviations from this posture. Participants were then asked to practise a few transactions so that they would feel comfortable performing the scanning tasks with the additional equipment attached to their bodies. No restrictions were placed on the participant in terms of her scanning speed: participants were simply asked to scan at a normal, comfortable pace. However, participants were instructed not to reach past a marked distance on the checkstand (30 cm) in order to keep all participants' reach envelopes within recommended ranges (SZW 1998).

During each scanning task, EMG and posture data collection began after the cashier successfully scanned one item and continued until the next to the last product had been scanned. One trial consisted of continuously scanning 13 items so the sampling period was not time based, but instead based on number of products. For each condition 10 trials were performed by the participant. Two different product sets were alternated through the trials. All products were introduced in a random order on the conveyor belt. At the conclusion of 10 trials, the participants reported their comfort level. Participants were instructed to consider both the scanner and the posture when choosing a comfort level. At the end of the experiment participants reported which condition they preferred overall.

2.6. *Data analysis*

To normalize the RMS EMG for each participant, programmes were developed to process the data as a percent of maximum voluntary contraction (%MVC). The posture data were also evaluated in a similar manner, by 'normalizing' the posture to the neutral values collected for each condition. Single-factor repeated measures ANOVAs were run using SPSS to test for differences between the four conditions. Appropriate *post-hoc* tests were conducted using orthogonal contrasts in order to compare between conditions. Tenth and 50th percentile of the EMG data and 50th percentile of the posture data were used in all analyses. Tenth percentile EMG data were used to quantify the static load on the muscle in order to compare the data with previous benchmarks (Björksten and Jonsson 1977). Two participants' data were dropped from the EMG analyses after careful evaluation (due to incomplete data sets), resulting in EMG data reports from eight participants. Comfort results were analysed using the Friedman test for non-parametric data.

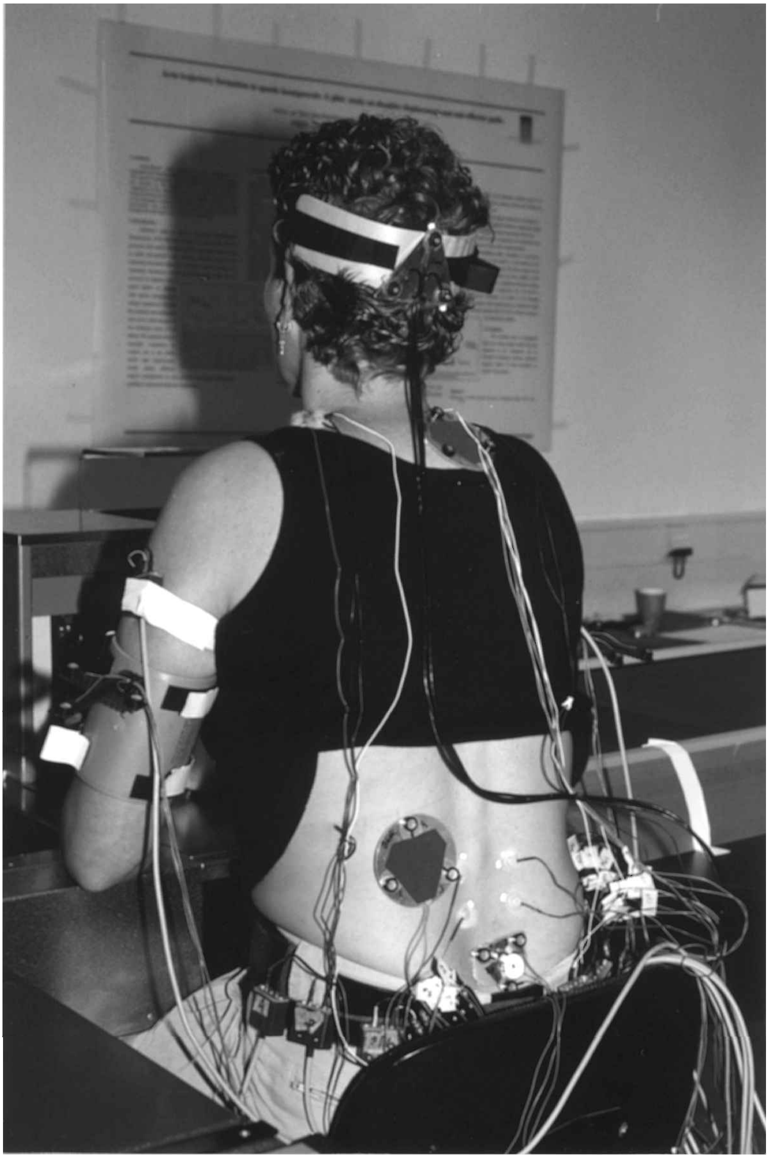

Figure 6. A participant with rigid body placement and electrode placement.

3. Results

3.1. *Electromyography*

All muscle activity is reported by percent of maximum voluntary contraction (% MVC). Tables 1 and 2 display the median and tenth percentile EMG data in terms of the ANOVA analysis by condition. Statistically significant differences were found for most muscles, especially those of the neck and shoulders. Differences between conditions for the median data (at $p < 0.05$) were found for the left and right deltoid, left and right levator scapulae, left trapezius, and left erector spinae. For all muscles, however, a general trend followed such that standing produced less muscle

Table 1. Median EMGs by condition (% MVC).

Median	F	p	Bioptic stand	Vertical stand	Bioptic sit	Vertical sit
Left delt	**30.5**	**0.000**	5.1	5.7	7.3	8.9
Right delt	**11.1**	**0.000**	6.4	6.8	8.7	9.5
Left lev	**25.5**	**0.000**	6.2	6.7	8.9	9.5
Right lev	**4.5**	**0.014**	8.1	9.3	9.4	10.4
Left trap	**21.9**	**0.000**	8.2	8.2	11.6	12.1
Right trap	2.9	0.055	7.8	8.8	9.1	10.6
Left eres	**3.1**	**0.047**	9.8	10.1	11.8	12.5
Right eres	1.6	0.215	8.5	9.3	10.0	10.4

*Muscles in **bold** indicate significance at $p < 0.05$.

Table 2. Tenth percentile EMGs by condition (% MVC).

10th	F	p	Bioptic stand	Vertical stand	Bioptic sit	Vertical sit
Left delt	**17.7**	**0.000**	3.6	3.9	5.2	5.9
Right delt	**7.9**	**0.001**	3.9	4.3	5.5	5.7
Left lev	**25.9**	**0.000**	4.8	5.2	7.0	7.2
Right lev	**4.1**	**0.020**	6.2	7.1	7.6	8.0
Left trap	**30.3**	**0.000**	6.1	6.1	9.1	9.3
Right trap	2.4	0.098	6.0	6.6	6.9	8.0
Left eres	2.7	0.073	7.4	7.5	9.4	10.0
Right eres	1.7	0.205	6.8	7.3	8.4	8.5

*Muscles in **bold** indicate significance at $p < 0.05$.

activity than sitting. In addition, bi-optic standing displayed less muscle activity than vertical standing, and the same trend was true for sitting. The *post-hoc* test results are displayed in figure 7, which further illustrates the trends mentioned above. Although there were no significant differences for the erector spinae muscles of the back, they did follow the same trend as the upper extremity muscles.

3.2. *Posture*

Medians from the posture data are reported in table 3, while results from the *post-hoc* tests are illustrated in figure 8. Postures of interest include left and right shoulder abduction and flexion and trunk and neck flexion. Shoulder abduction for both arms was significantly less for the standing conditions ($\sim 20°$) than for the sitting (27°), because participants were able to scan with their arms closer to their torsos when standing. Although there were no statistically significant differences for arm flexion, the trends are interesting to note. Because the vertical scanner was mounted slightly to the left of the mid-sagittal plane, left arm flexion is lower for the vertical scanner while right arm flexion is higher. For neck flexion, the standing conditions produced higher values than the sitting.

3.3. *Performance*

Cashier performance was measured as the time it took to scan 13 items of a typical transaction. Data collection began after the first item was scanned and continued until the next-to-last item was released after scanning. The bi-optic scanner in both

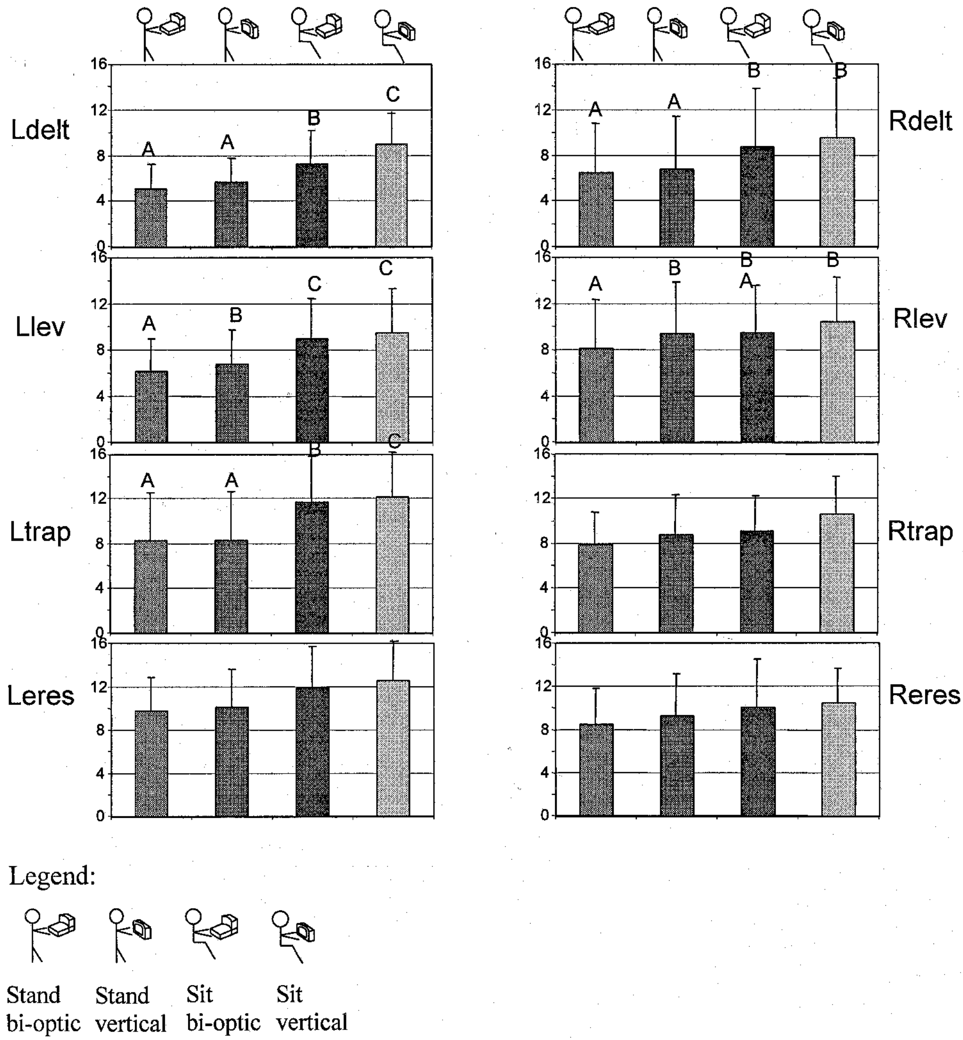

Figure 7. Means used in the test for differences between median EMGs (% MVC). *Post-hoc* test results group differences between conditions as A, B or C.

postures had significantly better performance than the vertical scanner in a seated posture (figure 9). On average, bi-optic transactions (19 s) were ~18% faster than those using the vertical single-window scanner (23 s).

3.4. *Preference*

Subjective reports of discomfort and preference were provided by the cashiers after completing 10 transactions of each condition and at the end of the experiment. Comfort rankings are shown in figure 10 for each combination of scanner and posture, along with statistical differences among conditions. Sitting while using the bi-optic scanner was rated 2.0 (on a scale of 1–7), with one denoting very comfortable. The next most comfortable condition for the cashiers was standing while using the bi-optic scanner, with an overall rating of 2.5. Overall, six of 10

Table 3. Median within-subject posture values averaged across condition (degrees from neutral). A negative direction denotes the direction of body part movement for a negative data value.

Posture-median	F	p	Bioptic stand	Vertical stand	Bioptic sit	Vertical sit	Direction negative (−)
Thoracic flexion	2.0	0.139	3.0	5.8	2.0	2.7	back
Thoracic lateral	6.5	0.002	−1.4	−2.2	1.1	2.0	left
Thoracic rotation	3.1	0.045	1.4	2.0	1.6	−1.3	ccw/left
Neck flexion	**5.8**	**0.005**	17.7	17.7	11.1	10.2	back
Neck lateral	6.0	0.003	−3.5	−3.2	−3.4	−2.1	right
Neck rotation	2.5	0.082	−13.4	−12.6	−14.8	−13.2	right
Left arm abduction	**9.8**	**0.000**	18.2	19.9	25.0	28.8	in
Left arm flexion	2.2	0.105	8.9	7.9	7.3	5.2	back
Left arm rotation	**2.9**	**0.057**	16.6	19.2	17.3	15.8	forward
Low back flexion	0.3	0.824	3.1	2.1	1.8	0.6	back
Low back lateral	0.3	0.839	0.6	−1.8	−2.1	−1.9	left
Low back rotation	2.3	0.103	3.2	0.7	−0.3	1.1	ccw/left
Right arm abduction	**4.7**	**0.010**	20.2	20.3	27.1	27.3	in
Right arm flexion	0.7	0.552	8.7	9.8	8.3	11.5	back
Right arm rotation	1.1	0.384	−12.1	−8.5	−14.5	−15.4	backward

*Postures in **bold** indicate significance at $p < 0.05$.

cashiers preferred the sitting bi-optic condition, while four of 10 chose the standing bi-optic condition.

No cashiers selected the vertical scanner in either posture as their preferred condition. A few cashiers noted that they thought the bi-optic scanner was more comfortable to use because they did not have to lift or turn items. For the cashiers who preferred standing, some mentioned that they felt more comfortable in their arms and could move around and reach for items more easily. For the cashiers who preferred sitting to standing, most indicated that sitting was less tiring.

4. Discussion

The results of this research indicate that for all muscle groups and for shoulder posture the best condition was the standing posture and bi-optic scanner, while the worst condition was the seated and vertically mounted single-window scanner. Regardless of scanner type, the seated conditions resulted in greater muscle activity in the shoulder and neck and more extreme postures for the shoulders than the standing conditions. This may explain why cashiers in seated workstations often experience MSD symptoms in the neck and shoulders (Sällström and Schmidt 1984, Buckle 1987, Krueger *et al.* 1988, Hinnen *et al.* 1992). Despite the physiological disadvantages for the shoulder and neck found in the present study, the cashiers preferred sitting to standing. It is possible that these cashiers were not aware of the possible long-term consequences of this stress nor did they attribute any neck or shoulder symptoms they may experience to their seated working conditions. In addition, since cashiers were asked about their total body comfort, they may have been concerned about tiring their lower extremities if required to work standing.

The median levels of trapezius muscle activity observed in this study (8–12% MVC) were comparable with levels (14–16% MVC) found in light load

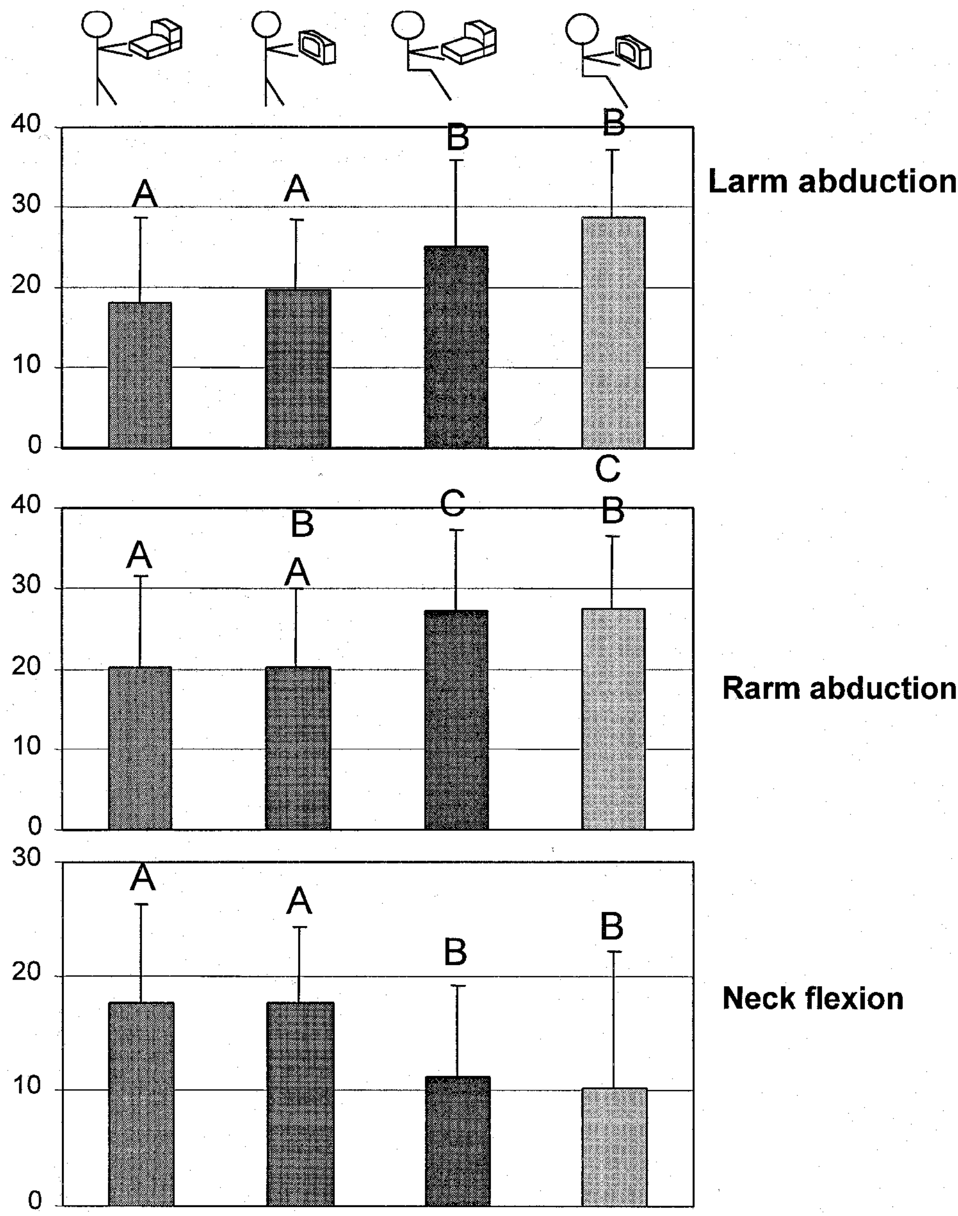

Figure 8. Median postures (degrees from neutral). *Post-hoc* test results group differences between conditions as A, B or C.

repetitive jobs (Christensen 1986, Jensen *et al.* 1993). In similar research on cashier work posture, Lannerstern and Harms-Ringdahl (1990) reported lower levels of muscle activity in the trapezius muscles (4–9% MVC) and right levator scapulae (2–3% MVC), but their findings confirmed that the standing posture produced lower levels of EMG than sitting for the shoulder, neck, and back muscles tested. Lower levels of muscle activity may have been measured in the previous work because the

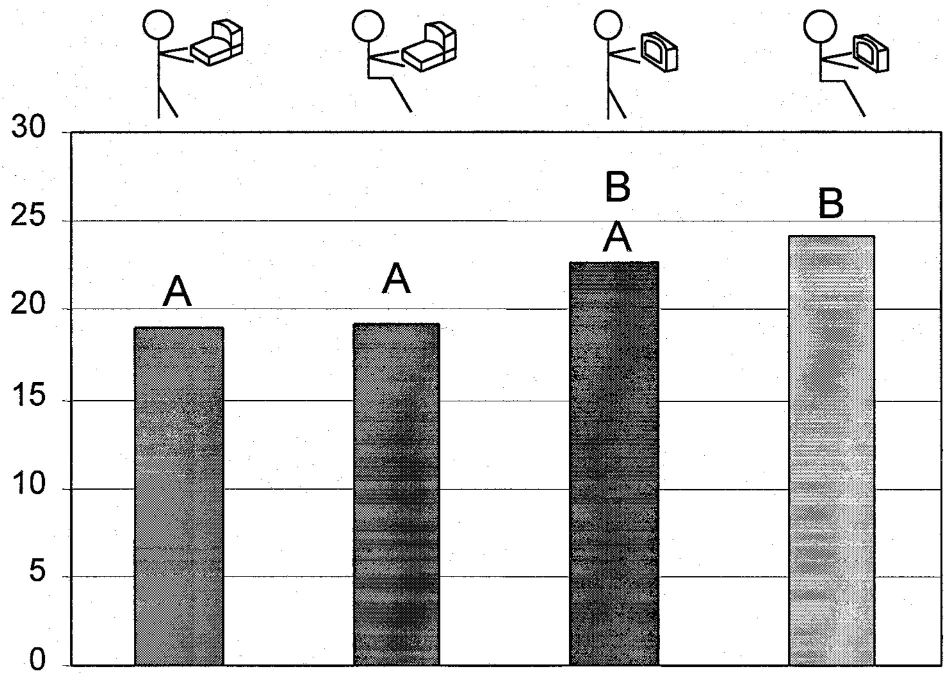

Figure 9. Performance data: time (s) to complete a 13-item transaction. *Post-hoc* test results group differences between conditions as A, B or C.

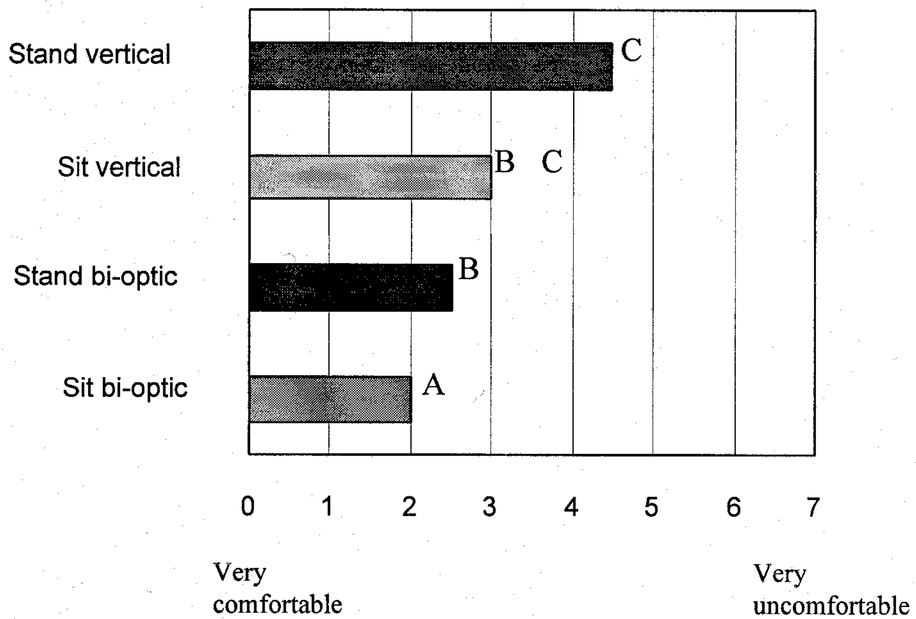

Figure 10. Subjective median comfort rating of a scanner and condition across participants. *Post-hoc* test results group differences between conditions as A, B or C.

scanner was not operational and because the data collection included other less stressful tasks such as payment.

Levels of muscle activity were also compared with benchmarks for long duration tasks recommended by Björksten and Jonsson (1977). The median muscle activity for all muscles did not exceed their benchmark of 10–14% MVC for any of the conditions. However, the static levels ($p = 0.1$) were well above their recommendation of 2–5% MVC for most muscles and conditions. High levels of static loading suggest that the muscles rarely return to resting levels and therefore cannot fully recover. Although high levels of static loading were observed during scanning, it should be noted that the scanning task only represents 40–50% of a customer transaction (Lehman 1998). Additional tasks that may provide muscular relief include payment, waiting for the customer, wait time between customers and other miscellaneous tasks.

Seated cashiers required shoulder postures that exceeded recommended joint angles. Many researchers recommend that shoulder abduction angles should not exceed 20° for continuous work (Tichauer 1968, Chaffin and Andersson 1984, Grandjean 1988). In the present study, the standing condition allowed the participants to work with their shoulders abducted at 20° or less, but in the seated condition, average shoulder abduction angles ranged between 25 and 29°. Aarås (1988) recommends shoulder flexion angles of $<15°$ for continuous tasks. Both right and left shoulder flexion were below this benchmark for all conditions. In the bi-optic scanning conditions, the right and left shoulder joint angles were fairly balanced, whereas a trend towards more right shoulder flexion was observed for the single window scanning condition. When the neutral trials were further analysed, the average lumbar extension angle (lordosis) was 15.4° while standing and 0.6° while sitting. These results indicate that participants' normal spinal curvature was flattened when sitting, which results in higher disc pressure (Andersson *et al.* 1974).

It is generally accepted that neck flexion should be $<20–30°$ for a prolonged period and that 15° is acceptable for static jobs (Chaffin and Andersson 1984, Grandjean 1988). The standing conditions exhibited neck flexions of 17–18° and only 10–11° for seated conditions. However, in this study, the participants had no display, keyboard or customer with which to interact. Cashiers would probably be less apt to focus on the products and scanner in actual work and more on the customer or display, especially when using the bi-optic scanner which requires less orienting of barcodes to a window.

Muscle activity was lowest in the bi-optic standing condition not only because participants were able to scan without abducting their arms, but also because the centred position allowed the participants to share the work more evenly between the right and left upper extremities. Lifting, reaching and item manipulation were reduced due to the scanner's two-window technology. The ease of use of the bi-optic scanner was validated by the productivity results, where cashiers scanned 18% faster with the bi-optic. Furthermore, all participants preferred the bi-optic scanner and rated it more comfortable. The *post-hoc* comparison graphs show the trend that the bi-optic produced less stress than the vertical scanner within each posture. Previous research has already demonstrated the benefits of bi-optic scanning over single-window scanners in reducing risk factors that may contribute to MSD of the hand/wrist (Lehman 1996). It now appears that risk of MSD of the entire upper extremity may be reduced by utilizing bi-optic rather than single-window scanners. Although more cashiers preferred sitting to standing, these cashiers had never experienced a standing workstation before this test. If standing workstations are to be implemented, it is important that cashiers get accustomed to this different posture before assessing their acceptance and whole body comfort.

Researchers have indicated that loads <1 kg may cause fatigue if handled repetitively (Aarås 1988, Wiker *et al.* 1989). In the bi-optic conditions, products were usually pushed or slid across the scanner and therefore participants probably did not exert as much force to counteract the entire product weight. With further analysis of EMG data within trials, average peak loads of 23.0, 24.8, 32.8 and 33.7% MVC were recorded for the right trapezius during the 6-kg box movement for sitting bi-optic, standing bi-optic, standing vertical and sitting vertical conditions, respectively. Less muscle activity was recorded for the bi-optic conditions. Cashiers who used a smooth, two-handed sliding motion for this box had lower muscle activity levels. The high peak loads observed for the heavy product in each trial demonstrates that training cashiers to minimize lifting is important in reducing muscle load.

Ergonomics guidelines were followed by using a front-facing checkstand design, reducing reach and lifting by moving conveyors inward, and providing an adjustable chair and footrest. One cannot assume the same results for cashiers working at a checkstand that does not meet these criteria. Checkstand design is of equal importance as work posture and scanner type when designing a solution to minimize MSD in cashiering occupations. Typically, European checkstands are 2–3 cm thinner in counter depth than the one used in this experiment, which may affect shoulder abduction and muscle activity somewhat.

Methodological limitations of using EMG to record activity of muscles in free dynamic tasks exist. It is difficult to determine whether the pick up area remains constant as a muscle contracts and extends because the electrode on the skin may not remain over the same muscle fibres. In addition, as a muscle's length changes, its activation level will vary to produce a constant force level (Winter 1990). The MVCs in this study were performed at a single posture and therefore the muscle length–strength relationship was not quantified. As a result, the % MVC might vary somewhat depending on the posture. Finally, the velocity of muscle contraction has also been shown to affect the EMG-muscle force relationship (Winter 1990).

Although the static loads reported were high, data were only collected for the task of scanning. Most cashiers receive scheduled rest breaks and unscheduled micro breaks when waiting between customer transactions during non-peak times. Before concluding that scanning leads to fatigue, an understanding of whether tasks such as payment and microbreaks allow muscles to return to resting levels with sufficient frequency and duration to eliminate fatigue is needed. In addition, further research is required to measure muscle loading and fatigue over a full work shift to understand requirements for postural relief aids (e.g. lean bar, chair, floor mats), job rotation, rest break schedules, and other work organization interventions.

5. Conclusions

It is recommended that retailers integrate bi-optic scanners centred with the cashier's mid-sagittal plane into a standing workstation that provides postural relief for cashiers. Based on the results of this experiment, the researchers make the following summary points:

- Standing required significantly lower muscle activity for shoulders and neck than sitting.
- Lower levels of muscle activity are required using the bi-optic versus the single window vertically mounted scanner.
- High static levels of muscle loading were measured, indicating that muscles may rarely return to resting levels during the activity of scanning.
- Right and left shoulder abduction was significantly lower for standing conditions than seated conditions because participants could work below elbow height.
- For all muscle activity measures and for shoulder posture, the lowest values were observed for the standing bi-optic condition whereas the highest were seen for the seated vertical scanner condition.
- Low back posture and muscle activity showed no significant differences between the four posture/scanner conditions.
- Six cashiers preferred the sitting condition compared with four who chose the standing condition.
- All cashiers preferred using the bi-optic scanner over the vertical scanner.

Because scanning is estimated to account for $<50\%$ of customer transaction tasks, cashiers may have sufficient time to rest their muscles during other tasks and rest periods in order to minimize fatigue. Activities are underway to conduct further research in live environments to assess standing checkstand design concepts, postural relief aids and rest break recommendations to ensure adequate muscular rest for cashiers.

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