ERGONOMIC IMPACT OF TECHNOLOGICAL CHANGE IN OFFICES AND SUPERMARKETS

by

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ABSTRACT

In many of today's industries, new technology has been introduced without appropriate ergonomic analysis, leading to adverse health, safety, and productivity effects. This thesis describes the results of three studies into two such industries, which primarily employ women: (1) office work; and (2) supermarket cashier operations.

The objectives of the office study are: (1) to validate Tynan's use of the ergonomic composite score for evaluating the extent to which optimal ergonomic features have been incorporated into video display terminal (VDT) furniture; and (2) to examine the degree to which technologically advanced office workstations are tailored to the needs of users.

Sixteen VDT users evaluated furniture at four VDT workstations. User ratings of overall furniture discomfort were correlated with the corresponding calculated ergonomic composite scores (ECSs). A more rigorous method for calculating ECSs established an even higher correlation, suggesting that the modified ECS scoring method is a useful evaluative tool for predicting user acceptance of VDT workstation furniture.

The supermarket research is divided into two phases. The first phase investigated occupational health problems and performance decrements of cashier operations. Questionnaire responses and objective measures of hand strength, leg edema, postural fatigue, and anthropometric dimensions were compared with dimensions of check-stands presently in use by operators.

Negative features of check-stand design documented include protruding objects, excessive register keyboard heights, and low bag-wells, resulting in poor working postures. Postural fatigue was linked to lower back, neck, left shoulder, and arm discomfort. There were significant changes in calf size linked to continuous standing. These findings suggest that poorly human factored checkstands are contributing to health complaints of cashier operators.

The second supermarket study compared different cashiering methods, in relation to health complaints and work performance. Two cash register types (touch-checking and electronic scanning) and two different bagging methods were evaluated, relative to questionnaire responses and video tape recordings of operators using different methods. The findings suggest that pricing followed by bagging is a preferred cashier work method for either register type, in that it decreases the total time spent in keying, in transition, and in a bent over posture, activities which have negative impact on work efficiency and operator health.

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A. STUDY 1. EVALUATING A MULTI-USER VDT-WORKSTATION

I. INTRODUCTION

Recent years have brought technological advances into the office, primarily in the form of computer/word processing terminals - collectively referred to as visual display terminals (VDTs). Often VDTs are treated like typewriters, placed on non-adjustable desks or tables with little concern given for good viewing conditions and working postures.

Fixed workstations and non-adjustable chairs and work surfaces severely constrain the number of choices of working postures that the VDT operator can reasonably assume. In addition to limiting eye movements related to the location of the screen, keyboard, and source document, maintaining a fixed (static) posture requires continued muscle tension and has resulted in a multitude of postural and visual problems amongst VDT operators (Cakir et al., 1979; Grandjean and Vigliani, 1980; and Stammerjohn et al., 1981). Furthermore, it is becoming increasingly common that a VDT is shared by several users (2-4 persons/VDT) over an entire working day for varying lengths of time. In order to eliminate the constrained postures adopted by operators and accommodate a range of users, the VDT furniture must be adjustable. Adjustable VDT workstations can substantially contribute to comfortable and suitable working postures (Arndt, 1983; Grandjean et al., 1983).

II. LITERATURE REVIEW

The Chair. In an office environment the principal fixture of physical support, comfort, and well-being is the chair. Historically, chair design has evolved in terms of stylistic criteria, with little attention paid to postural support, task facilitation, and other characteristics of user 'fit'(McLeod et al., 1980). Poor seating has been shown to relate to a series of chronic health problems, resulting from improper fit between the chair occupant and the design. These problems range from blood vessel constriction and potential venous thrombosis, to possible kyphosis (hunch back) of the spine and back pain. Links also have been demonstrated between seating design and affective dimensions such as satisfaction and comfort, including performance decrement (McLeod et al., 1980).

Of particular significance to the designer is the location of the seat-pan and back, head, and arm rests, as well as their size and configuration, since it is these elements of the chair and seat that function as stabilizers, and can contribute to or alleviate health problems. Additional emphasis should be placed on variable sitting postures depending on task and the need to stress and relax variable muscles.

Seat height is based on popliteal height (the distance taken vertically from the floor to the dorsal surface of the leg just behind the knee). The correct seat height allows the feet to be placed firmly on the floor. Seat depth is a function of buttock-popliteal length (the horizontal distance from the rearmost surface of the buttock to behind the knee). Seat depth should be large enough to provide adequate back-side support, however excessive seat depth will cause irritation to the back of the lower legs.

Backrest size, configuration, and location are very important considerations, and most disputed in the literature. The primary function of the backrest is to provide support for the lumbar region and hence to accommodate to some extent the spinal profile. There has been considerable disagreement as to the height of the backrest. Grandjean (1980) advocates a total backrest height of 48-50 cm above the seat surface, a breadth of 32-36 cm, and a lumbar pad 10-20 cm above the lowest point of the seat surface. In the British Standard 3893 (1965), complete backrest support is considered restrictive of spinal movement and of the arms. Panero and Zelnik (1979) have concluded that previously recommended sizes for secretarial chairs are too small and suggest a backrest height of 19-25 cm with a height adjustablility of 0-8 cm above the seat surface. Figure 1 illustrates Grandjean's and Panero's concepts of optimal chair design.

Traditionally backrest shapes have been concave. However, increased attempts by manufacturers to maintain the lordotic curvature of the human spine while sitting has resulted in the development of the convex shaped backrest, also known as lumbar pad or lower back support. Grandjean (1980) suggests fixing the lumbar pad 10-20 cm above the lowest point of seat surface. Fixing any feature on a chair limits the number of users who can be adequately fitted. A recent study has demonstrated that the location of the beginning of the curvature differs significantly among the sexes (O'Neill, 1983). Similar differences may be found between older and younger workers. This supports the philosophy that a smaller backrest with adjustability, versus a full backrest with minimal or no backrest height adjustment, is preferable.

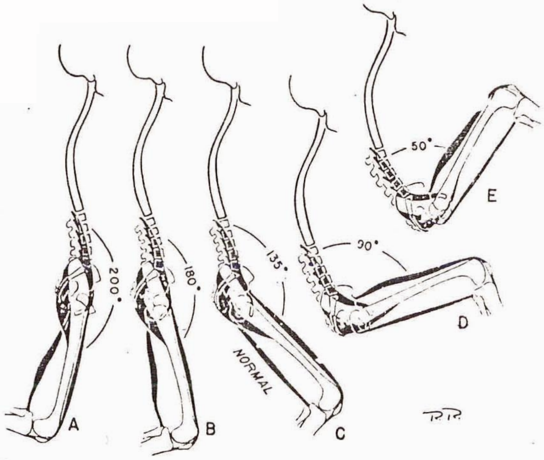
To achieve a right-angled sitting position, a bending of the hip joints of 60 degrees is produced, accompanied by a flattening out of the lumbar curve by about 30 degrees, caused by the stretching of the hamstring and gluteal muscles (Keegan, 1953). Obliterating the lumbar curve through this posture results in pressure changes in the 4th and 5th lumbar discs (L4, L5), caused by anterior wedging and stretching of the posterior ligaments of these discs, which represent the primary focus of most lower back problems. Hence, the optimum or physiologically normal position of the adult spine, with respect to the pull of the anterior and posterior thigh muscles on the pelvis, is with both the trunk-thigh and the knee angles approximately 135 degrees (Keegan, 1953), as illustrated in Figure 2. Andersson <u>et al</u>. (1975) demonstrated minimal myoelectric activity and minimal disc pressure when the trunk is supported by a backrest with an inclination of 10-20 degrees at the height of L4 and L5. A

Figure 1.

An example of a chair with a high backrest and lumbar pad.

An example of a chair with a small backrest which is height adjustable.

Figure 2.



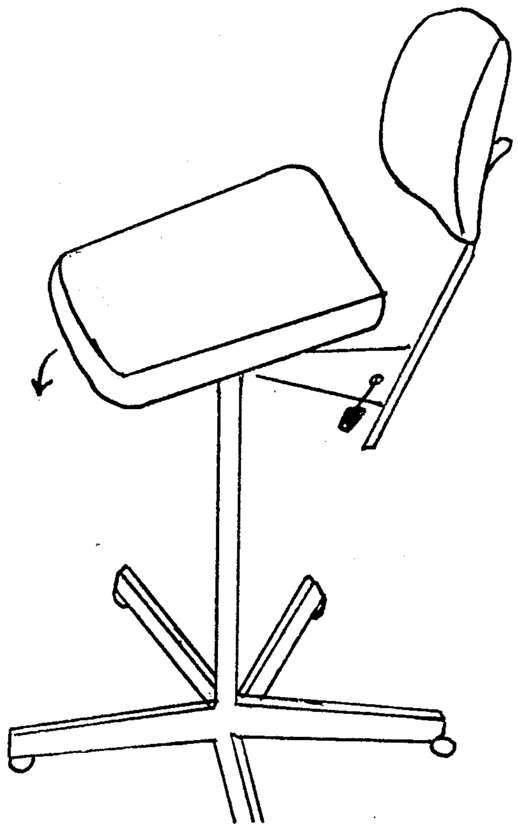
Keegan's illustration of the effects of the hamstrings and gluteal muscles in relation to the quadriceps as various postures are adopted. 2c shows the front and back muscles in balance with one another placing the least amount of stress on the lower back.

recent field study has demonstrated that reference VDT operators instinctively assume this preferred posture and ignore the recommended upright trunk position (Grandjean et al., 1983). Alternatively this posture may be achieved with a seat-pan that tilts 15-20 degrees forward (Mandel, 1981). Figure 3 illustrates a chair with a positive seat tilt. The advantages of a positive seat-pan tilt include an alternative sitting posture and reduced pressure in the lumbar intervertebral discs (Keegan, 1953), especially for individuals with tight hamstrings (Stokes and Abery, 1980).

Many researchers have suggested a slight rearward slope of the entire seat-pan. This declination is supposed to tilt the trunk toward the backrest and, at the same time, prevent forward slipping of the buttocks. However, if one does not lean against the backrest during work, a distinct rearward slope of the seat tends to rotate the pelvis backward, causing kyphosis of the lumbar spine, stressing the intervertebral discs and ligaments of the lower back.

In a 5 hour sitting study to determine the effect of sitting fatigue on orthostatic responses, hemodynamic responses included a 15% decrease in calf blood flow, 19% increase in venous pooling in the calf and a compensatory increase in blood pressure (Shvartz et al., 1982). This and other evidence suggests prolonged sitting constitutes a liability to the health and well-being of office workers. A chair which has horizontal backrest adjustments and variable seat-tilt provides for

Figure 3.



An example of a chair adjusted into the positive seat-pan tilt position.

frequent variations in postures to be assumed. Variable sitting postures stress varying body structures, encourage diffusion of essential nutrients to the intervertebral discs, and assist movement of blood flow in the buttock and lower legs.

General agreement exists with respect to padding. The purpose of padding is essentially to distribute the pressure, due to the weight of the body at the point of interface, over a larger surface area. Excessive padding decreases the stability of the ischial tuberosities, requiring increased body stabilization by internal muscular activity. The range of 2.5-5 cm seat compression has been considered adequate (Panero and Zelnik, 1979). The front edge of the seat should curve downwards, to prevent irritation of the underside of the thighs between the seat edge and the femur. The seat and backrest should be slip resistant and of a cloth fabric to remove body generated heat and moisture.

The VDT-Table. In table design emphasis must be placed on the relevant features of the task under consideration, including anthropometric measures.

VDT operators have to keep their hands on the keyboard and direct their eyes at the screen or source document. This requires a rather fixed position of hands, arms, shoulders, and head. Consequently, undersirable body postures are primarily caused by the location of the working level height, viewing distance, angle of the screen, and the source document.

The working level is defined as the distance between the underside of the thighs and the palms of the hand. To assess the correct working level the correct sitting posture must be assumed. From an anatomical, biomechanical, and physiological perspective, the correct sitting posture at a table with a keyboard must avoid excessive wrist extension, and must keep the elbows and forearms down and horizontal. Unnecessary abduction of the upper arm or elevation of the forearms will result in discomfort in the neck and shoulder muscles, which stabilize and support the abducted arm. Furthermore, if elbow abduction exceeds 23 degrees or 2.5 cm elevation, work metabolism increases dramatically (Jonsson and Hagberg, 1974).

Anthropometrically, the elbow is 2.5-5 cm above the level of the thighs. This means that the elevation of the keyboard over the table top should be kept as small as possible, if table height is not to compromise leg room. Thus, table height should correspond to elbow height.

Another common problem is positioning of the screen so that it is comfortable to view. This is influenced by three parameters: viewing distance, viewing angle of the screen, and location of the source document. A viewing distance of 45-80 cm is recommended (Hunting et al., 1981a), depending on operator preference. If the screen distance is not adjustable, operators may lean forward to read the screen or source document, thus losing the benefit of the backrest, or stretch their arms out in order to gain some distance from the screen.

In VDT screen viewing, the center of the screen should be positioned at operator eye level or slightly below. Any further lowering of the screen forces the head to be tilted forward, activating and stressing neck and back muscles which must control the flexion. The literature suggests that some operators prefer a viewing angle of approximately 15-25 degrees below the horizontal, and a screen angle of 0-7 degrees, as illustrated in Figure 4 (Miller and Suther, 1981). The most likely explanation for this observation is that at this angle the overhead office lights disappear from the direct line of vision, enabling the eyes to adapt to a dark screen. Lowered viewing angles are only recommended for VDT operators who wear bifocals. The cumulative effect of such a posture (head tilted forward) is neck and back pain (Kumar and Scaife, 1979). To read a screen at eye level would force bifocal wearers to tilt their heads backwards.

Source document location is usually flat on the table surface and to one side of the keyboard. This necessitates twisting of the head sideways through a fairly large angle and bending the head forward to reduce the viewing distance, resulting in considerable muscular strain and fatigue (Hunting et al., 1981a, 1981b). Hence the use of a document holder, placed at the same level as the VDT screen, has been advocated. Alternatively, relocation of the screen and source document may be appropriate depending on viewing frequency of either one or the other.

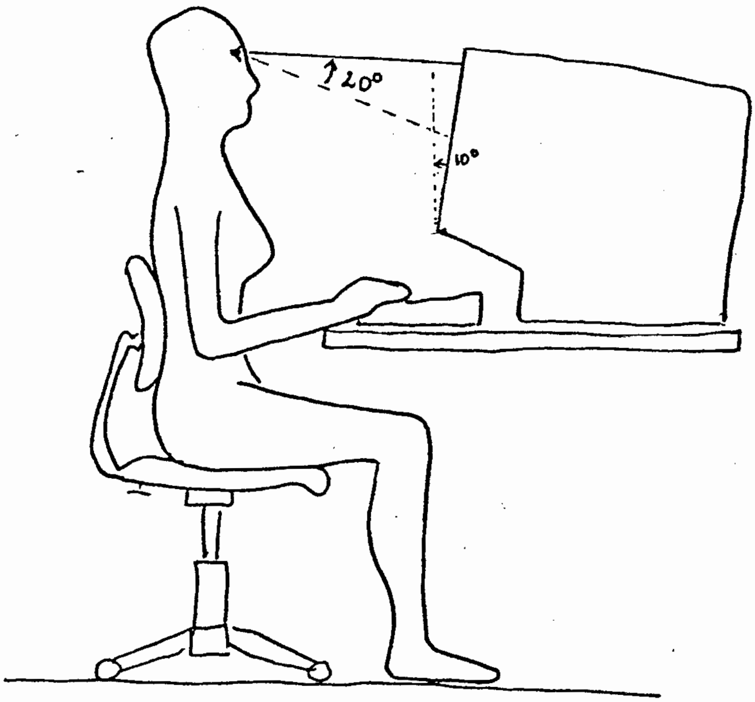


Figure 4. Viewing angles - 20 degrees below eye level and a 10degree backward slope of the VDT screen.

In order to accommodate the layout of equipment, size of the table becomes crucial. The VDT screen is usually larger than the previously used typewriters, suggesting that tables used for a non-VDT task are probably not adequate. Furthermore, additional space may be required for reference material and other work documents, including storage for personal belongings.

Comfort. Generally the feeling of 'comfort' is associated with a healthy sitting posture and a suitable chair and table. Hence, comfort has been used as a criterion for chair evaluation (Corlett and Bishop, 1976; Hunting *et al.*, 1981b; Drury and Coury, 1982). Comfort connotes a variety of feelings and is difficult to define. It has been suggested that its antonym, discomfort, apparently can be sensed by the subject and can be described more easily. Branton (1972) suggests that the absence of discomfort does not mean the presence of a positive feeling but merely the presence of no feeling at all. This suggests that the ideal workstation is one in which the person loses all awareness of his seat, table, and posture.

Evaluation of Furniture. Various researchers and regulatory agencies have developed standards for chair and table adjustability ranges (Panero and Zelnik, 1979; Drury and Coury, 1982; Eastman Kodak Co., 1983). Methods for evaluating chairs have included: comparing chairs against anthropometric data and chair design principles; using fitting trials to adjust the chair to the operator; and lastly evaluating chairs experimentally in a laboratory setting or at a real workplace

(Drury and Coury, 1982).

The major shortcoming of all of these methods is that they are not absolute evaluations but relative evaluations. For example, although a parameter adjustment range of a prototype chair might fall within the recommended guidelines, this does not mean the chair satisfies the condition. Only if the adjustment range exceeds the recommended range does the chair fulfill the condition. Furthermore, technological limitations often force the designer to compromise between the desirable workstation qualities which are not considered in any of these methods.

Tynan (1981) has described an objective method for evaluating furniture characteristics, termed "the ergonomic composite score". The ergonomic composite score represents an attempt to evaluate the extent to which optimal human factors features have been incorporated into VDT furniture. The score is based on rules for good ergonomic design, "the ideal standard", which are derived from the literature, anthropometric tables, and European regulations. Each feature on the chair or desk is measured, and compared to the ideal standard. Based on the degree of deviation each feature is multiplied by a weighting factor and given a score. The weighting factor makes the scores for a test item proportional to the range of acceptable measures of that item and allows scores with different units to be considered (Tynan, 1981).

(M-S=D) x N.F. = N.D.

M=maximum or minimum measure of feature

S=maximum or minimum standard for feature

D=deviation from standard

N.F.=weighting factor for feature

=100/(maximum std - minimum std)

N.D.=weighted deviation

All the scored deviations are added together for a given chair or table to give an ergonomic composite score. The lower the ergonomic composite score the closer the furniture is to being the "ideal" chair or table. The advantages of this method are that it quantifies design trade-offs and eliminates the need for lengthy fitting trials. A sample calculation is in Appendix A.

<u>Critique of the Ergonomic Composite Score</u>

Tynan (1981) made no attempt to validate his method (Appendix A) for compiling an ergonomic composite score for furniture. One method of validation is to compare the values determined by the technique for different furniture items with ratings assigned to these pieces by actual users (criterion validation). In other words, subjective evaluations by users are compared with the theoretical ergonomic composite score. Should the results correlate (i.e., the chair preferred by users is also the one with the lowest ergonomic score), the validity for using the ergonomic composite score as an evaluation technique is demonstrated. The Tynan method also has inherently high content validation, as the content is based on previously established literature (Cakir et al., 1979; Panero and Zelnik, 1979; Mandel, 1981; Eastman Kodak Co., 1983). The ergonomic composite score may be useful as an evaluative tool. However, there are several weaknesses in the method which, if modified or evaluated, could make the score more acceptable, versatile, and rigorous.

The distribution ranges given for the standard ergonomic chair and table will satisfy 90% of the user population (i.e. from the 5th to 95th percentile). Originally Tynan (1981) suggested that the magnitude of any adjustable parameter had to exceed the range of the standard in order to obtain a score of zero. If it is within the range, the larger deviation of the two unsatisfied conditions is to be added onto the ergonomic composite score. On the other hand, if a fixed parameter falls within the given range standard, it is considered to have satisfied the condition of the standard and is assigned a score of 0. The fallacy of this latter assumption is that the dimension may only be suitable for a small percentage of the users. As an example, assume that a seat width for a given chair is 410 mm (satisfying approximately 20% of the users). This measurement falls within the standard range of 400-450 mm (5th-95th percentile of users) and hence, according to Tynan, it obtains a score of zero. Similarly, another chair with seat width=440mm also would be evaluated as 0 even though it satisfies approximately 70% of the user population. These subtle differences need to be addressed as industries become more competitive and chairs become more similar to one another.

Since the fixed chair dimensions found in this study frequently fall into the range of the ergonomic standard, thereby obtaining a score of zero, I decided that a more stringent test evaluation was needed. To achieve this, only one end of the standard range for each parameter was determined as being acceptable. Thus for the seat width standard of 300-360 mm, the upper limit of 360 mm was preferred which would satisfy 90% of the population without causing discomfort to slender users. Similar rationalization was applied to the other fixed dimensions, the end result being that all fixed dimensions actually had to reach the upper limit of the ergonomic standard ranges (thereby satisfying at least 90% of the population) to achieve a 0 score. The exception is seat depth, whose lower limit requirements became the standard to avoid calf irritation in short legged users.

Another problem with the original Tynan method is that it does not differentiate between a dimension that is adjustable for half the population (e.g., 5th-50th percentile), and one that is fixed at the 50th percentile. For example, the ergonomic standard for seat height is 370-520mm. One chair may be adjustable from 370-445mm and another chair may have a fixed seat height of 445mm. By Tynan's method both chairs would obtain the same ergonomic score, since 445mm is equi-distant from either end of the range. However, the former chair satisfies 45%

of the users, but the latter chair only a fraction of users who happen to have a popliteal height at or near 445mm. To increase the rigor of the formula in this aspect, the adjustable parameter had to exceed the range at both ends to obtain a score of zero. If neither of the conditions were satisfied both were added on to the ergonomic composite score. Rules for chair evaluation, and sample calculations of Tynan's method and the modified version of the ergonomic composite score, are summarized in Appendix A and B respectively. Appendices C and D summarize the rules for evaluating VDT desks.

Further problems with the Tynan procedure are that all variables are considered to be independent of one another and that the normalization factors are arbitrary. However, no study to my knowledge has yet examined the interrelationship of chair and/or desk parameters, nor quantified the importance of one parameter versus another. Tynan's independence and normalization assumptions therefore were also used in this study.

Lastly, there may be other factors not considered in the Tynan formula that may be decisive in determining which chair or desk is preferred (e.g., location and ease of operating adjustment levers), qualities difficult to quantify but necessary to evaluate when choosing adjustable furniture.

III. THE STUDY

A comfortable and healthy working posture while operating a VDT is difficult or impossible to achieve with a fixed table or chair height, especially for short or large operators. This has encouraged furniture designers to develop VDT tables with independently adjustable VDT surfaces and keyboard surfaces, along with adjustable chairs. However, due to the variable applications of standards and design compromises, VDT furniture adjustability ranges are inconsistent and highly variable.

Considering the numerous systems on the market, questions arise as to which one to purchase, or which part of a system should be given priority in purchasing when investment is limited. Furthermore, prior to purchasing, some kind of evaluation becomes all the more important when the furniture is being used in a multi-user (sharing a workstation) situation, and 90-95% of the user population must be accommodated to avoid posture related discomforts. The objective of this study is to evaluate three chairs and three VDT tables, advertised by the manufacturer as 'ergonomically designed' by comparing user preference with ergonomic composite scores using Tynan's method (1981) and this study's modified method. A further objective is to validate the ergonomic composite score as an acceptable and simple technique for evaluating chairs and tables, thereby providing insight into the question of how the ergonomic attributes of modern furniture and equipment may be analyzed in an objective manner. This leads to two specific hypotheses for this study: (1) that ranking of VDT furniture by the objective Tynan or modified method can be directly correlated with user subjective evaluation; and (2) the modified method provides a better correlation with the subjective rankings than the (original) Tynan method.

IV. METHODS

Recommended Ergonomic Standard.

VDT workstations and sitting postures have been extensively evaluated in Europe and the U.S. (Cakir *et al.*, 1979; Floyd and Roberts, 1958; Grandjean and Vigliani, 1980; Hunting *et al.*, 1981a; Schoberth, 1979; and Stammerjohn *et al.*, 1981). In addition, some European countries (Sweden, Germany, England) have developed standards which specify both voluntary and mandatory design requirements for VDT's, tables, and chairs.

Furthermore, human engineering data exist (Panero and Zelnik, 1979; Eastman Kodak Co., 1983) and can be applied to the ergonomic design of VDT workstations.

Based on the above sources, ergonomic standards for office chairs and VDT desks were developed to suit operator dimensions and individual requirements encompassing 90% of the population (95th percentile male to 5th percentile female) (Appendix E). Flexibility is an essential part of the design of furniture for any workstation.

VDT Chairs and Desks

Subject Characteristics. Sixteen VDT users (14 female and 2 male) from the cataloguing department of the Simon Fraser University library participated in the study. The height and age of the subjects ranged from 152-183 cm and 21-60 years, respectively (Table 1).

TABLE 1: Subject Characteristics (n=16)

	RANGE	MEAN	S.D.
Height (cm)	152-183	165	8.5
Age (years)	21-60	40	11.3
Number of Years Working	2-40	15	9.8

Eyeglasses....13 respondents wore glasses

Workstations. The subjects shared four identical VDT workstations for varying lengths of time, from 1 to 6 hours per day. The dimensions of the VDT screens in use were 343mm high, 413mm wide and 381mm deep. The keyboard was 48mm in height (A,S,D,...row), 420mm wide, and 203mm deep. The keyboard was attached to the screen by a 30cm cord, providing some flexibility in location (Photo 1). Prior to setting-up the new furniture, a questionnaire (Appendix G) was distributed to evaluate the existing (original) workstations and work environment. The original workstation refers to the table and chair in use at the library prior to the introduction of the new workstations. The questionnaire queries the most common somatic complaints of VDT operators, in addition to determining the effects chair and desk characteristics have on comfort and task function. It also assesses the ease of adjustments. "Ergonomically" designed chairs and desks were given on loan by three manufacturers. The three chairs were manufactured by Labofa, Gutman and Helse; the three tables were manufactured by Gutman, NKR, and Marinko.

The original chair has a swivel height adjustment, and variable backrest tension (Photo 1). The Gutman chair (Photo 2) has a pneumatic height adjustment, a contoured seat pan, and a cam lock lever which adjusts both backrest height and horizontal adjustment. The Labofa chair (Photo 3) has a rather large, flat seat-pan with a screw type lever for backrest adjustments. The Helse chair (Photo 4) is the only chair which has a pneumatically controlled horizontal backrest adjustment. The seat pan is slightly contoured and capable of tilting 10 degrees forward. In the ensuing study, the Gutman, Labofa, and Helse chairs will be referred to as chairs A, B, and C respectively.

Except for the original table, all the tables tested had separate surfaces for the keyboard and the screen. The original table surface was non-adjustable, with a flat work surface at a height of 640mm (Photo 1). The primary differences between the NKR (Photo 5), Gutman (Photo 6), and Marinko (Photo 7) tables are the locations of the adjustment cranks. To adjust the screen surface of the Gutman table, a lever underneath the surface has to be pulled out, and the work surface subsequently must be leaned on and pushed down. The NKR lever adjustments are located underneath the table surface (on the panel that houses the adjustment mechanism), and require relatively simple cranking to adjust the work surface heights. The Marinko table is unique in that the adjustments are located on the surface of the table, so that the table can be adjusted in an upright posture. In this study, the NKR, Gutman, and Marinko tables will be referred to as Desks E, F and G, respectively.

Three of the original workstations, were replaced with three new workstations, set-up with the borrowed equipment. The rationale for choosing the library site are: (i) the library was interested in purchasing 'ergonomically' designed VDT furniture for their VDT workstations; and (ii) the workstations in the library are in a multi-user format, conforming to the predicted model of future 'shared' workstations, which will necessitate the accommodation of a wide variety of workers.

The new furniture was evaluated by each VDT user after a loan period of approximately three weeks. This time period enabled the workers to become accustomed to the furniture. The same questionnaire (Appendix G) that was used to evaluate the original workstation was used to evaluate the new workstations. In addition, a visual analogue questionnaire (Appendix G) was used to determine the frequency of use and whether or not the furniture was adjusted to the users' requirements. Seminars and guidelines also were given, to teach users how to adjust the new furniture to achieve optimum working postures.

PHOTO 1. Existing (original) Work Station.

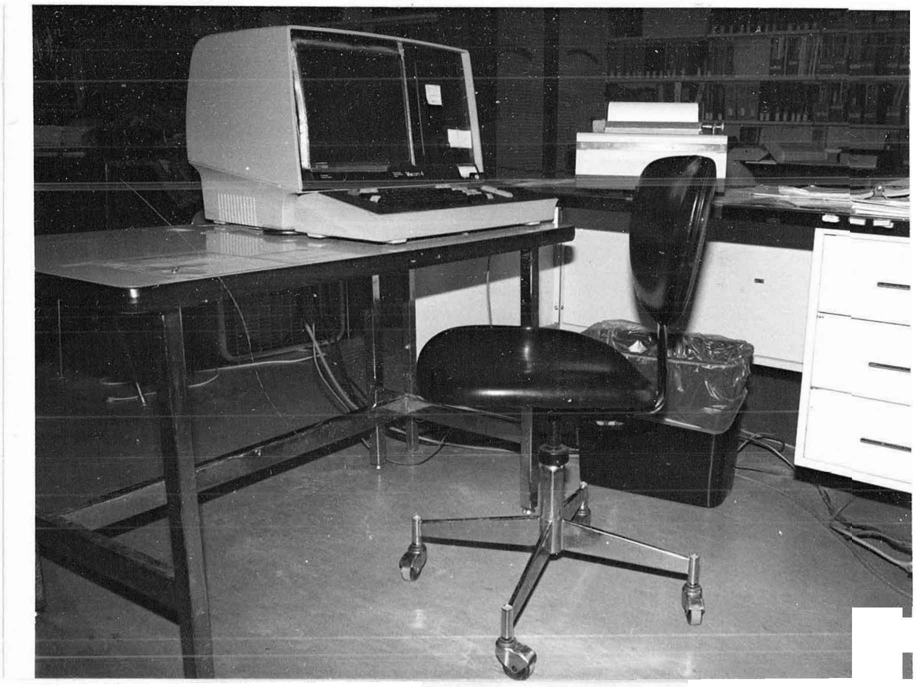


PHOTO 2.

Chair A - Gutmann

PHOTO 3.

Chair B - Labofa

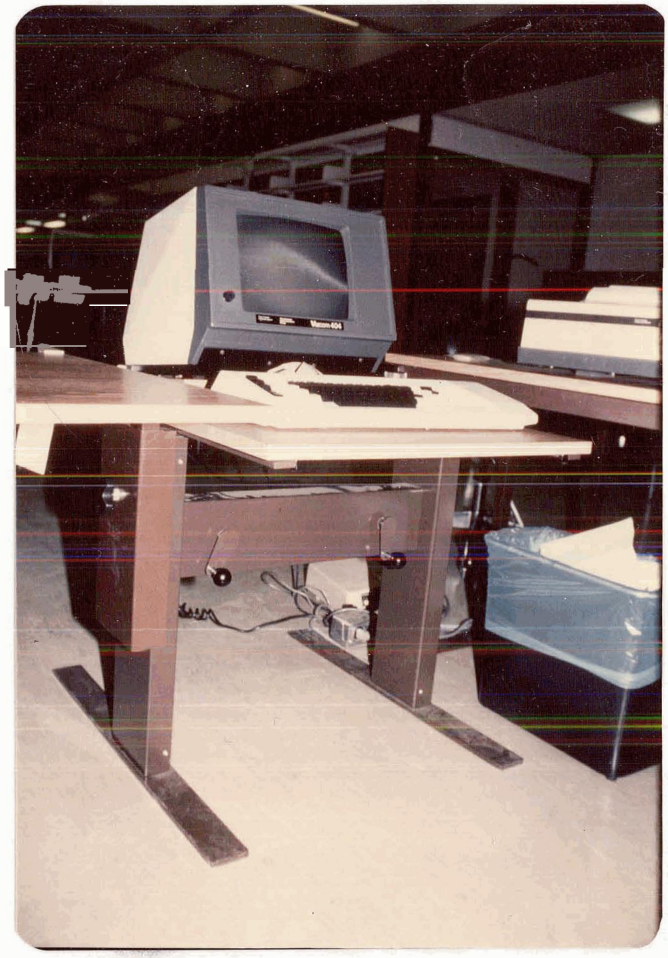
PHOTO 4.

Chair C - Helse

PHOTO 5.

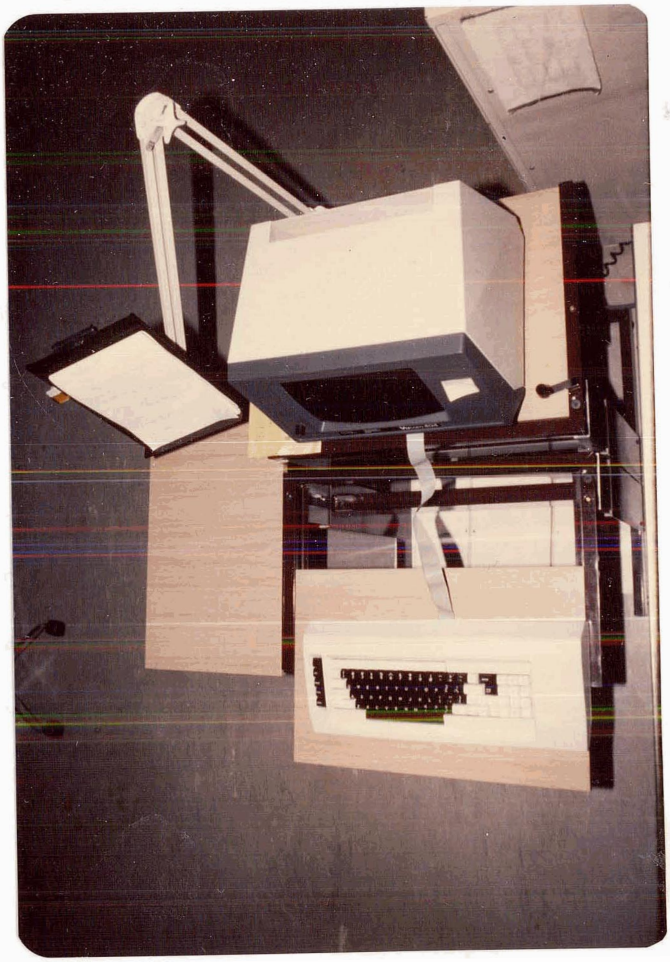
Desk E - NKR

PHOTO 6.



Desk F - Gutmann

PHOTO 7.



Desk G - Marinko

Data Analysis. Questionnaires were evaluated using frequency analysis and Fischer's Exact Test, applied when there are fewer than 21 cases, (Hull and Nie, 1979) to assess whether there are any associations between overall furniture rating and somatic complaints of back, neck or shoulder pain, and arm stiffness. Binomial testing (Crow et al., 1960) was applied to measure differences in preferences for the new desk and chair characteristics compared to the original workstation.

Quantitative evaluation of the furniture is based on the formula developed by Tynan (1981), and this study's modified formula, both of which assign a score to each feature on the desk or chair, as it compares to the 'ideal standard' set out by anthropometric and biomechanical data. All the scored deviations are added together, for any given chair or table, to give an ergonomic composite score for the item. The lower the ergonomic composite score, the closer the item is to being the 'ideal' chair or table. Rules for calculating the composite score, and sample calculations, are given in Appendices A - D.

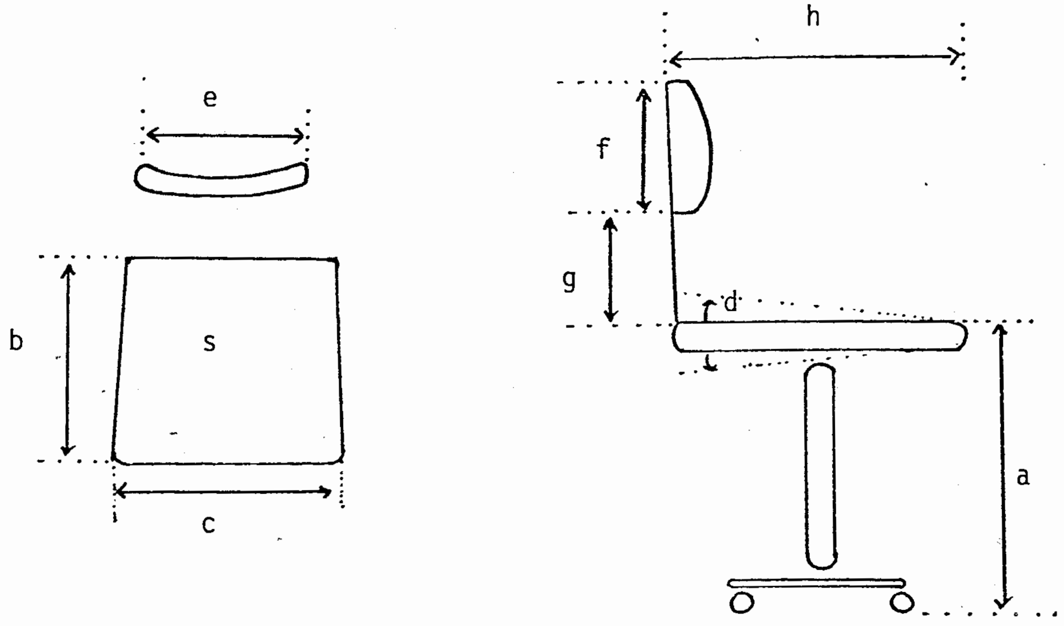
Chair parameters measured were the range of seat and backrest height (vertical) adjustability, seat depth and width dimensions and angle adjustability, and backrest width and height dimensions and horizontal (fore and aft) adjustability (Figure 5).

The VDT desk dimensions must consider the dimensions of the VDT (due to the different models available), since it is the VDT set up (screen and keyboard dimensions) that defines the necessary desk requirements essential to a good working posture. For example, the criteria developed for the ergonomic standard desk (Figure 6) include VDT screen height and keyboard height (home-row reference point). These parameters in turn determine viewing angle and distance, and the keyboard-wrist relationship, respectively. Figures 5 and 6 summarize all of the chair and desk characteristics that are evaluated in this study. The methods of measurement of the dimensions are defined in Appendix F. User questionnaire overall furniture discomfort rating was plotted against the ergonomic composite scores developed by the two methods described above. R-square values using Spearman Rho correlation coefficients (Hull and Nie, 1979) were calculated for chairs and desks (Tables 6a).

V. RESULTS

Questionnaire responses (Appendix G) indicate that no one workstation was predominantly used during the three week test period. However, users reported less frequent usage of Table A due to its complex adjustment mechanism. Ninety percent of the time, chairs were readjusted to suit the user, whereas table adjustment depended upon whether the new user was satisfied with

Figure 5: Chair Measurements and Values for the Ergonomic Standard (mm).

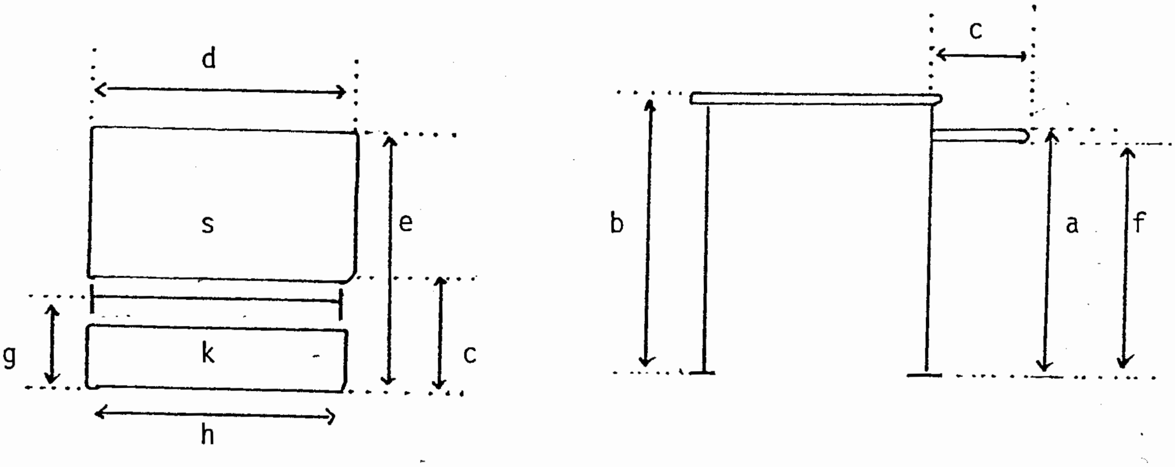


(i) Front View (ii) Side View

a-seat height adjustment (370-520)
b-seat depth (380-420)
c-seat width (400-450)
d-seat angle (-5 to +10 degrees)
e-backrest width (300-360)
f-backrest height (230-300)
g-backrest height adjustment (70-80)
h-horizontal backrest adjutment (350-500)
s-seat pan
(Refer to Appendix F for definitions of measurement).

Figure 6: Desk Measurements and Values for

the Ergonomic Standard (mm).



(i) Front view (ii) Side view

a-keyboard height range (690-750)
b-screen height range(1000-1250)
c-viewing distance (450-700)
d-work surface width (1200-1600)
e-work surface depth (800-900)
f-leg clearance height (650-720)
g-leg clearance depth (430-460)
h-leg clearance width (500-600)
k-keyboard surface
s-screen surface
(Refer to Appendix F for definition of measurement).

the set-up left by the previous user.

Due to the small subject sample size, statistical analysis of the questionnaire can only indicate trends. The study is exploratory rather than confirmatory.

QUESTIONNAIRE ANALYSIS

Subject Somatic Complaints.

As shown in Table 2, the most frequently reported complaints were: back pain, neck/shoulder pain, arm pain/stiffness, itchy, tearing eyes, and painful or stiff legs. All other complaints were mentioned by less than one-third of the respondents. By Fischer's Exact Test, no statistically significant relationship was found between any of the health complaints and age (<40, >40), physical height (<66 inches, >66 inches) or the number of years worked (<10 years, >10 years).

None of the users suffered arthritis, rheumatism, glaucoma, colitis, cataracts, or hemorrhoids - diseases which could affect the subjective evaluation of the chairs and tables. Thirteen of the operators wore corrective lenses, of which 3 were bifocals (Table 1).

Desk and Chairs

The Fischer's Exact Test (Hull and Nie, 1979) was applied to measure the independence between the original workstation

TABLE 2: Percentage of Subjects Reporting Somatic Health Complaints (n=16)

Tearing or itchy eyes	66%
Neck or shoulder stiffness or pain	63%
Skin rash and/or itchy skin	13%
Arm pain or stiffness	50%
Stiff or sore wrists	31%
Loss of feeling in fingers or wrist	25%
Lower back pain	69%
Muscle-joint pain or swelling	13%
Pain or stiffness in legs	38%

set-up and the associated health symptoms (as reported in Appendix G). Positive findings (at $p<0.05$) were: (1) neck and shoulder pain was associated with neck discomfort in the original chairs and with glare from the table top, which may have induced operators to assume awkward postures; and (2) eyesight complaints were associated with the glare from the keyboard and screen. Low back pain was not associated with chair comfort with respect to the lower back.

In Table 3, operators' subjective responses for the chairs are tabulated. Values represent the percentage of discomfort responses for various body parts (just "uncomfortable" responses).

The binomial test was used to assess user preferences for new desk and chair characteristics, relative to the original furniture. Based on the overall rating for comfort given in the questionnaire, the binomial test demonstrated chair C was significantly preferred ($p<0.05$). Particular features that were reported to be better on chair C, compared to the original chair, were low back, upper leg, and lower leg comfort, and provision of lower back support on leaning forward ($p<0.05$).

Table 4 lists the percentage of users who reported inadequacies and bodily discomforts associated with working on the various desks. In the overall rating of desks, desks E and G were decisively preferred ($p<0.01$) over the original desk, with the primary feature being ease of table adjustability. The qualities of adjustability, table tilt, and matt work surface in all three new desks (E, F and G) were considered positive features, relative to the original desk ($p<0.01$).

The reasons why the number of subjects did not remain constant for the evaluation of the new furniture are: (1) two subjects never had the occasion to try the new furniture; (2) one subject went on holiday; and (3) some subjects did not fully complete the questionnaire.

TABLE 3: SUBJECTIVE CHAIR EVALUATION - Distribution of User Responses (%).

Percent responses of bodily discomforts experienced with each chair, and the ease of chair adjustment. Raw count in brackets.

Discomfort to:	ORIGINAL CHAIR n=16	CHAIR A n=13	CHAIR B n=12	CHAIR C n=13
Neck	38 (6)	15 (2)	0	0
Shoulder	38 (6)	23 (3)	0	0
Upper Back	31 (5)	38 (5)	25 (3)	8 (1)
Lower Back	56 (9)	46 (6)	25 (3)	8 (1)
Buttock	25 (4)	38 (5)	25 (3)	0
Upper Leg	38 (6)	23 (3)	33 (4)	0
Lower Leg	38 (6)	15 (2)	17 (2)	0
Arms	13 (2)	15 (2)	8 (1)	8 (1)
Overall	50 (8)	23 (3)	25 (3)	8 (1)
Leaning back in chair:	38 (6)	46 (6)	25 (3)	8 (1)
Leaning forward in chair:	38 (6)	31 (4)	17 (2)	8 (1)
Ease of chair adjustment:	6 (1)	23 (3)	8 (1)	77 (10)

TABLE 4: SUBJECTIVE DESK EVALUATION - Distribution of User Responses (%).

Percent responses to work space inadequacies as a result of desk design, and general discomfort thereof. Raw count in brackets.

	ORIGINAL DESK n=16	DESK E n=11	DESK F n=12	DESK G n=11
Inadequacies:				
Leg Room	31 (5)	18 (2)	8 (1)	18 (2)
Range of Table Adjustment	80 (12)	0	33 (4)	0
Ease of Height Adjustment	87 (13)	0	50 (6)	0
Range of Table Tilt	80 (12)	0	92 (10)	0
Ease of Table Adjustment	80 (12)	0	92 (10)	0
Range of Keyboard Adjustment	53 (8)	0	8 (1)	0
Keyboard Armrest	77 (10)	25 (2)	30 (3)	25 (2)
Work-Surface Area	53 (8)	0	50 (6)	0
Glare of Table Surface	80 (12)	0	0	0
Overall Rating	67 (10)	9 (1)	58 (7)	9 (1)
General Discomfort to:				
Neck	91 (10)	9 (1)	73 (8)	9 (1)
Arms	91 (10)	0	82 (9)	9 (1)
Legs	64 (7)	27 (3)	92 (10)	27 (3)
Overall	91 (10)	0	73 (8)	0

Ergonomic Composite Score Analysis

Table 5 presents the main dimensions and ranges of adjustability for the ergonomic standard chair, the original chair, and new chairs A, B and C. The ergonomic standard chair is the reference chair used to calculate the ergonomic composite scores for the other chairs. The resultant ergonomic composite scores using Tynan's method are 1148, 234, 319 and 180.5, for the original chair and chairs A, B and C, respectively. The scores obtained with the modified method are 1327, 376, 501 and 359.

Table 6 provides the main dimensions and characteristics of the original desk, and desks E, F and G. The respective Tynan ergonomic composite scores are 609, 157, 698.5 and 107, whereas the modified ergonomic composite scores are 1004.5, 157, 1013.5 and 205.

Figures 7 and 8 are scatterplots summarizing the results of the subjective and objective evaluations of the desks and chairs. Table 6a shows the values for r-squared using the original and modified methods for calculating the ECS. No significant differences are shown between the correlation coefficients. Subjective evaluation (Table 3) rated chair C as the most easily adjustable chair and providing the most comfort. This subjective response is echoed in the composite score (Table 5) which is considerably lower for chair C than for chairs A, B or the original chair. Desks E and G were preferred when compared to the original desk (Table 4) and this preference is mirrored in the lowest composite scores for these two desks (Table 6). The features of adjustability, table surface tilt, and matt work surface were qualities valued in all of the new tables.

TABLE 5: MAIN CHARACTERISTICS AND DIMENSIONS OF CHAIRS INVESTIGATED

	Ergonomic Standard	Original Chair	Chair A	Chair B	Chair C
SEAT					
a) Height Adjustment from Floor	370-520	406-508(SA)	445-572(P)	460-540(P)	420-540(P)
b) Depth	380-420	415	400	450	420
c) Width	400-450	432	440	445	450
d) Angle	-5^{o}-$+10^{o}$	0^{o}	-5^{o}	-5^{o}	$-5^{o}+10^{o}$(CL)
BACKREST					
e) Width	300-360	381(base)	390	390	270-440
f) Height	230-300	304	250	250	280
g) Height Adjustment from Seat	0-80	173(fixed)	0-100(CL)	0-140(SA)	0-80(CL)
h) Horizontal Adjustment from Seat Edge	350-500	415-422(SA)	400-530(CL)	400-590(SA)	370-550(P)
Leg Base Number	5	4	5	5	5
Tynan Ergonomic Composite Score	0	1148	234	319	180.5
Modified Ergonomic Composite Score	0	1327	376	501	359

CL=Cam Lever P=Pneumatic Lever SA=Screw Adjustment

TABLE 6: MAIN CHARACTERISTICS AND DIMENSIONS OF DESKS INVESTIGATED

(mm)	Ergonomic Standard	Original Desk	Desk E	Desk F	Desk G
a) Keyboard Height (home row)	690-750	715	632-759	480-937	620-838
b) Screen Height (top surface)	1000-1250	1007	900-1115	950-1127	937-1153
c) Viewing Distance	450-700	175-230	350-686	291-410	483-686
WORK SURFACE:					
d) Width	1200-1600	1070	1041	1194	978
c) Depth	800-900	610	991+	749	1016
LEG CLEARANCE:					
f) Height	650-720	620	559-686	406-813	572-790
g) Depth	430-460	610	356-457	254	381-584
h) Width	500-600	850	635	737	508
i) Adjustment Lever Location	On Top of Work Surface	Non-adjustable	Underneath Surface on Stabilizer	Underneath Work Surface Behind Stabilizer	On Top of Work Surface
Tynan Ergonomic Composite Score	0	609	157	698.5	107
Modified Ergonomic Composite Score	0	1004.5	157	1013.5	205

TABLE 6a: R-squared values for original and modified ergonomic composite scores (ECS).

	ECS	MECS
Chairs	1.00	1.00
Desks	0.54	0.54
Combined (Desks & Chairs)	0.68	0.68

Figure 7: Comparison of Subjective & Objective Evaluation for Chairs & Desks using Tynan Method for Calculating Ergonomic Composite Score

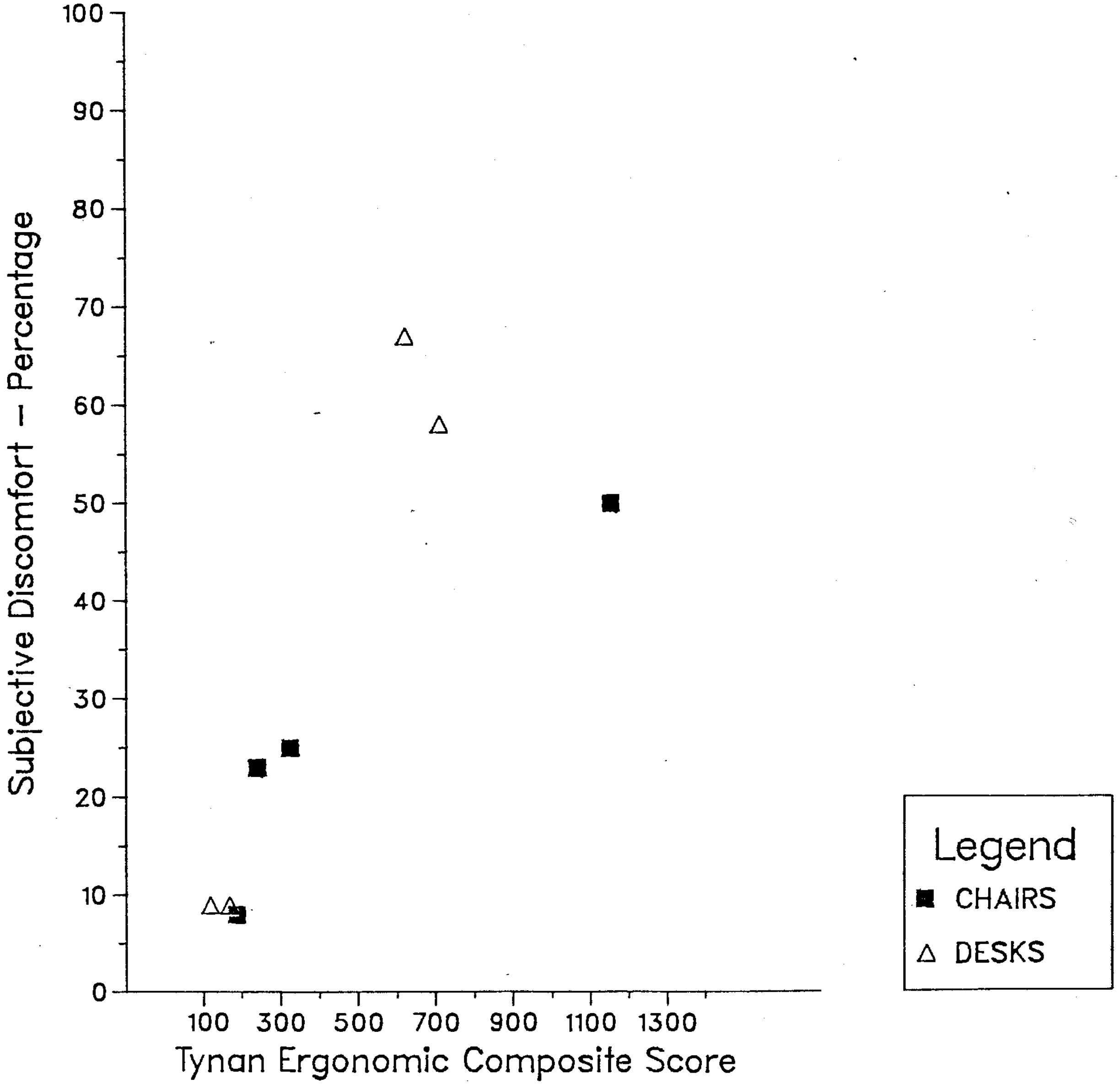
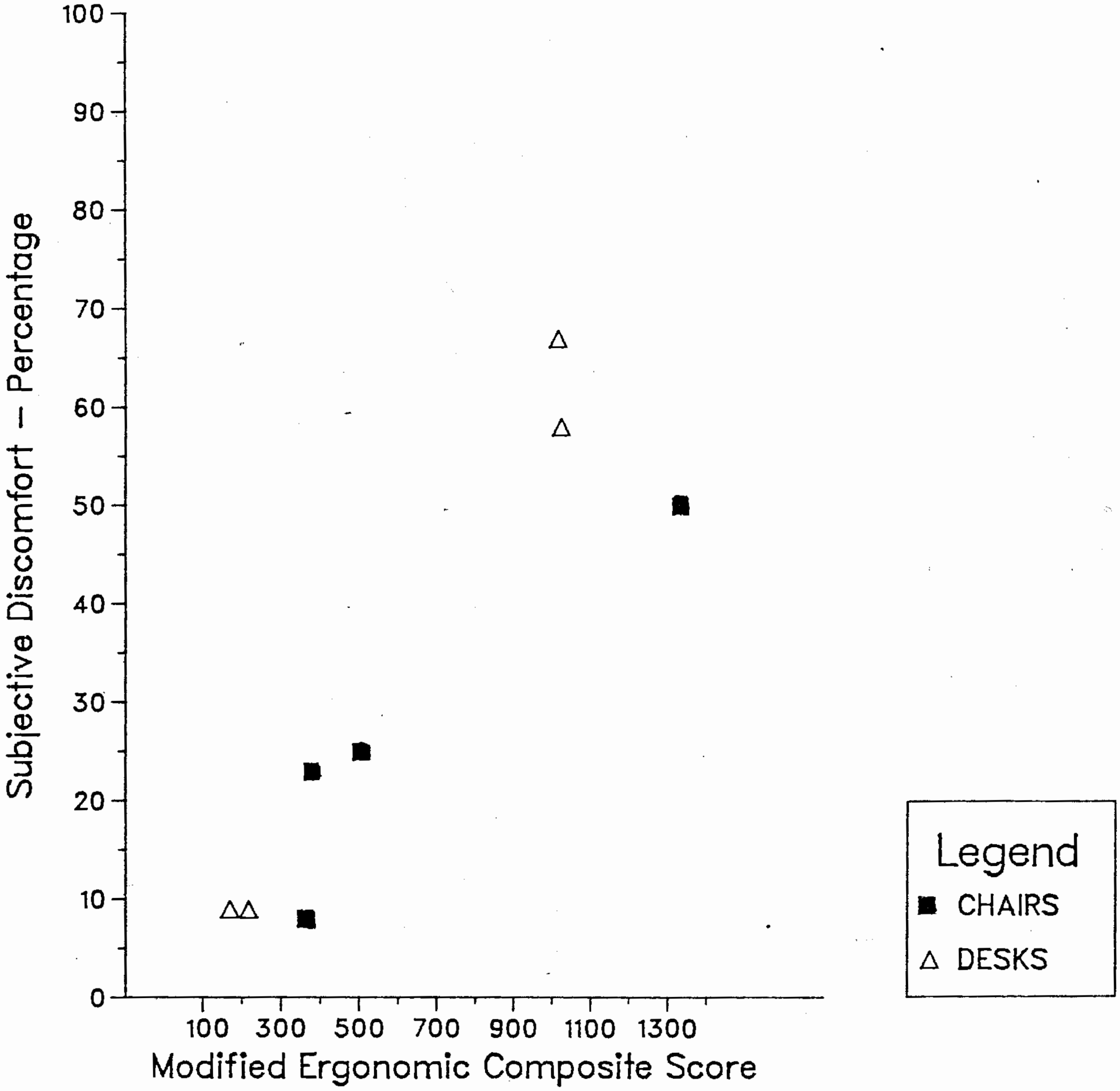


Figure 8: Comparison of Subjective & Objective Evaluation for Chairs & Desks using Modified Method for Calculating Ergonomic Composite Score



VI. DISCUSSION

Chairs. To ensure the design of ergonomically correct seating, the contoured shapes and the overall dimensions of a seating product must correspond to the ninety percent anthropometric range of the adult male/female user population. If the seat and backrest shapes do not fit the contours of the user population, discomfort is unavoidable. The critical areas in a chair for user comfort are:

1. seat height adjustment
2. location of the sacro-lumbar curve (backrest height, width, and shape)
3. seat width, depth, and angle
4. range of backrest support
5. ease and location of adjustment levers
6. seat padding

The positive features of chair C are: (1) all angle and height adjustments of the seat and backrest can be carried out from the seated position; (2) levers are either pneumatic adjustments or cam lock levers, which eliminates the difficulty some people have unwinding screw type adjustments which have been tightened by the previous person; (3) this was the only chair providing the full range of seat angle adjustments (from minus 5 to plus 10 degrees forward); (4) it had the lowest seat height to accommodate the 5th percentile female; (5) each feature was independently adjustable (e.g., the backrest could be adjusted independently of the seat); (6)the backrest was contoured in a convex manner to support the lower back, and slightly concave to support the upper back; (7) the backrest was shaped to provide a wide support at the base and narrowed at elbow height (to 270 mm) to allow unconstrained arm/elbow movements; and (8) backrest support could be maintained upon leaning forward, due to the extensive range and ease of the horizontal adjustment.

Relative to Chair C, Chair A has a number of negative qualities. One is excessive seat depth. If a seat is too deep, a person with short thighs tends to slide forward to the edge of the seat (to relieve the pressure of the seat edge pressing into the calf), and thus loses the support of the backrest. Also, the backrest is too wide, interfering with arm/elbow clearance. The entire backrest contour was concave, which induces the user to adopt a kyphotic position stressing the lower back ligaments. Lastly, the lowest seat height adjustment only accommodates 20% of the females and 80% of the males.

Chair B is also excessive in seat depth, and the backrest is too wide and not high enough, resulting in inadequate support of the mid-back muscles. Once again, the seat height could not be lowered sufficiently to accommodate the full user range. The literature on seating suggests a strong relationship between popliteal height and the seat height adjustment (Hockenberry, 1982), which may explain why chair C was favoured over chairs A and B.

Adjustability of chairs A and B is made difficult by cam-lock levers located underneath the seat, and awkward screw (knob) type locks behind the backrest. Considering the biomechanical limitations of the hand in reaching back and twisting, as well as the fact that the adjustment must be based on touch only, this type of lock is not well designed for the location. It makes little sense to provide an adjustable chair, especially in a multi-user situation, when the adjustment levers are awkward to use, and therefore will not be engaged. Relative to the other chairs, the preferred chair C is most optimally human factored to the dynamic action of sitting, in that it allows many different postures to be assumed, and it is anthropometrically designed to accommodate the greatest proportion of users.

Desks

Factors related to VDT desks which have been repeatedly identified as contributing to visual stress and postural discomfort are keyboard/screen height, viewing distance, and source document location (Arndt, 1983; Grandjean et al., 1983). Providing a large work surface allows for a variety of arrangements in equipment and source document layouts. Separate height adjustable keyboard and screen surfaces permit the proper set-up of the VDT, based on the terminal's dimensions.

Both subjectively and objectively, desk F tended to be the 'least ideal' desk. The desk's high score is related to a support bar located underneath the keyboard surface, which results in lack of leg depth clearance, and an inadequate work surface depth, which restricts the viewing distance. The operators also rated the desk poorly because of the awkward location of the adjustment lever, which is below the table surface and in behind the stabilizer bar. Table width also is limited by pointed metal side stabilizers which make ingress and egress hazardous.

Desk E and G have similar composite scores. Most of the points assigned for the ergonomic composite scores for these two desks are because the parameters did not quite extend over the full range. No one feature overwhelmingly dominates the score. The screen surface for both desks can be angle adjusted and the keyboard can be pulled out to increase viewing distance. For desk F the opposite is true; the keyboard can be angle adjusted and the screen surface pulled in and out.

Subjective evaluation for desks E and G revealed few dissatisfactions. Given this information, it may be useful to analyze the adjustment lever locations to determine which of the tables is more functional. Use of adjustable features depends on how much time and effort are needed to make the changes, and on the perceived benefits to the operator. Desk E has its adjustment cranks mounted on the stabilizing panel beneath the keyboard surface, whereas the adjustment crank for desk G is on the top of the work surface. The latter location is preferred as the desk surfaces can be adjusted while sitting upright in front of the terminal.

Advantages and Disadvantages of Ergonomic Composite Score

Based on the r-squared values, the modified composite score does not predict user preferences better than Tynan's original method. Due to the limited number of ordinals available in the rating system of the questionnaire used to evaluate furniture discomfort, it was necessary to use the Spearman Rho ranking method. This test does not reveal a distinction between the two methods which suggests that using a continuous analogue scale in the questionnaire and using Pearson Correlation statistics may have provided better discrimination. Agreement of the composite scores with the subjective evaluations of users suggests an acceptable criterion validity for both methods. However, the modified method developed in this study has greater stringency, in that it with one exception assigned higher scores for the various chairs and tables than did the original method (Table 5, 6). Moreover, the modified method corrects some of the short comings of the original method, as discussed earlier.

The major advantages of using the modified ergonomic composite score are: (1) it is simple to use; (2) it can be applied in a relatively short time; (3) it may be easily interpreted by others; (4) it can be easily changed to include new results for good ergonomic design (Tynan, 1981) and (5) it is designed on a standard which accommodates 90% of the North American user population. The disadvantages discussed earlier are that: (1) the method does not consider furniture quality; (2) each design rule is given equal weighting; and (3) it does not necessarily predict operator performance or acceptance. It is known that an anthropometrically correct chair is not always considered comfortable (Branton and Grayson; 1967, Drury and Coury, 1982).

Using subjective evaluation by users for a given design requires a large test group. This may be a lengthy process and subject to numerous biases. It is difficult to assess the finer degrees of discomfort between users - what may be uncomfortable to one person could represent borderline comfort to another person. Nevertheless, subjective evaluation is valuable in underlining the qualitative short-comings of a design, and it provides an opportunity for user/worker participation in decision-making regarding work-station design and configuration.

VII. CONCLUSION

It is evident that more research is necessary into ergonomic standards for particular workstations, and into their use as guidelines to manufacturers and to users who must decide on what to buy. The decision made by the user or employer on design preference, a decision that may be effective anywhere from one to twenty years, should not be resolved without some objective criteria. All manufacturers in this study correctly advertised adjustability in their design, but the degree and quality of adjustibility was not carefully specified. To advocate total adjustability as 'adequate ergonomic consideration' fails to answer who will be accommodated by the adjustments - an important question when the product is meant for multiple users. Furthermore, not every person will need to employ the adjustment options, although if the adjustment is possible, more people will be accommodated and able to achieve a healthy working posture. Preliminary results indicate a 24.5% improvement in performance, as well as a decrease in musculoskeletal complaints, as a function of good ergonomic design characteristics (Dainoff et al., 1982).

These considerations support the conclusions that: (1) ergonomic analysis should be incorporated as an integral aspect of design, manufacture, selection, and purchase of office furniture; (2) this study has demonstrated that both objective and subjective methods approaches can be applied to such analysis; and (3) further research is needed to develop more rigorous approaches to such analysis, and to explore the question of which approach is preferable for different application situations.

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B. STUDY 2. OCCUPATIONAL HEALTH DISORDERS OF CASHIER OPERATORS IN SUPERMARKETS RELATED TO ERGONOMICS

I. INTRODUCTION

In industry, much research has been directed at increasing the sophistication and mechanization of the machinery being used, thereby altering the work procedure considerably. Unfortunately, very little attention has been directed to achieving the corresponding level of change in the design of the workstation.

In the last five years, cash registers have undergone dramatic changes. From simple, mechanical adding machines, they have evolved to computerized touch-checking registers (the operator punches prices into the register without looking at the keys), and to electronic scanners, which eliminate manual key-in of product prices.

In British Columbia, approximately 5,000 women are employed as cashier operators in supermarkets. Ninety-five percent of the cashier operators stand and either touch-check or scan the products delivered to them on a turn-stile. This is followed by bagging of the items in either plastic or paper bags, and loading of the bags into a buggy. Either before or after bagging the groceries, the checker receives payment. This study addresses the question of whether the ergonomic aspects of supermarket check-stands, particularly in relation to new cash register designs and procedures, can be related to health problems reported by cashier operators.

II. LITERATURE REVIEW

Much of the literature examining the health problems of cashier operators in supermarkets originates from Japan and deals specifically with the upper body. Very little has been done in investigating the entire workstation and register design, in relation to more general health problems of cashiers. Research findings on the occupational health of cashier operators may be considered in relation to a number of distinct risk factors and health disorders: (1) anthropometric considerations; (2) occupational cervico-brachial syndrome; (3) prolonged standing; (4) back problems; and (5) stress and fatigue. These topics are reviewed in the following subsections.

Anthropometry. A French study on self-service cashiers (Salord, 1978) has identified the following check-stand design factors as giving rise to discomfort: inadequate working space; poor workstation layout; small character size on register keys; glare factors; and noise. In designing a product, it is necessary to remember that people not only vary in height but also in proportions. Two women of the same height are likely to differ in arm or leg length, sitting height, hand size, and so forth. Hence "body size" means not just height but any body measurement which is important for the work space being designed. To design a work space properly, the range of sizes of the user population must be known.

Anthropometry is defined as the application of scientific physical measurement methods to the human body in order to optimize the interface between humans and machines, and assuring the suitability of manufactured products for the intended user population (Roebuck et al., 1975). Knowledge of the average body dimensions of the group of users is not sufficient. The distribution of sizes within the group must be estimated. The total range of variation may be large compared with the designer's room for maneouvre, and it may be impossible to accommodate all users without discomfort. If so, some of the user population must be "sacrificed" (say 2, 10 or even 20 percent) for any particular measurement such as leg length or hip width (N. Thomas, Personal Communication).

A specific position for one piece of equipment can usually be tolerated without discomfort by one size of user, but not by a whole group of users of different sizes. In the latter case the equipment should be made in several sizes, or should be adjustable. Optimum design tends to minimize stress, yet encourages the operator to move and stretch a bit without assuming awkward and painful postures.

Two basic principles of ergonomics, with respect to man-machine interaction, that should not be violated are:

1. Keep forward reaches short (Tichauer, 1976). Numerous industrial engineering tests discuss "normal" and

"extended" reach areas, specifying that for continuous work women and men can repeatedly reach forward as far as 25 inches (63.5 cm) (Niebel, 1967). This assumption is fallacious since a repeated forward reach exceeding 16 inches (40.64 cm) is equivalent to a severe lifting task (Tichauer 1968a, 1976).

2. Keep the elbows down (Tichauer, 1976). Elevation of the unsupported upper arm for long intervals may produce fatigue and decrements of performance time. The optimal height of work surfaces depends on the standing elbow height of the operator and on the type of work. In general, surfaces should be between 5 and 10 cm below the elbows (Redgrove, 1979).

Violating these ergonomic principles leads to low productivity, poor morale, a feeling of ill health, and sometimes real occupational disease (Tichauer, 1968b).

Occupational Cervico-Brachial Syndrome. Studies on Japanese cashier operators have revealed a high prevalence of general fatigue, headache, sleeplessness, and low back pain, as well as dullness and pain in the shoulder, arm, hand, and fingers. The latter symptoms are classified as occupational cervico-brachial syndrome (OCBS). OCBS is a pattern of pain specific to the arm, neck, and shoulder muscles. This pain is a result of impeded blood flow to certain muscles due to stasis caused by unnatural posture. The result is local fatigue/pain which may spread to tendons, ligaments, and connective tissue (Grandjean, 1978).

These dysfunctions are attributed to repetitive upper limb motion with static load (Ohara _et al_., 1976a), increased operating speed (Ohara _et al_., 1976b), and a response to excessive spring loading of the cash register (Onishi _et al_., 1975; Sakuria and Miwa, 1975).

Operating a key-board requires the fingers to act dynamically, but the muscles of the arms, neck, and shoulders must be held rigid in order to keep the hand in the proper operating position. This makes extremely stressful demands on continuous users of equipment of this type. Hence, the cash register industry has manufactured electronic scanners which reduce the usage of the keyboard. However, OCBS symptoms are observed even in the absence of keyboard use (Ohara _et al_., 1976a).

One study (Komoike _et al_., 1977) reported that 17%, another that 31% (Ohara _et al_., 1976a), of cashier operators suffered from some degree of the syndrome. In fact, cashier operators had considerably more OCBS symptoms than typists, telephone operators, clerks, and saleswomen (Ohara _et al_., 1976a). The authors argue that these general symptoms are reflective of muscular fatigue. Visual fatigue has been associated with maintaining fixed head, neck, and eye, positions (Ferguson and Duncan, 1974) and may be contributing to OCBS symptoms.

Prolonged Standing. Studies on Swiss cashier operators (Grandjean _et al_., 1968a, 1968b) reported health problems in 39.5% of those examined. Fifty percent of the problems were located in the feet, legs, and lower back, a function of the static standing posture required on the job. Arguments against standing are numerous. Upright standing (orthostatism) often stresses the spine and back muscles, causing severe pain after a prolonged period (National Safety News, 1977). Relative to sitting, standing makes greater physical demands on the body - it requires higher energy consumption, places greater strain on the circulatory system (especially in the lower limbs/legs), is more tiring, and makes it more difficult to avoid unnatural postures.

In general, maintaining any set of muscles in a rigid, unsupported position for long periods of time will result in muscular strain (Olishifski and McElroy, 1971).

An epidemiological survey studying the effects of working posture on 54 saleswomen divided into 3 different groups - standing, walking, and sitting activity groups - showed that more subjects in the standing group suffered regularly from pain in the legs (26%), feet (9%), and back (8%), as well as from varicose veins, relative to subjects in the other two groups (Guberan and Rougemont, 1974).

Much confusion and a wide divergence of views exist in the voluminous literature on the aetiology of varicose veins in the lower extremities (Wagner and Herbert, 1949; Borschberg, 1967). Varicose veins result from pooling of blood in the lower extremities, which causes an increased pressure on the blood vessels and dilation of the veins, rendering the venous pump ineffective in returning blood to the heart and overcoming gravity (Foote, 1960).

Occupations involving prolonged standing seem to have a higher frequency and severity of varicose veins than others which allow either a sitting position or normal exercise (Askar and Emara, 1970; Fernandez, 1972). Standing has been implicated as a contributory factor to varicose veins, and for initiating or aggravating foot disorders (Mekkey et al., 1968; Turvey, 1970). A study of a varied-terrain (spongy material) versus an even, hard floor surface used by 65 subjects in normal standing work situations found that subjects using the varied-terrain floor surface reported less fatigue and discomfort on and off the job (Brantingham et al., 1970).

Back Problems. In B.C. during 1982, a staggering $48,739,506 was awarded for wage-loss claims related to back strains for all occupations. This cost represents 48% of both the temporary and permanent-partial disability costs for the year. In particular, low-back problems are prevalent among cashier operators.

During lifting with the back bent, the spine forms an arch, with the result that the lower back muscles are subject to strain and there is an uneven pressure on the inter-vertebral discs. Lifting with the back bent and legs straight imposes excessive stress on the muscles of the back for two reasons (Olishifski and McElroy, 1971). First, the back must be inclined at a greater angle to the vertical for the hands to reach the object. Since the "effective weight" (of the object plus the upper part of the worker's body) increases rapidly as the angle is increased, a much greater effort is required to raise the back to its vertical position. Second, muscular effort is required to "straighten" the spine.

A study (Mital et al., 1978) indicated that both weight and work rate were important in causing back injuries, although work rate was a more accurate and logical single measure of back injuries or stress than weight. A light load at a high rate of lift could be equally (or more) stressful than a heavier load at a lesser rate of lift. In this regard, the work speed of the cashier operator has increased tremendously with The use of the electronic scanners.

Stress and Fatigue. Stress falls into two major classes. One narrow definition refers to stress as an excess of environmental demands over capacity to meet such demands. The second broad definition refers to stress as inappropriate person-environment interaction (Dainoff, 1979). Fatigue may be defined as a general response to stress over time (Cameron, 1974). Traditionally three approaches are used to measure fatigue. These are: a) changes in performance; b) changes in subjective feelings (emotional states); and c) changes in physiological state.

Unfortunately, fatigue indicators may change at different times, because of different work-loads and different work intensities, leading to the appearance of contradictory conclusions (Cameron, 1974).

III. THE STUDY

Despite new cash register innovations, the check-stand design itself has undergone only minimal change. The thesis of this study is that the current supermarket check-stand design is inappropriately constructed with respect to working heights and reaches, in relation to the body dimensions of cashier operators and work demands of the task, thus contributing to the health complaints of cashier operators and to diminished work efficiency.

This study examines the ergonomic problems of supermarket check-stands existing in the Lower Mainland, with the following objectives:

1. To examine the design of check-out systems in relation to anthropometric measures and health problems of cashier operators;
2. To measure changes in hand force grip and leg edema among cashier operators over a working day;
3. To examine postural fatigue among cashier operators, using a fatigue inventory questionnaire developed by Corlett and Bishop (1976); and

4. To utilize information provided by the Workers' Compensation Board of B.C. regarding awarded claims of cashier operators to further target ergonomic problems.

The hypotheses of this study are that: (1) incongruencies between anthropometric dimensions of cashier operators, and work station designs, presently in use, contribute to the health problems of checkers; (2) hand grip strength will decrease, reflecting physical fatigue, from the beginning to the end of the day in cashier operators; (3) lower leg circumference will increase in cashier operators from the beginning to the end of the shift; (4) changes in postural fatigue patterns will occur, relative to the body parts most used in cashiering, from the beginning to the end of the day; and (5) WCB wage-loss claims to cashier operators will reflect injuries to specific body parts mostly involved in cashiering relative to other occupations which do not involve the same activities.

IV. METHODS

For this study, a cashier operator survey questionnaire was developed (Appendix H). Relative to personal interviewing, the questionnaire method for obtaining information is less direct, less personal and often yields less detail. On the other hand, it also is less expensive, reaches a larger population sample, and is quicker to administer than the interviewing method. To control for questionnaire biases and problems, careful consideration must be given to the wording of the questions. In addition, I relied upon feedback and constructive criticism from other researchers and from a small sample of the subject group in an attempt to control bias.

The questionnaire developed (Appendix H) is specific to the workstation and to work requirements of cashier operators. Information was collected on complaints pertaining to the check-stand and cash register design (height, width, etc.), to specific and general health problems, and to the general work environment. Initially, 5 firms had been identified for the study, but in the end only two firms agreed to participate. Approximately one hundred and seventy questionnaires were distributed in ten branches of the two supermarket firms. Because some questionnaires were distributed by the managers of the stores, it was not possible to determine exactly how many had been distributed. Furthermore, it was discovered that managers in two stores did not hand out any questionnaires (approximately 20% of the questionnaires). Seventy-four completed questionnaires were returned, which represents a response rate of approximately 43 percent. A possible reason why the response rate was not higher may have been due to a decision by some managers to collect the questionnaires themselves which may have discouraged some cashier operators from answering the questionnaire.

A control group was not employed in this study because an appropriate one was not available. Choosing a control group not involved in grocery cashiering would result in comparing occupations, and not the actual ergonomics of the task. A more ideal control group would be cashier operators who differ in the way they carry out the task. For example, one might investigate 'the health effects of cash register usage on the upper body'. In this case, an appropriate control group would consist of operators that do not use a cash register yet carry out all other functions. However, operations tabulating grocery prices with pad and pencil are extinct. Alternatively, one might question 'the health effects on the back and lower limbs' of standing while cashiering. However, at the pesent time seated cashier operators are only found in Europe.

In addition to the questionnaire, all cashier operators (twelve in total) from one supermarket store were asked to participate in gathering the other test measurements. Anthropometric measurements relevant to check-stand design were collected from these subjects (Table 8), along with the dimensions of three check-stands of different designs (touch checking and bagging, scan and bag, scanning followed by bagging) which they used (Table 9). Three other test measurements were taken at the beginning and end of the day:

1. Hand grip strength - using a hand dynomometer;
2. Leg edema - measuring largest calf circumference with a tape measure; and
3. Postural fatigue - using a subjective fatigue inventory sheet developed by Corlett and Bishop, (1976) (Appendix I).

The reasons for choosing these test parameters are that they are easily administered in the workplace, create little or no interference with the job, and are descriptive of possible fatigue or physiological changes taking place in the checker. Operators in the test store employed the following work method: (1) first, scan all products; (2) walk around to the back of the check-stand and bag the items; and (3) return to the cash register to accept the money. The test measurements were carried out on a Tuesday (a relatively quiet business day). Questionnaires were analyzed based on frequency responses and chi-square analysis. Changes in test measurements from the start to the end of the work shift were analyzed using a paired t-test.

Finally, B.C. Workers' Compensation Board statistics for accepted wage-loss claims for cashier operators were analyzed to provide additional information for causes and severity. These injury statistics were also compared with those for other occupations (counter and department store sales clerks, and typists), and with the overall injury rates for all B.C. workers combined.

V. RESULTS

Anthropometric Findings. All cashiers were female. The mean age was 28 years, and only 7 percent had worked as cashiers for less than one year. Table 7 presents the age and height distribution of the respondents to the questionnaire, and describes the type of cash registers used, the form of moving groceries along the turn-stile, and the bagging methods the respondents employed. Sixty percent of the respondents were between the ages of 20-29; eighty-two percent ranged in height from 152cm-168cm. Cash register usage was evenly split between keying and scanner types. On average, questionnaire respondents had been employed as cashier operators for 7 years. However, it was not possible to distinguish part-time operators from full-time operators since most cashier operators work variable hours.

Anthropometric values for the twelve test subjects, relevant to checkstand design, are presented in Table 8. Elbow height ranges from 98.5 to 108.7 cm. The heights of the cash register buttons, and in some cases the cash register tills (Table 9), exceed the standing elbow heights of all the checkers measured. Two of three check-stands tested (Table 9) exceed the 41 cm maximum reach recommendation.

TABLE 7 - RESPONSE FREQUENCIES TO QUESTIONNAIRE SURVEY (n=74)

AGE DISTRIBUTION		HEIGHT DISTRIBUTION		CASH REGISTERS USED		FORM OF MOVING GROCERIES		BAGGING METHOD OF ITEMS	
Age	Percent Respondents	Height	Percent Respondents	Type	Percent Respondents	Type	Percent Respondents	Use	Percent Respondents
under 29	14.1	under 5 ft.	1.4	Electronic Scanner	45.9	Leg Activated Lever			
20-24	39.4	5'0"-5'2"	23.0			-knee	51.4		
25-29	21.1	5'3"-5'4"	25.7	Manual key-in (Sweda)	50.0	-thigh	9.5	Bag-Well	79.7
30-39	7.0	5'5"-5'6"	32.4			Electronic Eye	37.8		
40-49	11.3	5'7"-5'8"	10.8	Manual key-in (NCR)	1.4			Customer, Counter	20.3
50-61	7.0	5'9"-5'10"	6.8	Other	2.7	With Hands	1.4		

TABLE 8: ANTHROPOMETRIC VARIABLES OF TWELVE CASHIER OPERATORS
(Average age=28 yrs. Work experience 7-3/4 yrs.)

WEIGHT (kg)	HEIGHT (cm)	ELBOW HEIGHT (cm)	ARM LENGTH (cm)	KNEE HEIGHT (cm)
62.2	168.3	107.0	75.0	46.0
65.9	167.2	104.6	70.5	45.4
61.3	165.8	101.5	70.7	34.6
66.5	168.0	107.1	71.6	46.0
46.2	157.5	100.2	66.1	45.6
64.2	163.4	104.3	70.4	45.0
58.3	172.3	108.8	75.9	48.0
57.4	165.0	103.8	72.1	45.8
64.7	167.9	108.7	72.1	42.0
51.1	158.7	98.5	67.5	45.3
65.2	167.4	107.2	74.2	47.0
62.6	162.4	104.3	73.4	45.3
RANGE OF VALUES				
46.2-66.5	157.5-172.3	98.5-108.7	66.1-75.9	34.6 48.0
MEAN				
60.5	165.3	104.7	71.6	44.7
STANDARD DEVIATION				
6.3	4.2	3.3	2.9	3.5

TABLE 9 - CHECK-STAND DESIGN

TYPE OF CHECKING	PHOTO REF. NO.	TOTAL REACH From items on turnstile to checker - in cm	CASH REGISTER HEIGHT (cm)	CASH REGISTER BUTTON HEIGHT (cm)	BAG-WELL HEIGHT (cm)	PEDAL HEIGHT To move groceries (cm)
Manual checking and bagging (standing at an angle)	3	30 - 40 cm	108.0	112.0	54.5	43-53
Scanning followed by bagging (leaning over scanner at an angle to get goods)	4	28 cm electronic scanner wd. +15-50 cm item on turn-stile 43-78 cm	110.0	114.8	54.5	electr-onic eye
Scanning and bagging (standing behind the bags and reaching over)	5	28 cm electronic scanner wd. 6 cm metal plate 10-35 cm item on turn-stile 20 cm bag well wd. 64-89 cm	115.0	119.0	50.0	40-48

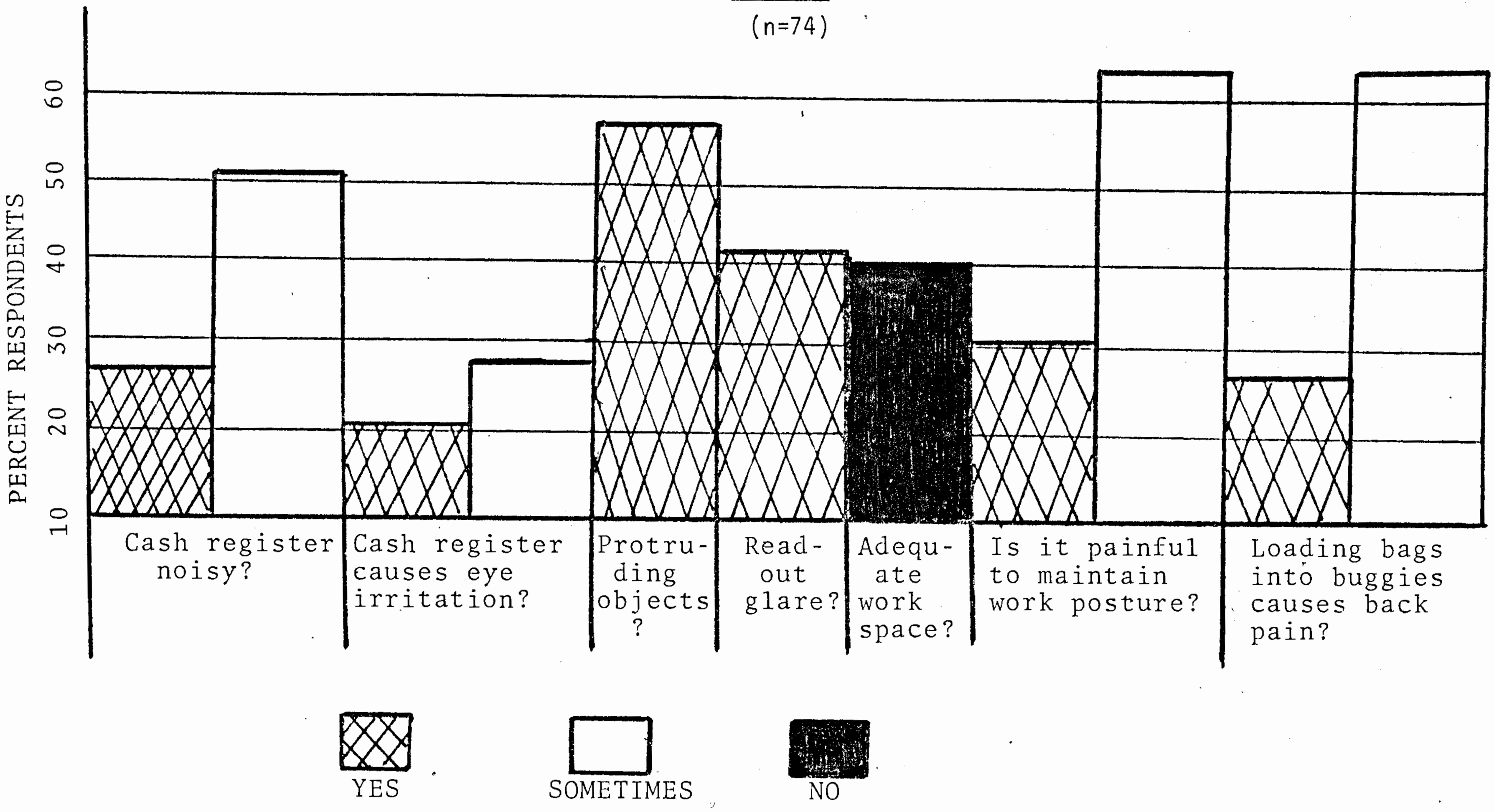
Work Station Design. Figure 9 is a summary of the responses to the questionnaires pertaining to the design of the work station. Features of check-stand design designated negative by more than 10% of the respondents are considered ergonomically unacceptable and tabulated in the figure. The 10% level is chosen because it is the rule most commonly used by human engineers in evaluating the range of tool and equipment acceptability for a given target population (Ducharme, 1978).

As shown in Figure 9, the negative check-stand design feature definitely identified ("yes" response) most frequently is protruding objects. When asked about protruding objects in the work place, cashier operators cited the following:

- plastic bag hooks, scanner sides, cash register drawer, bag flap, edge of counter top;
- my arm constantly hits the metal corner of the cash register;
- bagging ledge bruises knee;
- customer buggy rams hip;
- some brown bags give me paper cuts because they are not serrated;
- scrape arm on left corner of scanner;
- scanner case protrudes by 2 inches and has sharp corners, yet I have to lean against it (my hips) to get food items;
- cigarette counter restricts view, resulting in having to duck under at times to get a buggy; and
- bruise knee with screws and door handles of check-stand.

FIGURE 9 - QUESTIONNAIRE RESPONSES TO CHECK-STAND DESIGN

(n=74)



Additional check-stand design or work features which are considered unacceptable (Figure 9) include: (1) poor work posture resulting in discomfort and pain, occasionally for 63% of the respondents, and continuously for 30% of the respondents; (2) loading bags into buggies causing back pain; (3) inadequate work space; (4) cash register being perceived as noisy; (5) reflected glare from read-out display; and (6) eye irritation related to cash register use.

Cross-tabulations using chi-square analysis (Nie and Hull, 1975) of check-stand design responses in relation to design defects were carried out.

Association at a significance level of $p<0.05$ was found in the following instances: (1) the customer counter was reported to be too high for electronic scanner check-stands, and too low for manual key-in check-stands; (2) the bag-well height was reported to be too low by 92.3% of the respondents, regardless of the check-stand design; and (3) reports of thigh pain by operators using check-stands which had a leg actuated lever, rather than an electronic eye, to move the groceries on the turn-stile.

Health Complaints and Fatigue. This study's survey results for complaints about upper body parts show that 37.5% of respondents suffer from neck pain; 49.3% from shoulder pain (especially on the right side); 33.3% from arm pain; 28.8% from wrist pain (especially on the right side); 18.1% from hand pain (predominantly on the right side); and 15.3% from finger pain.

Photographs 8-14 illustrate postures which may explain these results, such as tilting the head forward, extending the wrist while scanning a product, and repeatedly stressing the shoulder joint while moving product items.

The results from the hand dynomometer show no significant differences ($p>0.05$) in the hand-strength of checkers from morning to afternoon (Table 10).

In the questionnaire survey, 47.3% of the respondents complained of headaches during the work day. One source of headaches may be the daily work pattern of modern cashier operator occupations, which require visual information processing related to keyboard manipulation and bagging groceries.

Questionnaire responses related to the lower extremities indicate: 27% suffer from leg swelling during work; 18.9% from varicose veins; 28.8% from hip pain (predominantly on the right side); 23.6% from thigh pain (predominantly on the right side); 34.2% from knee pain (predominantly on the left side); 16.4% from ankle pain; 45.2% from feet pain; and 15.3% from toe pain. These aches and pains were not age related.

The right hip and thigh pain may be due to stray buggies being pushed into the cashier operators workspace, whereas the left knee pain may be a function of using knee-activated levers for rotating the turn-stile. Chi-square analysis shows that thigh pain is significantly related ($p<0.05$) to more than 36 hours of work per week, as was feet pain ($p<0.05$) with

TABLE 10: CHANGES IN RIGHT & LEFT-HAND STRENGTH DURING A WORKDAY (kg)

MORNING		AFTERNOON	
right	left	right	left
27	29	31	27
32	25	33	16
32	26	34	28
30	19	33	20
29	22	30	24
37	31	31	18
34	26	32	31
29	29	30	30
31	24	28	24
27	26	27	25
28	25	27	25
MEAN			
30.5	25.6	30.5	24.4
STD.DEV.			
3.1	3.5	2.4	4.8

paired t-test of right hand, t=0.0000, SIGNIF=1.000

paired t-test of left hand, t=0.8091, SIGNIF=0.4373 increasing employment time.

In responses to the survey questionnaire, 67.6% of the respondents report low back pain. Low back pain in this study was related, not to age, but to the number of active years on the job ($p<0.05$).

The scores for the subjective fatigue inventory sheet (Table 12) indicate greater discomfort for certain body parts as a function of the posture adopted to complete the task, relative to the overall decrement in comfort. Most problems are specific to the lower back, neck, left shoulder, and arm. These results suggest that more activity is being carried out by the left side, and that excessive reaches may be contributing to the lower back pain. However the overall score measuring well being did not vary greatly during the day, for any body part affected.

In responses in the questionnaire to fatigue, 66.2% of the respondents said they experienced general fatigue. When asked if they ever experienced remarkable fatigue (implying extreme fatigue), 14.9% of the respondents said yes and 62.2% said sometimes, with the following explanations:

-after 8 hours of working at my maximum capacity, speed and constant lifting, and still having to be cheery at all times;

- when there is a continuous line-up and no wrappers;
- at the end of a long day/night shift; a busy, busy day;
- on a Saturday after working an 8-hour shift;
- directly after work, on late nights;

TABLE 11: CHANGES IN LEG CIRCUMFERENCE AS A MEASUREMENT OF BLOOD POOLING IN TWELVE CASHIER OPERATORS

	MORNING (cm)	AFTERNOON (cm)
	35.2	36.0
	34.9	34.6
	36.5	36.5
	38.4	39.2
	37.3	37.8
	33.0	33.3
	34.8	34.8
	33.7	34.4
	33.0	32.8
	35.4	35.3
	34.0	34.5
	36.1	36.3
MEAN	35.192	35.458

Paired t-test, t=-2.3591, Significance=0.0379

TABLE 12: RESULTS FROM SUBJECTIVE FATIGUE QUESTIONNAIRE FOR TWELVE CASHIER OPERATORS

Overall comfort score on a scale from 1=extremely comfortable to 7=extremely uncomfortable (Morning +Evening scores/2). Body part discomfort score on a scale from 0=no pain to 7= most painful. (* refers to body part specified)

SUBJECT NUMBER	MEAN OVERALL FEELING OF WELL-BEING SCORE	DISCOMFORT SCORE* -Morning	DISCOMFORT SCORE* -Afternoon	BODY PART AFFECTED
1	2	2	3	lower back
		2	3	left shoulder
2	1	0	0	-
3	2	1	5-6	left shoulder and arm
4	1	2	2	thighs, both right & left
5	1	0	0	-
6	3.5	4	6	cervical disc degeneration, and left shoulder & arm
7	1.3	0	2	mid back and right hand from twisting
8	3.5	4	6	lower back
9	1	0	0	-
10	1.5	4	5	right hand
11	2	2	2	neck
12	1	0	0	-

- when I stand a full 8 hours in one check-stand, especially the last 2 hours of a shift;
- after a day in the express check-out; and
- at busy times when there is not enough help.

Compensation Statistics. Workers' Compensation Board (WCB) work injury statistics represent another useful approach to analyzing causes and effects of injuries. In 1982, the total number of wage-loss claims in B.C. was 70,255, of which 16,529 (23.5%) were back strains and 15,899 (22.5%) were other strains (K. Mason, WCB Statistician, Personal Communication). The incidence among cashier operators of back injuries and other strains was 36% and 28% respectively, greater than the overall incidence of these wage-loss claims.

WCB wage-loss claim injury statistics for cashier operators in supermarkets covering the years 1972-1982 have been analyzed. The causes and effects are given in Table 13. The three most prevalent causes for a given year are indicated with an asterisk (*). Throughout this period, overexertion due to lifting is the largest single factor contributing to the injury statistics, accounting for 24-43% of all wage-loss injuries. The three most prevalent wage-loss injuries for the years analyzed are contusion/bruises, back strains, and other strains. Percentages are in brackets in Table 13. The contusion and bruises most probably result from protruding objects (struck by something) and inadequate work space, as noted above. However the most striking thing in Table 13 is the almost doubling of claims from

1980 - 1982. Possible reasons for this will be offered in the discussion section.

Table 14 shows that the highest incidence of wage-loss injuries occurs in cashier operators between the ages of 20-29. Figure 10 graphically describes the changes in age distribution and percent injuries. Unfortunately the interpretation of the WCB data is limited by the unavailability of workforce data (either from Statistics Canada or the Retail Clerks Union).

TABLE 13: Causes & Effects of Wage-Loss Injuries in Cashier Operators Working in Supermarkets for the Years 1972-1982. (Percentages in brackets)

(* 3 most prevalent causes for a given year).

Causes	No. of Injuries					
	1972	1974	1976	1978	1980	1982
Striking against something	6	5	5	10	6	17
Struck by something	11*	8	11*	20*	34*	29
Falls from elevation	1	4	5	5	7	11
Falls, slips on same level	14*	11*	5	18*	22	26
Reaching, twisting, etc.	10	11*	6	8	11	20
Repetitive motion	2	2	11*	14	16	41*
Overexertion due to lifting	17*	29*	42*	35*	43*	107*
Other overexertion	3	8	10	14	32*	49*
Other	2	5	3	5	7	22
TOTAL	66	83	98	129	178	322

Effects	No. of Injuries					
	1972	1974	1976	1978	1980	1982
Contusion, bruise	10(15)	13(16)	15(15)	27(21)	30(17)	35(11)
Cut	10	3	4	7	10	15
Fracture	5	1	0	5	5	3
Bursitis	1	1	4	4	6	10
Tenosynovitis	1	2	8	10	12	29
Back Strains	24(36)	39(47)	40(41)	43(33)	51(29)	117(36)
Other strains	13(20)	21(25)	23(23)	31(24)	53(30)	90(28)
Other	2	3	4	2	11	19
TOTAL	66	83	98	129	178	322

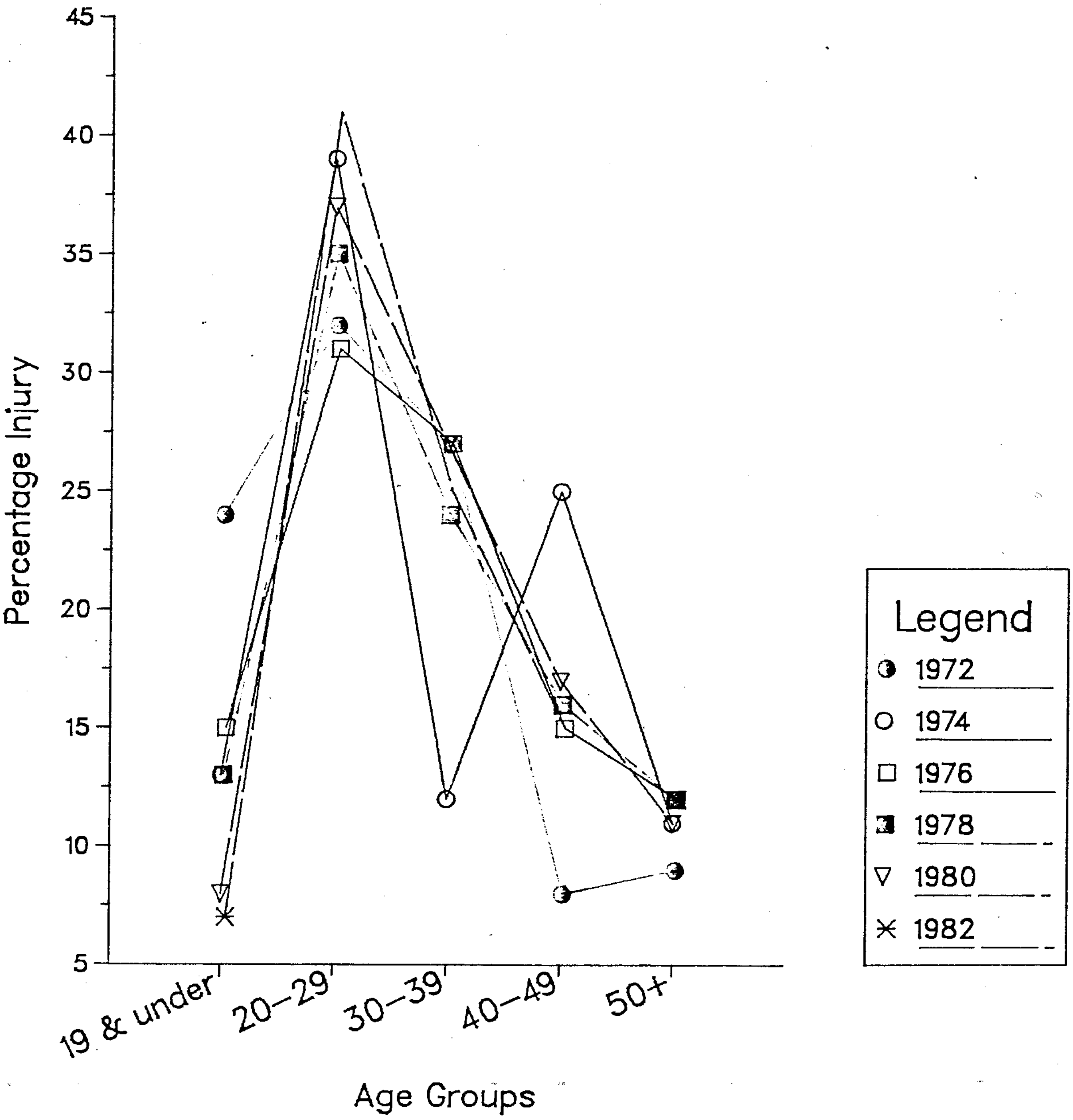
TABLE 14: Absolute Wage-Loss Injuries Related to Age Groups

Age Group	No. of Injuries					
	1972	1974	1976	1978	1980	1982
<19	16	11	15	17	15	22
20-29	21	32	30	45	65	131
30-39	18	10	26	31	49	81
40-49	5	21	15	21	31	50
50>	6	9	12	15	19	38
TOTAL	66	83	98	129	178	322

WCB wage-loss injuries for cashier operators (keying/standing /lifing activities) were compared with other occupations engaged in either sitting or standing all day: typists, stenographers (keying/sitting/no lifting activities), data processing equipment (DPE) operators (keying/sitting/no lifting activities), and retail sales clerks (keying/standing/occasional lifting activities). Table 15 summarizes 1982 wage-loss claims, causes, and effects for the above selected occupations.

Cashier operators have a higher percentage of wage-loss claim injuries related to overexertion (48%) and repetitive

Figure 10: Percent injuries related to age groups for the years 1972–1982.



motion (13%) than do workers in any of the other occupations. This may account for the higher percentage of wage-loss claims for back strains and tenosynovitis in this group. The major causes of wage-loss claim injuries amongst typists and DPE operators are slips and falls from elevation (49% and 40%, respectively) leading to back strains, and other strains including bruises, cuts, and fractures. Amongst sales clerks, overexertion contributes 33% to the overall wage-loss claim injuries, and, struck by or against objects 21 percent. It is evident from these data that it is difficult to draw any conclusion by comparing occupations. Depending on work activities and workstation layout, wage-loss claim injuries are specific to the occupation.

TABLE 15: Number of Wage-loss Claims, Year of Accident 1982, for Selected Occupations, by Cause and Effect (Percentage of total injury in brackets).

Cause	Cashier-related Retail Food	Typists Stenos	D.P.E. Opers.	Sales Clerks
Repetitive Motion	41(13)	3(2)	2(7)	9(11)
Other Voluntary Motion (Bend,etc)	15(5)	4(3)	1(3)	26(3.8)
Involuntary Motion	5(2)	3(2)	14(13)	24(3)
OVEREXERTION				
Pull,push	8(2)	0(0)	0(0)	18(2)
Carry	0(0)	0(0)	0(0)	1(0.1)
Lift & Turn	22(7)	0(0)	0(0)	19(3)
Lift, No Turn	85(26)	10(8)	3(10)	125(17)
Using Tools	0(0)	0(0)	0(0)	1(0.1)
Other	41(13)	20(15)	4(13)	81(11)
Slips	26(8)	31(24)	6(20)	101(14)
Struck by Objects	29(9)	15(12)	1(3)	116(17)
Struck against objects	17(5)	3(2)	0(0)	107(14)
Fall from Elevation	11(3)	33(25)	6(20)	75(10)
Other	22(7)	8(6)	3(10)	40(5)
TOTAL	322	130	30	743

Effect	Cashier-related Retail Food	Typists Stenos	D.P.E. Opers.	Sales Clerks
Bursitis	14(4)	0(0)	0(0)	6(1)
Tenosynovitis	29(9)	2(1)	1(3)	3(1)
Other joint, tendon Inflammation	0(0)	1(1)	1(3)	0(0)
Back Strain	117(36)	31(24)	10(33)	219(29)
Other Strain	90(28)	34(26)	11(37)	174(23)
Bruise	35(11)	30(23)	3(10)	121(16)
Cut	15(5)	12(9)	1(3)	138(19)
Fracture	3(1)	10(8)	2(7)	38(5)
Other	19(6)	19(8)	1(3)	44(6)
TOTAL	322	130	30	743

Photographs 8 and 9.

Excessive cash register heights, lead to right elbow abduction wrist flexion, and occasional bruising to the elbow as the till opens.

Excessively high placement of the receipt-giver, necessitates repetitive lifting of the arm.

Photographs 10 and 11.

High placement of the cash register buttons, promotes wrist extension. This posture may be maitained for extended periods of time, especially at touch-cheking tills.

Incongruity between the cash register height, and the bag-well base, force the checker to adopt an awkward posture.

Photographs 12 - 14. Postures leading to symptoms of OCBS.

Prolonged forward tilting of the head for viewing prices and products, stresses the neck and shoulder muscles.

Maintaining an imbalanced upper postures for bagging and keying items.

Repetitive moving and pushing of groceries, involving extended reaches and leaning forward, stresses the upper body and lower back.

Photographs 15 -17. Repetitive forward bending postures of the upper body stresses the lower back.

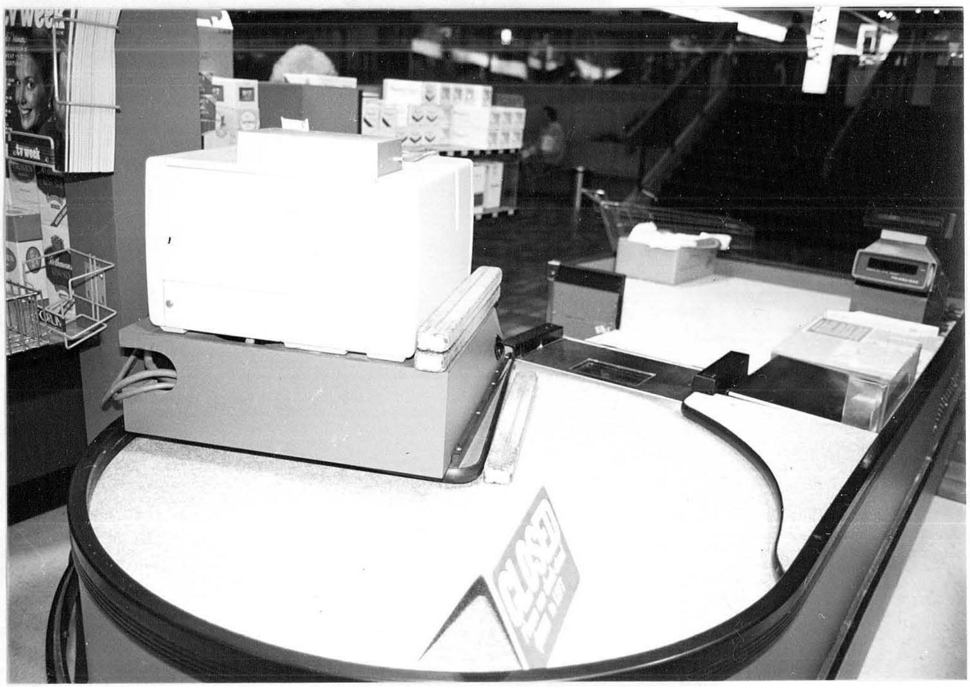
Scanning and bagging in one continous motion.

Scanning followed by bagging.

Wrapper help.

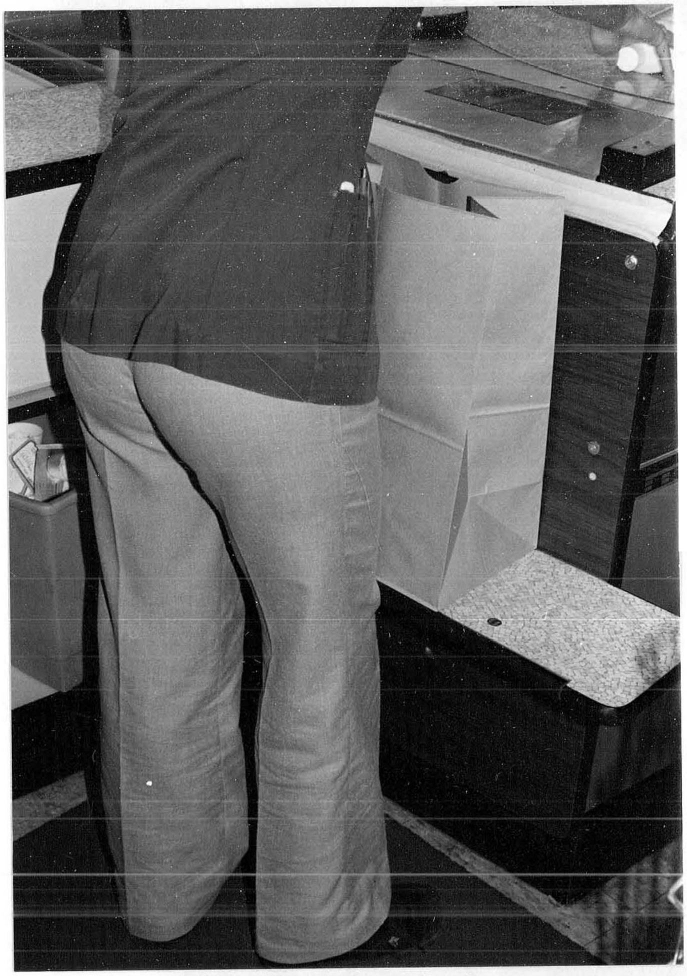
Photographs 18 and 19. Price read-outs.

There is no price read-out in front of the checker, only the small, printed numbers on the receipt.



The price read-out is actually situated behind the checker (little box to the right).

Photographs 20 - 21.



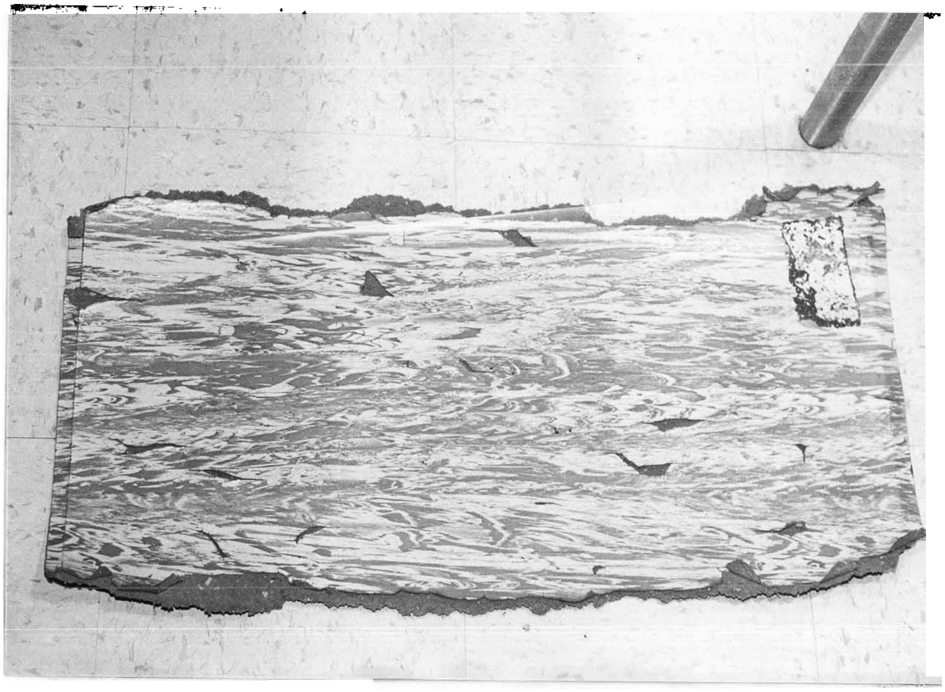
The unsatisfactory location of the bag-well causes the knees to strike against the ledge.

Low counter heights and inadequate leg space result in poor working postures.

Photographs 22 and 23. Bending, reaching and leaning forward as a function of poor workstation design.

Touch checking and bagging in one continous motion.

Photographs 24 and 25. Fatigue mats used by cashier operators (some do not even have one).



VI. DISCUSSION AND CONCLUSIONS

Results of this study suggest that British Columbia cashier operators suffer from the same problems affecting other operators around the world. Based on anthropometric data, the present check-stands require excessive reaching and bending in confined work spaces. These factors may be contributing to lower back injuries, contusions, bruises, and upper limb problems, which may be exacerbated by the need to stand throughout the workshift.

The anthropometric findings suggest that in the design of "new" check-stands, it is necessary to go beyond merely integrating new systems into existing workstations and examining the operation of the equipment. Marrying a twentieth century electronic scanner with a nineteenth century check-stand does not benefit anyone. Introducing electronic equipment, which drastically changes the function of the job, requires innovative new work methods and adherence to ergonomic principles, which optimize the user-system interface and minimize the health problems of cashier operators.

Body position should be considered as an integral part of all industrial operations, especially when new work-stations are developed with the introduction of technologically-advanced equipment. There are two basic tenets that should be stressed with respect to developing a workstation: (1) it should be possible to adopt more than one posture to complete the task; and (2) in most instances it is necessary to design the workstation to accommodate more than just one size of worker.

Questionnaire results for upper limb problems in this study may be interpreted in relation to changes in work method inherently involved in mechanized and partially automated processes. Both electronic keying and scanning have:
1) apparently made mental and physical workloads lighter, but have resulted in increased consistency of physical movements - meaning workloads are locally concentrated in bodily parts such as arms, shoulders, low back, or eyes, as evidenced in the postural fatigue pattern; and 2) produced a working situation with an elevated rate of work in which a worker is required to perform monotonous tasks with increased attention and patience (Ohara et al., 1976a).

Table 13 and photographs 12-17 suggest that OCBS is increasing with the use of electronic scanning and the reduced need for the keyboard, because awkward bending postures, incorrect counter heights, and mental stress of the work place are maintained, resulting in muscle tension and static activity (Ohara et al., 1976a).

Several possible explanations for the high incidence of headaches can be considered. There seemed to be a large number of respondents who experienced the "price read-out" to cause glare and eye squinting, especially if the sunshine reflected on it. A synergistic effect may have been induced through the muscle tensions in the neck and shoulders of the work posture adopted. From personal observation, it appeared that the "price read-outs" were often placed at an extended viewing distance (1 m) and in generally awkward locations (behind the cashier), potentially causing excessive fatigue and strain to the eyes and neck (Photographs 18-19). Alternatively, the headaches may be manifestations of psychological and physiological responses to mental stresses (Johannson et al., 1978) experienced by the operators.

The hand dynomometer did not record any changes in hand strength during the day. It may not be an ideal instrument for fatigue testing. For example, strength measurements are largely dependent on the motivation of the subject, which is not easily controlled.

This study attempted to measure the extent of lower extremity blood pooling taking place in cashier operators by measuring changes in leg circumference. Results are reported in Table 11. Significant changes in calf size over the day were measured amongst the subjects tested ($p<0.05$), despite the fact that the subjects did a fair amount of walking (as a function of work method).

This study measured statistically significant changes in leg circumference amongst cashier operators. However, the findings are limited by the lack of controls. Nevertheless as suggested by this study the stress of standing for a given workshift contributes in part to leg edema, feet pain, and postural fatigue in the lower back. Studies have shown that occupations with optional seating have definite advantages over occupations which require exclusive standing or sitting. Combined sitting and standing work situations are more beneficial to the circulatory system and skeletal systems, as they enable the worker to maintain: 1) better posture; 2) reduced muscular activity; 3) lower intravascular pressure; 4) decreased muscular fatigue; 5) a lower incidence of varicose veins; and 6) reduced low-back pain (Fernandez, 1972; Mueller, 1975; Ayoub, 1973).

Tyrer and Lee (1979) have advocated the following ergonomic principles for jobs in which work must be done standing, without provision for the operator to sit. Photographs 20-23 illustrate deficiences in observed register operator work stations, relative to these principles:

1. There must be sufficient foot and knee room for mobility (Photographs 20-21);
2. The worker should not have to adopt a bent posture (Photographs 22-23);
3. The working height should be such as to allow the use of the arm muscles to the best mechanical advantage;
4. Bench working height should be at, or just below, elbow height; and
5. Frequent walking to improve circulation should be allowed and encouraged.

Furthermore, fatigue floor mats of adequate thickness (e.g., 3-5 cm) should be provided (Photographs 24-25), as they promote phasic activity of muscles in the legs which help pump venous blood back toward the heart (Brantingham et al., 1970).

Finally, workers should be made aware of appropriate footwear in standing jobs. For example, tight bands of nylons, knee socks, or stockings intensify the discomfort of standing too long in one place.

The preponderance of low back injuries and pains reported by the operators strongly suggests the need for counter measures. Long standing produces muscle fatigue in the abdominal and buttock muscles, increases the curvature of the lower spine and puts a strain on the back. Photographs 12-14 illustrate postures which put strain on the back of checkers and wrappers due to poor ergonomic design. The significance of these observations in accounting for cashier back problems is strengthened by the recent review of Andersson (1979) on the importance of various work place factors to the occurrence and etiology of low back pain. This review found increased sickness and absence due to low back pain in:

1. jobs with high physical demand;
2. jobs with prolonged static work postures;
3. jobs with primarily bent over work postures - exerting greater loads on the back;
4. jobs with sudden (unexpected) high physical work loads or rapid stretch, flexion, and rotational movements; and
5. jobs under vibrational conditions.

Also, a positive relationship was established between low back pain and the number of years on a particular job, independent of the age of the individual, a finding confirmed by this study. Back strains represent the largest category of industrial diseases reported. It has been suggested that backaches are not usually caused by incorrectly lifting, but rather by overworked muscles that rebel against strain by going into sustained contraction or spasm (Imrie, 1983).

In general, this study has not found evidence of either subjective or objective fatigue amongst the subjects tested. Similar negative results have been obtained in a study of aircraft crew members under high workload conditions (Cameron, 1974). None of the fatigue indicators appeared during the work itself; crew members were "too busy to feel tired". However, delayed onset of subjective feelings of fatigue most likely would occur at the same time as the post-work physiological fatigue, interfering with the normal process of rest and recovery and leading to chronic feelings of fatigue. It also has been noted that in cases where performance deficits have been observed, they usually disappear rather quickly following a rest period.

The non-significant physical fatigue results (Table 12) are somewhat surprising, in light of supermarket records showing that a typical checker keys/scans from 490-800 items per hour, processes 50 to 60 customers per hour, and bags 50-80 bags per hour (an average brown paper bag with contents weighs 7.3 kg, and an average plastic bag 3.1 kg). Postural fatigue would be expected from work at check-stands requiring increased static posture standing in one place for long periods. However, subjects in this study first scanned all the goods, then moved around to the end of the check-stand to bag them, moved to get a buggy, and finally moved back into the check-stand. Furthermore, more significant fatigue results may have been obtained had a busier day been chosen to do the testing (Thursday to Saturday).

Other studies (Tanasescu et al., 1963) have shown the importance of correct body position in reducing fatigue. Constant standing, reaching, bending, and lifting parts (even small parts) produced fatigue during mid-shift and at the end of the shift. Proper placement of material and seating would reduce fatigue. Furthermore, there is an increased energy expenditure at the end of the week as compared to the beginning of the work week, not necessarily discernible to the worker, due to the small increment in physiological fatigue related to repetitive work in awkward postures, even in the case of light work (Taylor, 1915).

It has been recognized for many years that performance deteriorates at an increasing rate once fatigue has set in, and that to prolong working after this point more than proportionally increases the length of rest required to compensate (Taylor, 1915). The foregoing fatigue results and analyses regarding cashier operator work suggest that work stress and fatigue could be reduced through design of check-stands to reduce fatigue, such as by provision of optional sitting and standing arrangements.

The increase in the number of work related wage-loss claim injuries in cashier operators from 1972 to 1982 (Table 12) could be a function of: 1) an increased number of checkers employed in 1982 versus 1972; 2) increased awareness on the part of WCB and the operators themselves regarding work related injuries amongst cashier operators; and/or 3) recent mechanization and automation has resulted in an elevated work rate with insufficient attention paid to the overstrain and stress of workers (Ohara et al., 1976a; Johannsson et al., 1978).

Ideally, a work situation should be so designed that the performing individual produces at economically acceptable rates while, at the same time, enjoying high levels of emotional and physiological well-being (Tichauer, 1976).

By identifying cashier operation hazards related to ergonomic and human factors, this study represents a potential resource to management, unions, workers, manufacturers, engineers, etc. for resolving the design and health problems that exist in this industry. Manufacturers of products can no longer afford to ignore the increased demand for well-designed and safe products and systems. Whether this demand is due to consumer awareness, government interest and enforcement, or improved technology, efforts must be made to reduce poor design that causes injury loss and impaired performance. Effective application of present knowledge of ergonomic principles can be used to improve occupational health in the workplace, and further study of these principles should be pursued.

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C. STUDY 3. POSTURAL ANALYSIS OF CASHIER OPERATORS

I. INTRODUCTION

Some 260 years ago, Bernadiro Ramazzini, the founder of occupational medicine, realized that occupations conducted predominantly in a standing position engendered health problems peculiar to the posture, and suggested limiting the time spent in a standing posture.

However, before a decision can be made on the appropriate posture for a given work activity, careful consideration must be given to the anthropometric, physiological, and biomechanical characteristics of the worker on the one hand and the work requirements and physical constraints of the equipment on the other.

Inadequately designed workstations may result in the adoption of assymetrical work postures. For example, if the body weight is shifted onto a particular limb, constant contraction of antagonistic (balancing) muscles will be necessary in order to maintain the unfavourable position. Posture is the resultant product of balancing of body segments from the feet up and must be regarded as a composite whole. Assymetrical or dynamic movement of any one segment anteriorly, posteriorly, or laterally, leads to adjustment in some or all other segments. Postures adopted by workers may be repeated many times a day, and daily for many years, and thus can be expected to affect the musculo-skeletal system and work efficiency of the individual (Bullinger and Solf, 1979; Frankel and Nordin, 1980). Other research investigations have demonstrated a high correlation between repeatedly assumed, poor working postures and health complaints (Wickstrom, 1978; van Wely, 1970). Furthermore, over the years, several anatomical, biomechanical and physiological work tolerance principles have been established, neglect of which may result in unnecessary physical demands, discomfort, and occupational diseases (Barnes, 1968; Tichauer, 1978).

The effects of repetitive work on the well-being of workers were examined in study of 200 women workers in a watch industry (Ackerman-Liebrich et al., 1979). Positional constraints resulted in an increased incidence of upper limb problems. Additionally, the study found that the greater the individual's perception of work variability and autonomy, the greater was the perceived job satisfaction. Stress may arise from excessive physical environmental characteristics such as excessive noise or light, or may be psychological in nature involving conflict, frustration, or threat (Burrows et al., 1976). Stress exists when the demands on the person are perceived as taxing or exceeding an individual's adjustive capacity (Lazarus, 1976). Excessive stress gives rise to negative emotional experience (such as anxiety, fear, depression) which is accompanied by behavioural, cognitive, and physiological changes (Burrows et al., 1976).

The most common method of analyzing work methods is by direct observation. The reasons for this are that the technique is simple, unambiguous, and minimizes interference with the operator's job. The method entails the systematic observation of an operating system using variable or constant sampling. This results in a large number of instantaneous observations, recorded as frequencies of, and time spent, in certain activities or postures. The purpose of the sampling is to get an accurate description of what an operator or worker does so that a guide may be developed for corrective action.

II. LITERATURE REVIEW

Task and Posture Analysis

In the early 1900's, Fredrick Taylor proposed the concept of 'scientific management' to increase productivity. He stressed the need to 'determine the time required by a qualified and properly trained person working a normal pace to do a specific task or operation' (Barnes, 1968). Until the 1950's this type of analysis was known as time-and-motion study. Nowadays such analysis has been broken down into method study - determining the method by which an individual does a job - and work measurement - the time taken to complete sections of work (Applied Ergonomics Handbook, 1980). These types of studies are used as aids to planning production, estimating costs, and setting up pay schedules for different jobs.

Pre-determined motion time systems, of which the most familiar is Methods Time Measurement (MTM), involve a detailed analysis of short-cycle, repetitive jobs usually examining hand motions. MTM identifies a series of fundamental motions known as 'therbligs' (e.g. grasp, reach, move, hold) which are made, or which it is expected an operative will make, when carrying out a particular task (Konz, 1979). Time values are then assigned to each of these movements and summmed to reach a total time for the task. MTM systems assume that times for successive movements are independent of the individual, or of subsequent activity. Their usefulness is that time values can be assigned to new tasks in the pre-production planning stage (Applied Ergonomics Handbook, 1980).

In order for ergonomics to achieve its goal and assist in the integration of user-system interfaces, it is necessary for the ergonomic analyst to evaluate both the problem and its related design problems (Rohmert, 1980). The ergonomic approach to work evaluation is concerned with system analysis, work station analysis, and posture analysis.

System analysis includes defining the system aims and the various functions needed to achieve those aims, and identifying the work tasks of a work system. Process analysis is a method of system analysis, recording the various interactions of a man-machine system.

a. Process charts describe (i) the various stages in the manufacture or processing of a particular product; or

(ii) the various activities an operator goes through doing his job, using standardized symbols.

b. <u>Flow diagrams</u> are graphs of a process chart showing the locations of all the operations.

The process charts and flow diagrams are primarily used for analyzing work situations which are repetitive and standardized (Chapanis, 1963).

c. <u>Link analysis</u> is similar to a flow diagram except that the linkages between various components are expressed in statistical terms of relative frequencies between components. It is a useful method primarily in solving problems of layout and arrangement of workers and machines. However, it is not concerned with how long a worker spends at a piece of equipment (Chapanis, 1963).

Many different words have been used to describe the components of jobs, though the two most useful ones are function and task analysis (Drury, 1983). Functions are defined as complete operations which are carried out by one person or machine, and are usually further subdivided into tasks. Tasks are the smallest units of behaviour or activities. For example monetary exchange would be considered a function, with the following task subdivisions: receiving money, keying-in amount received, determining change, and giving change. The tasks can be large or small units of behaviour, depending on the size of the function (Drury, 1983).

Work station analysis primarily assesses work station dimensions relative to the functions carried out.

Posture analysis, as the name implies, analyzes the postures operatives assume in order to access and complete a task, and enumerates the length of time spent in each position. When an individual is assigned to a task, it become an integral part of the working environment. Inadequate postures maintained over long periods may cause pain extending beyond the work period and permanently poor physical postures (Corlett and Manenica, 1980). Short term effects have a major influence on performance.

Posture analysis of cashier operators

As discussed in the introduction, a number of studies have related poor postures and the physical demands of different jobs to an increased incidence of musculoskeletal diseases. However, postural analysis of cashier work is relatively sparse.

Grandjean and colleagues , (1968) analyzed the physical demands on sales clerks working in a clothing store. The following postures and times were identified: walking 58 min., standing without supports 3 hr. 55 min., standing against a support 1 hr. 30 min., and bent posture 62 min.. The majority of the health complaints were related to feet, leg, and back pain, as a function of the observed static postures.

Ivergard (1972) studied the behaviour and actions of Swedish cashiers and customers in a grocery store. Results indicated the greatest problems were goods getting stuck in the conveyor belt, the space on the conveyor belt was not large enough, and customers with large orders had problems when they had to pay for and pack their goods in the limited time available.

Elias and colleagues, (1981) did a motion and physiological work study of female checkers using touch-checking registers in a French supermarket. The main emphasis of the study was in identifying poor sitting postures and its effects on arm movement. From questionnaire responses, muscle fatigue was associated with a bent over posture and lifting the arms.

Hoffman (1982) assessed the impact of alternating various design factors in electronic scanning workstations on productivity. The results supported many of the workstation design parameters recommended in the European ergonomic literature, requiring a left-to-right package movement (in the Lower Mainland package movement is from right-to-left, in most instances).

Lastly, Japanese researchers (Ohara et al., 1976) have hypothesized that numerous health complaints, especially those specific to the upper body, would be eliminated with the introduction of touch checking registers (vs. mechanical registers). This has not occurred. The reason probably is that certain types of working postures and arm and hand motions known to cause upper limb disorders are still maintained in the new system (e.g. repetitive finger motion at a high speed; repetitive finger, wrist, and arm motions).

III. DETAILED TASK DESCRIPTIONS OF WORK PATTERNS OF B.C. CASHIER OPERATORS

The checkstand is the point in the store where goods and money change hands. A check-stand consists of three major areas: input, processing, and output (IBM, 1981). The input area is the interface with the shopper, the processing area is the operator and equipment area, and the output is the bagging section. In British Columbia, predominantly two types of cash registers are used - the touch-checking register (TC) and the electronic scanner (ES). Furthermore, there are two different work methods. One involves pricing the product followed by bagging in one continuous motion (P+B); the other method prices all products first, and then is followed by bagging all goods into plastic or paper bags (P-B).

A supermarket may choose any one of four basic methods for pricing and bagging grocery items.

1. Touch-checking Register:
   a. with immediate bagging in one continuous motion (TC:P+B); or
   b. bagging after everything has been keyed in (TC:P-B).
2. Electronic Scanning Register:
   a. with immediate bagging in one continuous motion (ES:P+B); or
   b. bagging after everything has been keyed in (ES:P-B).

Both P-B methods allow a wrapper or customer to help in the bagging process.

The different work methods chosen by the supermarkets, should be accompanied by different check-stand designs, designs which are based on the work-method employed and adhering to ergonomic concepts of user-system limitations.

In repetitive tasks, constrained static sitting or standing postures, and mental or visual stress, are often inherent. From an ergonomic standpoint, these postures pose the risk of pains in the back, shoulder, and neck (Maeda et al., 1980), and the stress produces mental and visual fatigue.

Touch-checking:P+B

Side views of TC operators keying and bagging are shown in Photos 26 and 27. A knee activated lever is used to move the turn-stile, thereby moving the grocery items toward the cashier operator. TC operators reach and grasp a grocery item with their left hand, and key-in with their right hand. The item is then released into a paper bag, sitting in the bag-well. This eliminates the double handling of the merchandise, and, theoretically reduces the total time necessary to process a customer. This type of work method is identified as price and bag (P+B). Usually soft items are placed to the side, to be bagged at the end using both hands. Produce is weighed and priced at the check-out counter. Produce placed on the weigh scale must first stabilize before the price can be keyed in. After all items have been keyed-in and bagged the customer is informed of the total cost. Using both hands to grasp the top of a filled grocery bag, a cashier operator pivots on her feet to place the bag into a buggy on the right hand side of the cash register. This is followed by a transition period of waiting for the customer to extract the necessary money or write a cheque. Once the cashier operator has received the money she keys-in the total, and extracts the change to be returned to the customer. To prepare for the next customer, a new set of paper bags are opened and placed into the bag well.

<u>Electronic Scanning:P-B</u>

Side views of ES operators, scanning followed by bagging, are shown in Photos 28 and 29. Like the TC system, a knee activated lever is used to advance the turn-stile. In ES, the operator selects an article with the right hand, passes it over the fixed slot scanner (window) which reads and decodes the Universal Product Code (UPC), by means of a laser beam to determine the price and to debit the item from the stock inventory. The item then is passed to the left hand and flung to the back of the check-stand. In the meantime, the right hand is reaching for the next article. Identical to TC, produce is weighed at the check-out. However, while the scale is stabilizing other products are being scanned. Once the scale has stabilized, the produce code is keyed-in with the right hand, while the left hand removes the article.

In some instances a UPC label cannot be read by the scanner due to damage or poor printing quality, in which case the checker is informed by the absence of a beep which is normally presented as each item is scanned. In this case, the operator has to either rescan the item or to manually key in the UPC code. Once all the items have been scanned, the operator informs the customer of the total. As the customer extracts money or writes a cheque, the cashier operator bags the items into plastic bags on top of the counter. Depending on the number of bags, a cashier operator may either pass the bag over the counter to the customer, or place it into a buggy. Once the bagging has been completed the cashier takes the money, rings in the amount received, selects the change, and passes the money over to the customer. The turn-stile is once again activated to process the next customer.

ES are rapidly replacing TC registers due to the economic advantages offered by ES register, such as facilitating product ordering, reducing invoicing error, exercising greater inventory control, facilitating sales analysis, monitoring stock levels, and speeding up check-out operation (Wilson et al., 1981).

Photographs 26-29 bear evidence to the fact that check-stand designs have undergone only minimal changes relative to cash register technology. The small incremental changes in design, combined with progressive innovations in register technology and work methods, may contribute to the health problems of cashier operators and, furthermore, do not allow for optimizing work efficiency.

IV. THE STUDY

The purpose of this study is to examine whether there are differences in cashier health complaints in relation to checking system (TC vs ES) and work method (P+B vs P-B), and to test whether there is an interaction between the cash register and work method factors.

Electronic scanning employs both hands alternately, to move products across a scanning window. Theoretically, ES cashiers should experience fewer health impairments in the right shoulder and arm than cashier operators using TC. A similar hypothesis can be formulated for work method. P+B operators should experience more back problems than P-B operators, due to the continued bent over posture employed in the former system (Photos 27 and 29).

On the other hand, there may be no statistically significant differences in the distribution of musculo-skeletal discomforts/pain, based on workstation layout, between the comparison groups. As noted in the first study (Section B), the reason may be that the lack of change in check-stand design, combined with progressive innovations in work methods, is the cause of health complaints of cashier operators.

Depending on which of the above theories is supported in the questionnaire analysis, it should be possible to explain the results through the analysis of the task and the various postures adopted in the work procedure. In other words, if pain in the lower limbs is identified with a particular work method, it may be attributed to static standing and/or task function such as keying and bagging in the same spot, allowing little flexibility in posture variability.

V. METHODS

Questionnaires

This study reanalyzed the questionnaires collected in Study 2 (Section B), grouping them into four groups based on: (i) cash register (ES vs TC); and (ii) bagging method (P-B vs P+B). To document variations in health impairments between the groups, the questions related to health were grouped into five categories: upper limb (15 questions), lower limb (15 questions), back (3 questions), psychological (4 questions), and all complaints combined (32 questions, eliminating duplicate questions). One point was given for each question answered affirmatively. Since some questionnaires from the previous study had missing data, only seventy-one questionnaires were analyzed. Frequency analysis and a 2 x 2 analysis of variance factorial design (Hull and Nie, 1979) was used to analyze the data obtained from the study.

Photographs 26. Keying and bagging in one contious motion (T-C:P+B).

Photograph 27. Keying followed by bagging (T-C:P-B).

Photograph 28. Scanning and bagging in one continous motion (ES:P+B).

Photograph 29. Scanning followed by bagging (ES:P-B).

Posture and Task Analysis

To analyze the various tasks and postures that may be contributing to the health complaints of cashier operators, 30 minute video recordings of six females in good health and employed as cashier operators for more than a year were carried out during normal work operations. Recordings of three checkers using the TC:P+B system (Safeway), and of three checkers using the ES:P-B system (Super Valu), were recorded on a Tuesday and Wednesday morning respectively.

The reasons these cashiering operations were chosen are:

1. these stores had participated in the previous study (Section B);
2. initial questionnaire analysis established no interaction between the type of cash register used and work method employed in affecting health complaints;
3. funding was limited and hence to gain the broadest understanding of the problem four different variables were studied: TC, ES, P-B and P+B.

Video recordings were analyzed based on: (i) activity sampling in 10 sec. intervals for basic work activities: scanning, keying, reaching, bagging, money transaction, transition, and lifting bag; and (ii) multi-moment sampling in 10 sec. intervals for basic work postures: head bent forward or straight; back straight, slightly bent (10 degrees), excessively bent (60-90 degrees) or twisted; and arms (right, left, both) under load.

VI. RESULTS

Questionnaires

The seventy-one questionnaires analyzed were grouped into the following work methods:

Work Method	N	% of Total
ES:P-B	18	25
ES:P+B	14	20
TC:P+B	32	45
TC:P-B	7	10
TOTAL	71	100

The histograms in Figures 11 to 15 report the percentage of cashier operators reporting health complaints related to body part and work method used. The results indicate that cashier operators using the P+B work method had more upper limb problems (Figure 11), lower limb problems (Figure 12), and over-all symptoms (Figure 15), than operators using the P-B system. There are no consistent relationships between cash register design (TC; ES) and health complaints. These results suggest that the bagging method may be a primary factor contributing to the health problems of cashier operators. Regardless of which system was in use, cashier operators reported a high incidence of back pain (Figure 13) and psychological symptoms (Fiure 14).

For the various symptom categories, regrouping the questionnaires to examine the individual effects of cash register or bagging method on health problems established no significant differences for cash registers. However, statistically significant differences were observed between bagging methods, relative to lower limb and all symptoms combined (Table 16).

<u>Posture and Task Analysis</u>

The number of observations, items, and bags per customer are comparable for the ES:P-B and TC:P+B tasks (Table 17).

Posture and task analyses are reported in the form of frequency bar charts in Figures 16 and 17. Postural analysis (Figure 16) indicates that cashier operators using the TC:P+B system show a higher percentage of bending their head, bending and twisting their torso, and having their arms engaged in a loaded activity. Task analysis (Figure 17) indicates that the action of scanning or pricing the items involves about 30 per cent of the cashiers' working time, for either system. The time spent in transition accounts for another 33 percent of a touch-checking operator's time, while only 15 per cent in the case of scanning operations. The short time spent keying (11%)

in ES:P-B reflects the nature of the system. Similarly, the number of times a cashier operator was observed bagging was slightly higher in ES:P-B, since bagging took place after all items had been scanned, rather than between keying activities as in the TC:P+B system.

Table 16: Analysis of variance summary for grouped health symptoms as a function of bagging method

	Observed Means		Mean	F
Symptom Group	P+B	P-B	Square	Value
Upper limb	1.15	0.84	1.34	1.67
Lower limb	1.46	1.03	2.71	4.03*
Back pain	1.29	1.41	0.25	0.48
Psychological	1.71	1.52	0.61	1.68
All symptoms	1.93	1.45	3.17	6.29*

Note df=1 for bagging method; df=64 for within. *p<0.05

Table 17: Workstation Task Characteristics.

	ES:P-B	TC:P+B
Number of observations	411	575
Number of customers	51	61
Number of items	734	911
Number of bags	93	96
Number observations/customer	8.1	9.8
Number items/customer	14.4	14.9
Number bags/customer	1.8	1.6

Figure 11: Percentage of cashier operators reporting upper limb symptoms by check-stand design

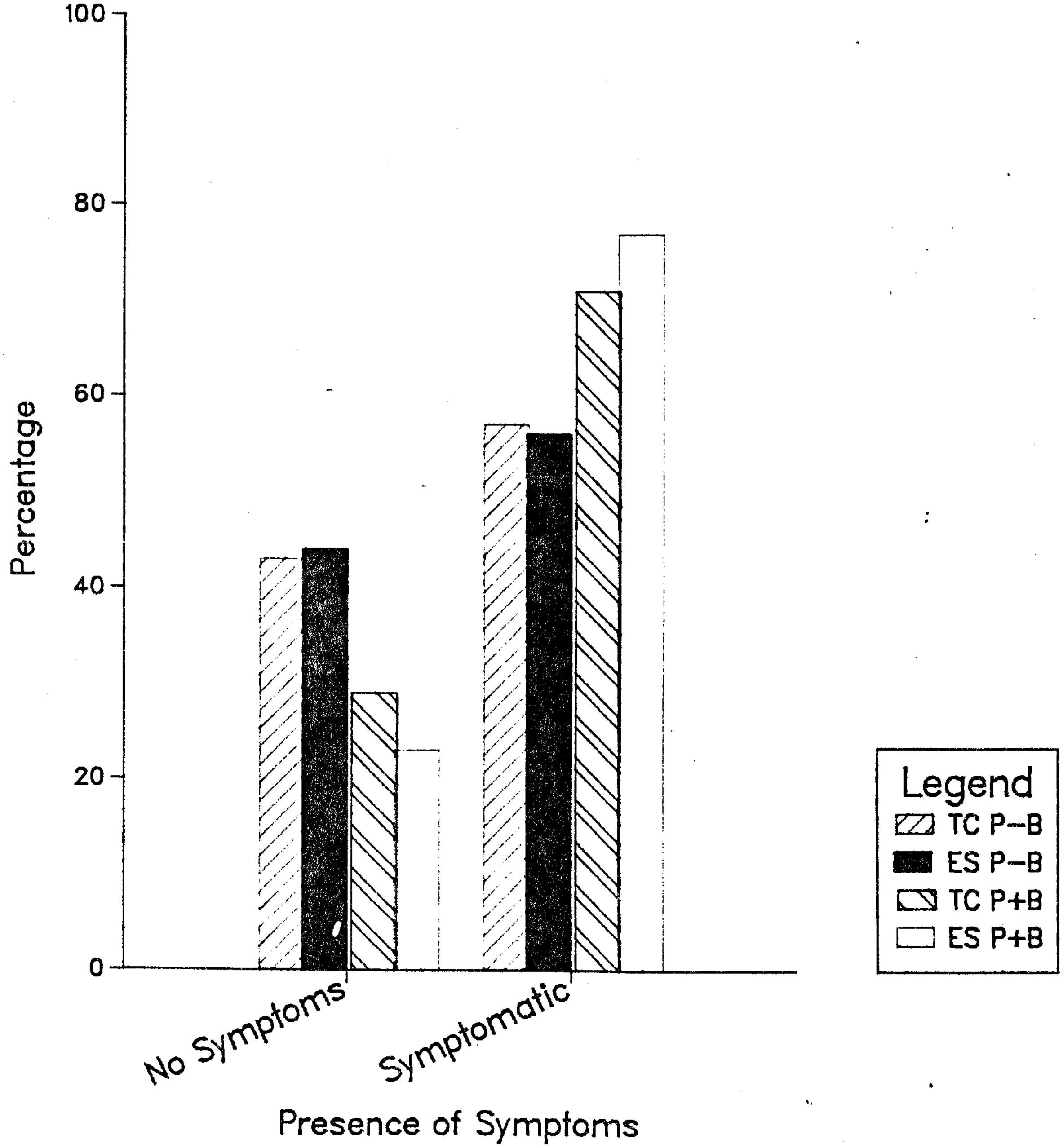


Figure 12: Percentage of cashier operators reporting lower limb symptoms by check-stand design

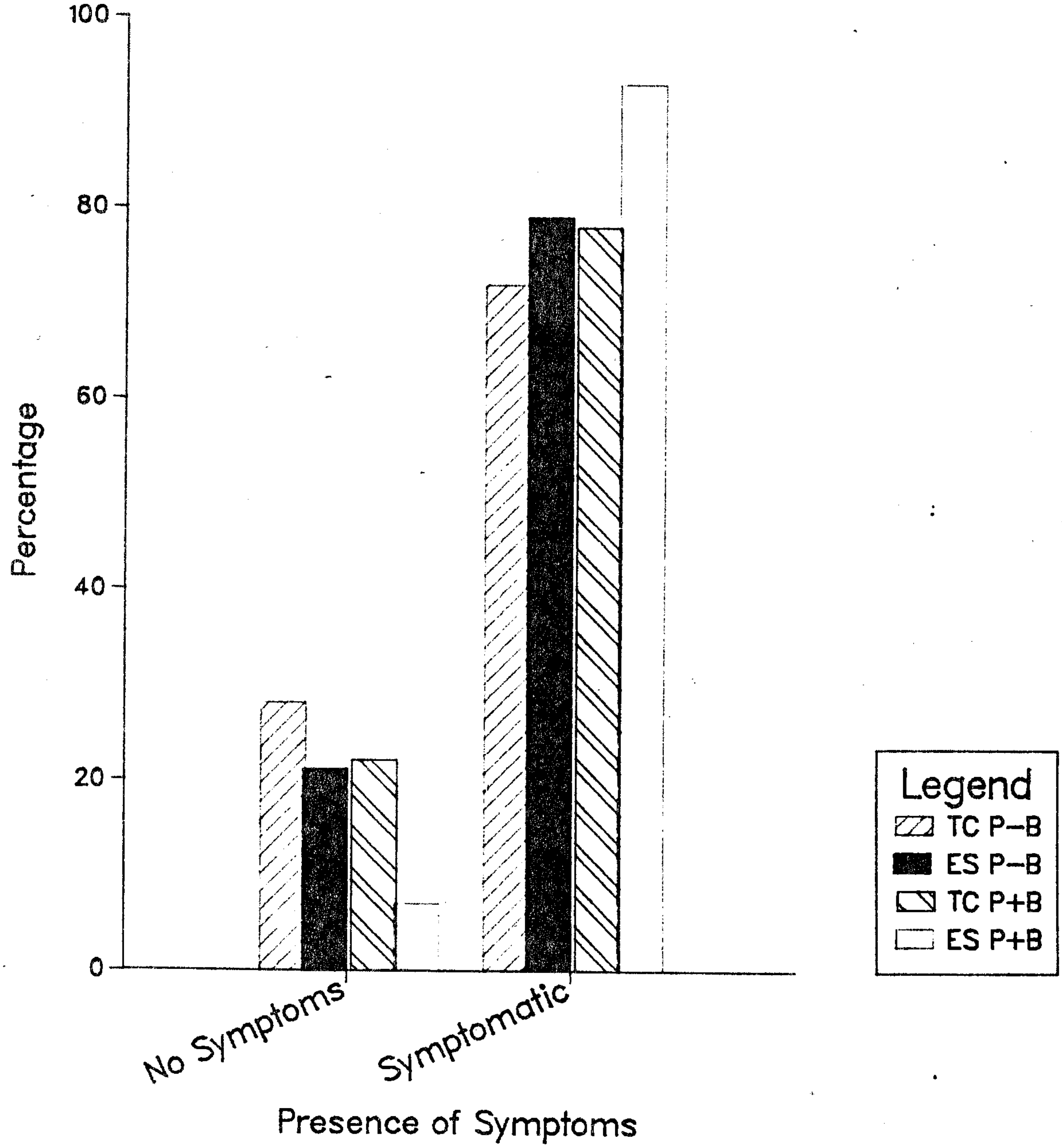


Figure 13: Percentage of cashier operators reporting back symptoms by check-stand design

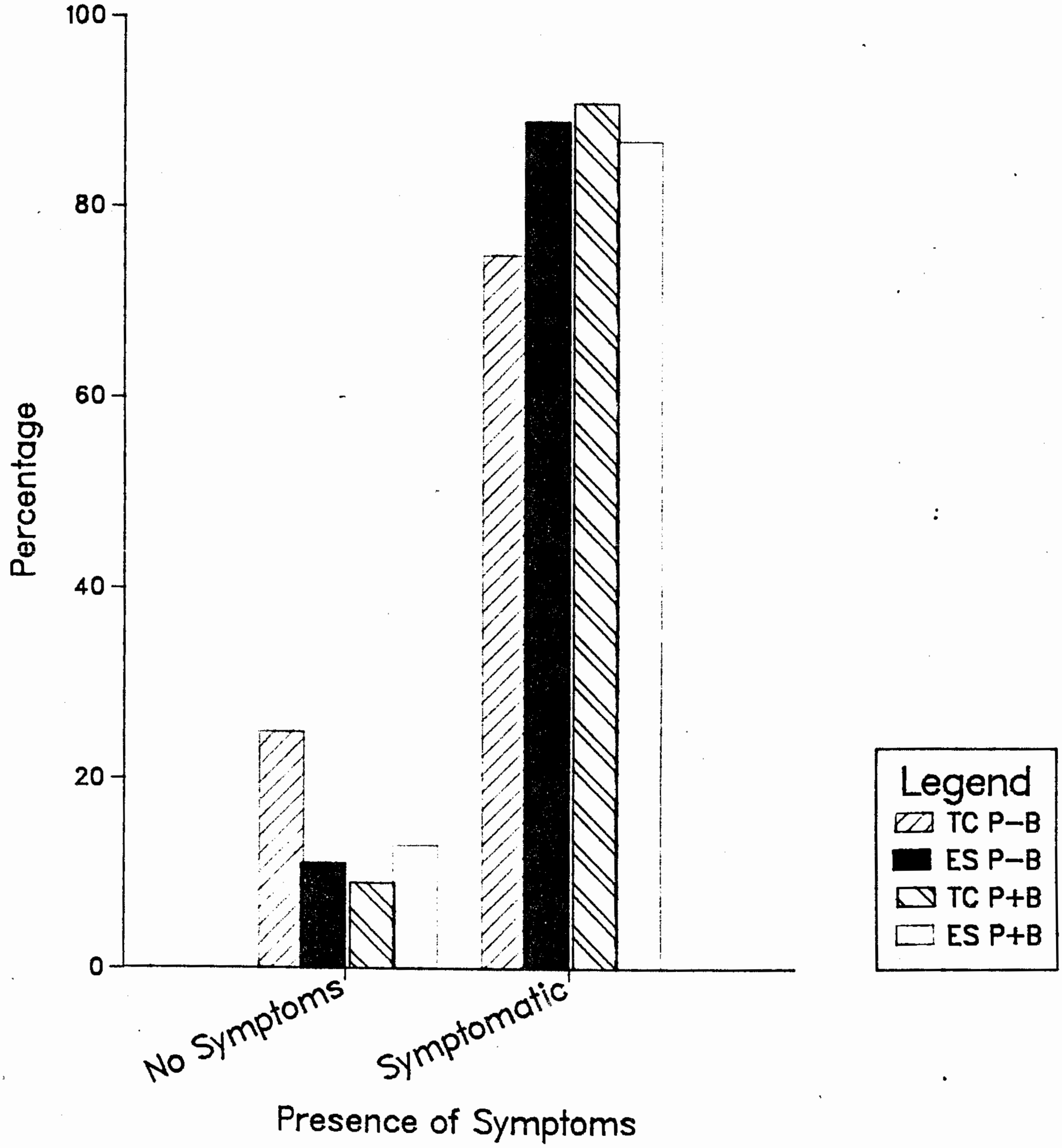


Figure 14: Percentage of cashier operators reporting psychological symptoms by check-stand design

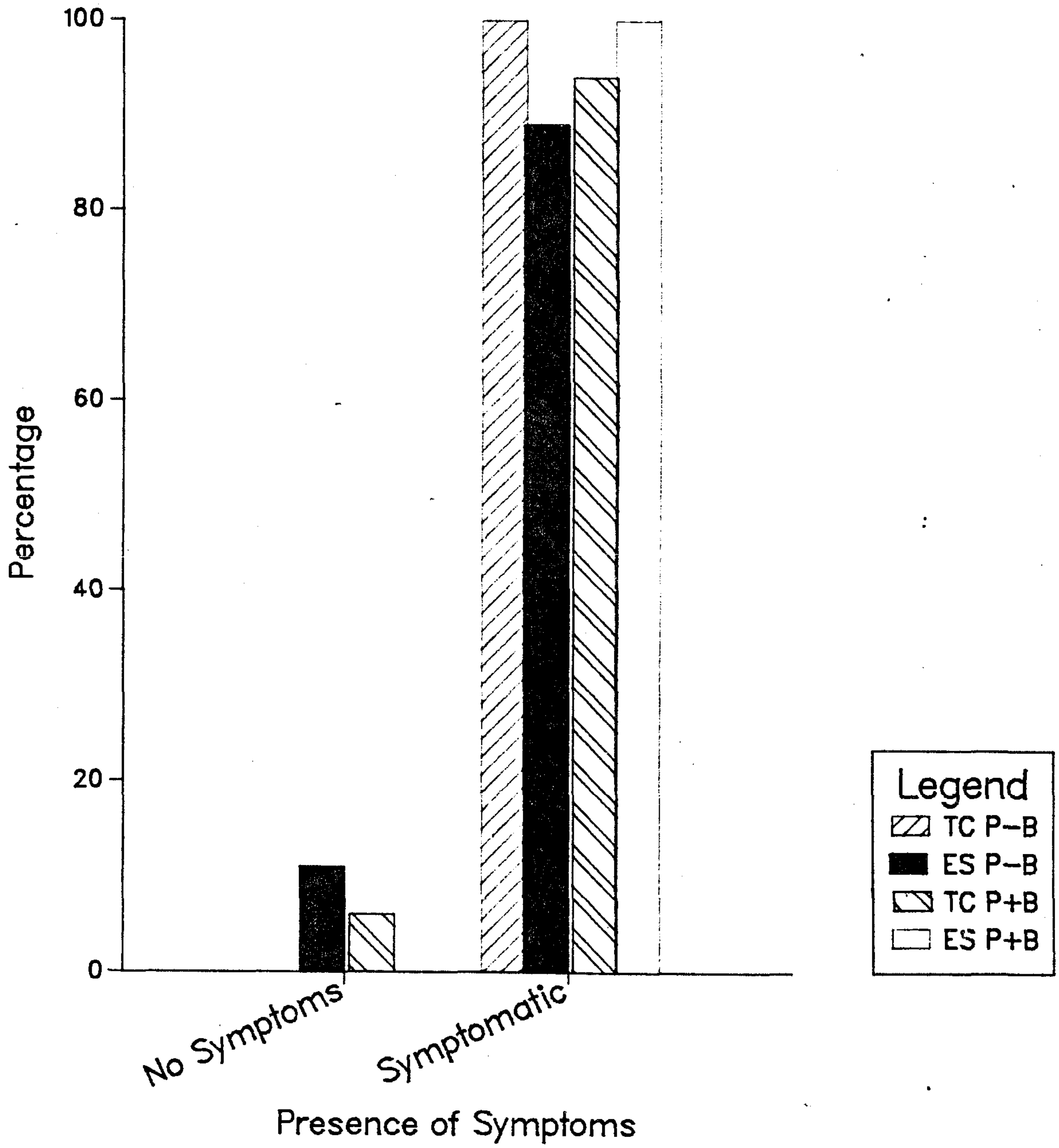


Figure 15: Percentage of cashier operators reporting symptoms by check-stand design

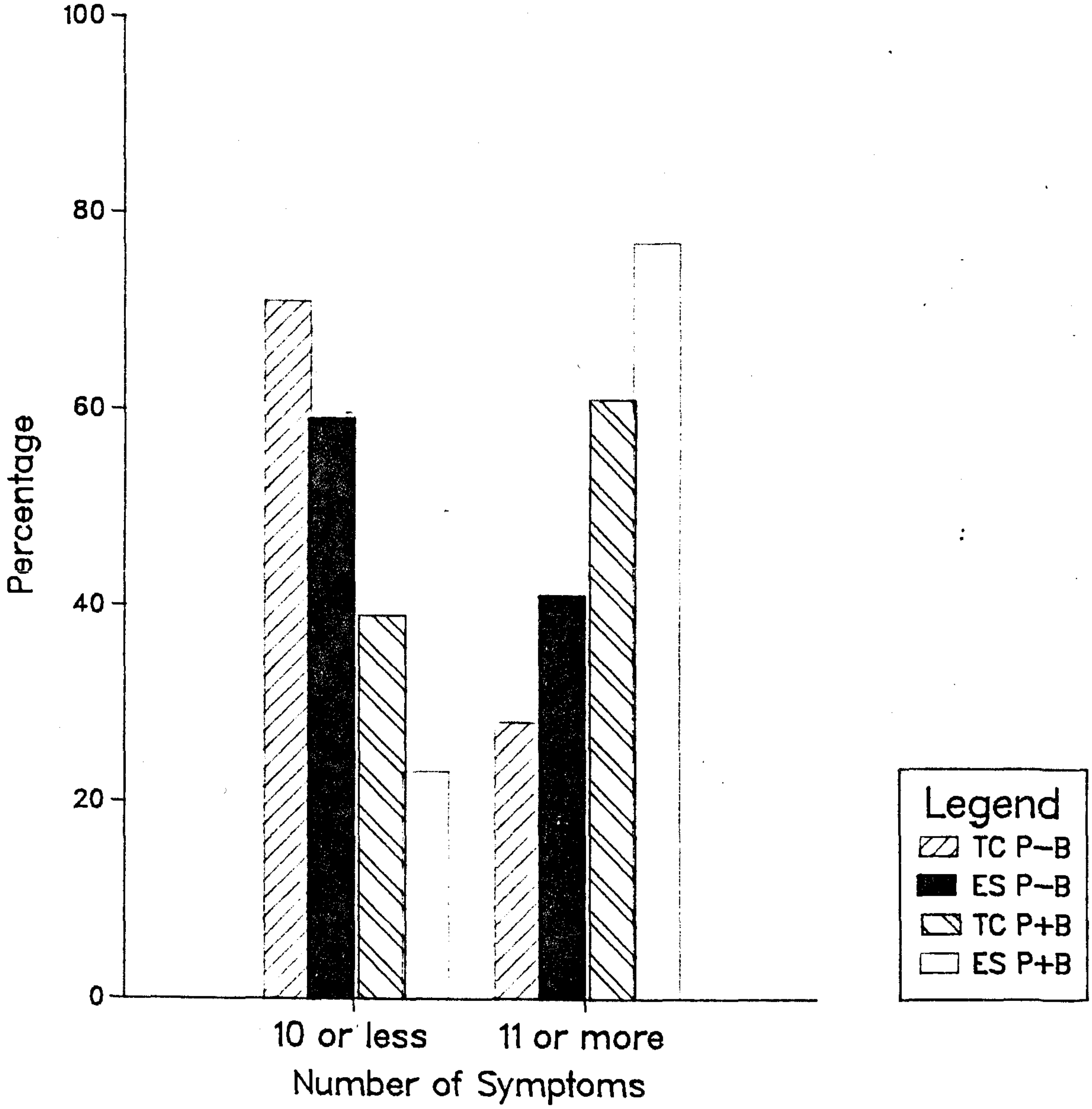


Figure 16: Posture Analysis of cashier operators
Using the TC:P+B vs ES:P–B Work Stations
ES:P–B=411 observations
TC:P+B=595 observations

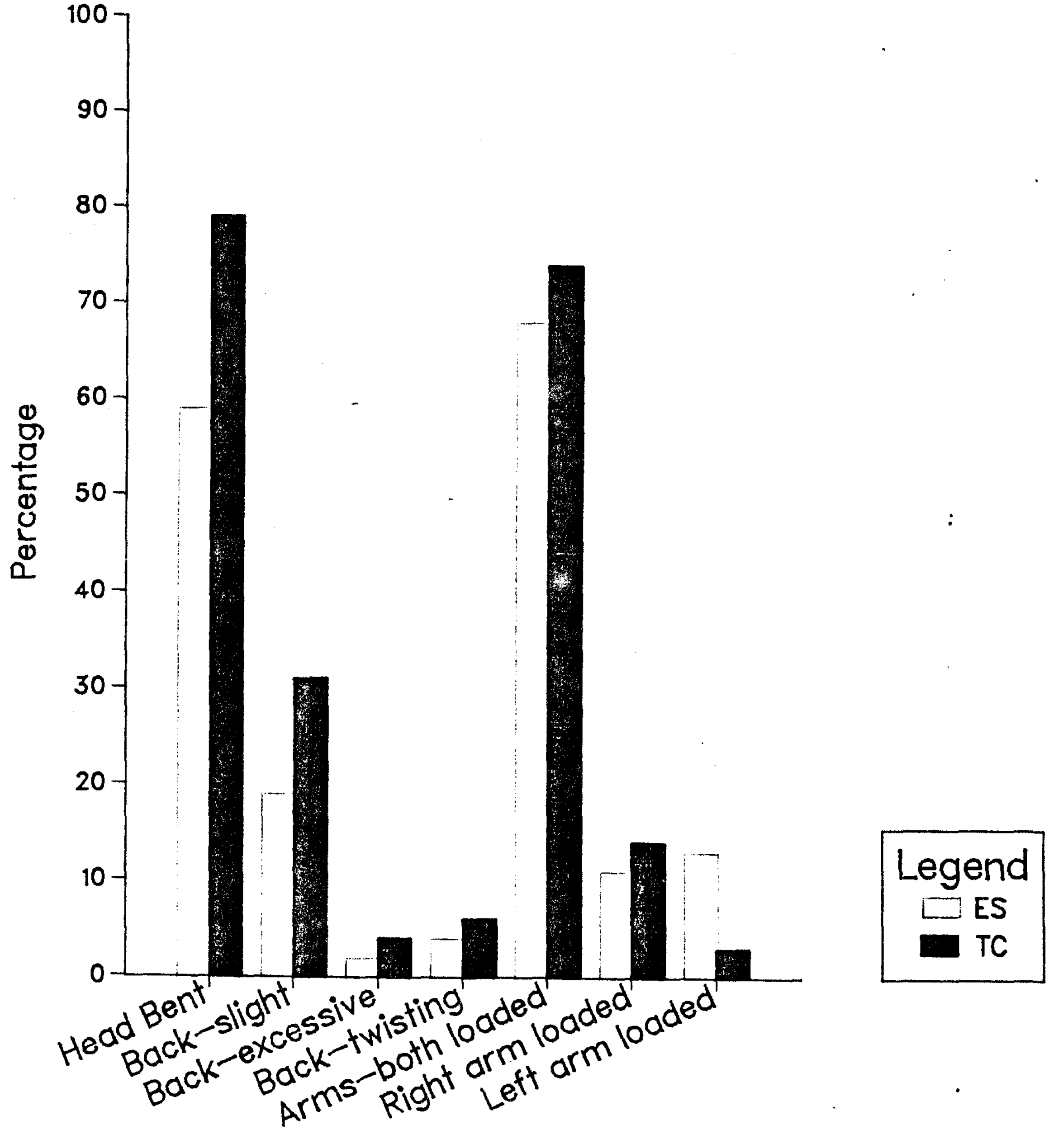
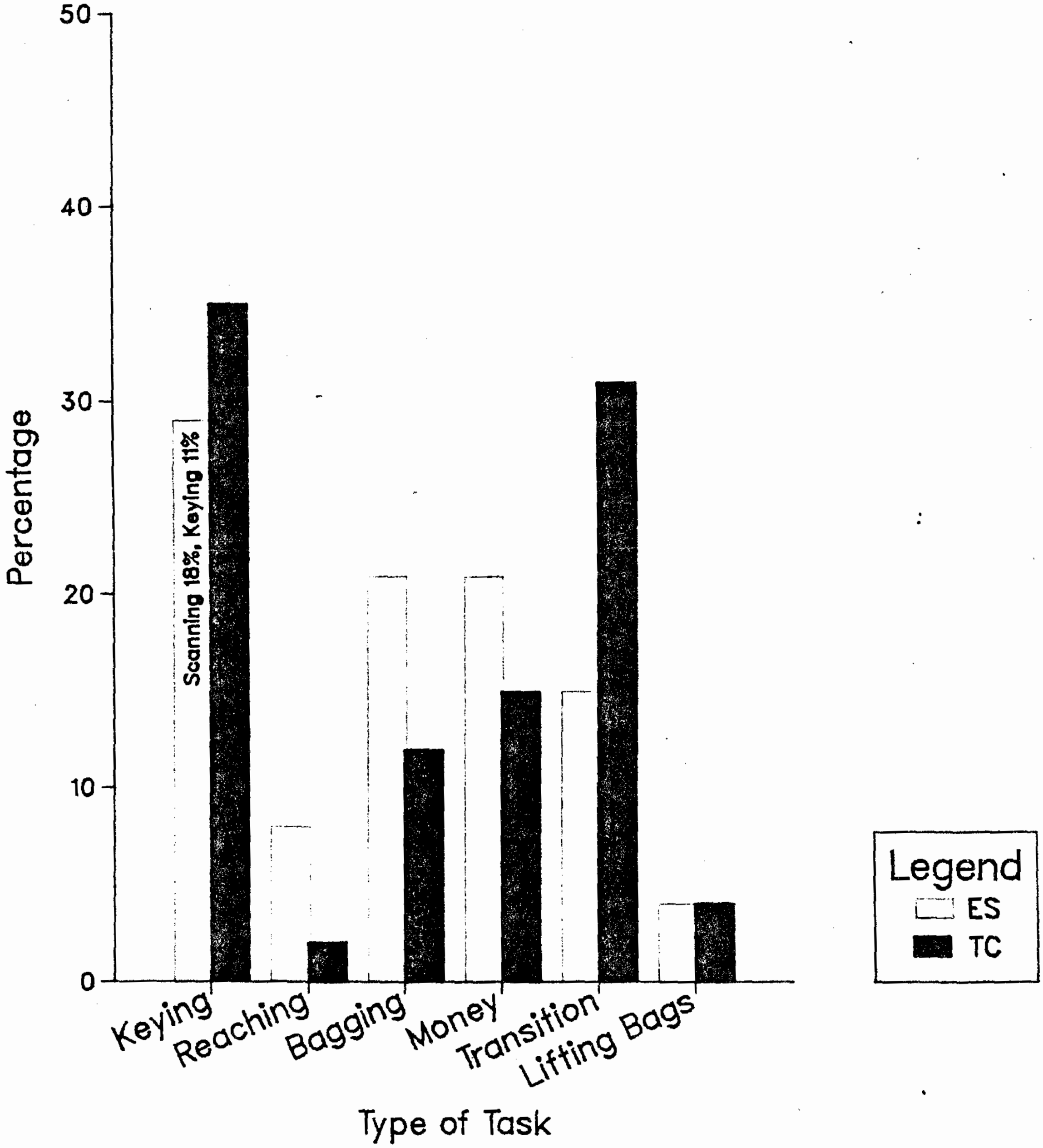


Figure 17: Task Analysis of cashier operators Using the TC:P+B vs ES:P−B Work Stations
ES:P−B=411 observations=100%
TC:P+B=595 observations=100%



VII. DISCUSSION

The definition of good posture has been summarised by Winters (1952) as 'The alignment which permits the musculo-skeletal system to function most efficiently when standing, is one in which the body segments are superimposed upon each other in a vertical column, so that the weight is centered at the gravital line which in turn passes through the center of the base of support...'. Unfortunately, body postures which working people often assume during their occupational activities impose inappropriate segment specific loads, with resultant psycho-physical stress and protypical adaptation reactions (e.g., "I'm used to it"), and/or even reduced functioning (such as fatigue or injury). The cost of a poorly designed workstation which commits the body to a poor postural disposition includes:

i) injuries and strains;

ii) increased fatigue;

iii) greater possibility of accidents; and/or

iv) greater probability of error.

Upper Limb Findings

Similar to findings in Japan (Ohara *et al*., 1976) (where mechanical cash registers were replaced with electronic cash registers which require less key-force depression), this study found that upper limb problems amongst cashier operators have not been reduced with the introduction of electronic scanners.

However, in the case of upper limb symptoms, the bagging method seems to have the greatest impact on the number of problems reported, regardless of cash register used (Figure 11). The work method of processing articles and bagging in one continuous motion imposes a considerable physical burden on the upper body through the height differences between the left and right task components (cash register or scanner height vs bag-well height). Continually extending the hand away from the body increases the torque in the shoulder due to the arm weight, shortens the active deltoid muscle and in turn reduces physiological efficiency, with concomitant upper arm (biceps) muscle fatigue (Chaffin, 1973).

Figure 16 demonstrates that cashier operators using TC:P+B method assumed bent-over postures for longer periods of time during the work day. One of the commonest complaints in bench type operations is neck and upper back discomfort. This is often due to workplace layout requiring the person to hold their head tilted forward to visualize their work. Tilting the head more than 30 degrees greatly increases the neck extensor fatigue rates. It also has been noted that this high forward tilt increases vertical spine compression (Tichauer, 1968). Maintaining a semi-bent posture for bagging necessitates a forced static work posture which can cause stressed back and neck muscles as well as shoulder and upper arm fatigue.

Static work is characterized by sustained exertion of specific muscle groups. During moderate to heavy contractions blood flow is reduced and metabolites accumulate, resulting in localized muscle pain in the muscle (Chaffin, 1973). Muscle fatigue is manifested not only as simple pain, but also in terms of other changes such as decreased ability of the muscles to relax and contract, decreased muscular co-ordination, decreased regional blood supply to the muscles, and elevation of the arterial pressure (Gundareva, 1978).

Reasons which may explain why ES:P+B operators reported the highest number of upper limb symptoms (Figure 11) are: 1) the ES workstation usually requires greater reaches which increase physical requirements substantially; 2) scanning increases physical item handling, eliminating the traditional way of using only the left hand for moving items; 3) increased work rates; and 4) the need for constantly orientating the grocery items for the scanner to read the UPC code, which involves extensive wrist flexion, extension, and rotation. The UPC symbol guidelines recommend the symbols to be located on the natural bottom of an item. In practice, less than 50% of the items may have the symbol in that location (IBM, 1981).

Lower Limb Findings

Questionnaire analysis has identified lower limb problems to be more significant in check-stands employing the P+B work method (Figure 13). Lower limb postures could not be verified by the posture analysis, since the legs were not visible to the camera. However, the above analysis strongly suggests that the static standing postures assumed during pricing and bagging are the primary cause for lower limb problems. The work method of pricing followed by bagging provides greater opportunity for walking during the bagging phase, which may be done either from inside the designated work area or by moving out and around to the end of the counter.

Prolonged standing has its greatest effect on the skeletal and circulatory system, with sales clerks reporting the greatest number of pain symptoms when compared to other occupations (Grandjean et al., 1968). The primary skeletal areas affected are the spinal column, shoulder girdle, and feet, whereas the venous system in the legs is the most affected circulatory system component. Relative to sitting or prone postures, heart rate is increased, cardiac output is decreased, and energy requirements are increased by 20 - 30% in a standing posture. Minimal dynamic muscle activity in the legs obstructs sufficient venous return. This leads to varicoses, especially in susceptible individuals, and usually exacerbates feet pain. Feet pain is caused by gradual compression of the tissues within the soles of the feet, reducing the shock-absorbing ability of the natural fibro-fatty padding beneath the heels and metatarsal heads (Turvey, 1970). This loss in cushioning irritates the pressure endings in the feet. Additional overstrain may make itself noticeable in the condition frequently referred to as 'flat foot', which results from loss of "springiness" in the arch due to stretching of the arch ligaments.

All of these considerations suggest that standing for any length of time should be kept to a minimum. Standing increases lower limb hydrostatic pressure, reduces venous pump activity, and increases leg volume (edema) by 4.5%, whereas occupations requiring walking 65% and sitting 35% of the time exhibit considerably reduced leg edema (Dupuis et al., 1980).

Low Back Pain

Regardless of which workstation and work method was applied, all operators experienced low back pain (Figure 13). Posture analysis shows that the head and back were bent more frequently in operators using the TC:P+B check-stand. The reasons for a bent head are several: 1) to read the price label on an article; 2) to read the display printer (located at upper arm height); and 3) to bag the articles at a bag-well height of 47 cm, necessitating a flexed posture.

The flexed position leads to a reduction in cervical and lumbar lordosis. Even slight torso inclinations of 20 degrees forward of the vertical cause the neck to be flexed, resulting in a forward displacement of the head (Davis, 1967). These two effects considerably lengthen the lever arm on which the weight of the upper body acts, and increase the moment which the muscles controlling spinal flexion must develop, thereby stressing the lower back (Kumar and Scaife, 1979). Even in slight flexion repeated lifting could possibly cause fatigue damage to the osteoligamentous spine (Adams and Hutton, 1981).

Workers exposed to excessive manual handling tasks, such as lifting, lowering, or pushing, pulling and carrying, were three times more susceptible to compensable low back injury (Snook *et al.*, 1978). Lifting is the activity most frequently (37-49%) associated with the onset of low back symptoms. Other activities that are commonly associated with the onset of low back symptoms are bending (12 - 14%), twisting (9 - 18%) and falling or slipping (7 - 13%) (Snook, 1982). Industrial lifting tasks requiring bending which start below a height of 76 cm (30 inches) are associated with 78% of the lifting injuries (Snook *et al.*, 1978). The annual rate of low back pain varies considerably among different industries. Recently compiled data by the State of California (California, 1980), for disabling back strains per 100 workers, showed that the average for all industries as 0.78%, whereas the rate for food stores was 1.44%, classified with other industries under a high annual rate (1.00 - 1.49%).

Although the task analysis in this study indicates that cashier operators using ES:P-B require more bagging time than TC:P+B operators, this probably is not the case. Throughout the keying entry activity, TC:P+B cashier operators were bagging between key entries, in addition to bagging double-handed the items put aside for the end. Increased bagging activity may have been documented had the sampling intervals used in the task analysis been shorter. In ES task analysis, bagging was observed as a single activity. The main difference between the two methods, however, is that most of ES bagging took place at a height of 92 cm, whereas TC bagging occurred at a height of 48cm, necessitating a stooped posture. Occassionally operators using either bagging method were observed twisting or twisting and bending. Relative to the intradiscal pressure or loads in the upright standing position, pressures are increased by 100% during forward leaning with weight lifting, and by 400% during forward flexion and rotation with weight lifing (Nachemson, 1981).

Psychological Stress

All cashier operators experienced a high degree of fatigue and irritability (Figure 14) in all check-stands. Strasser and Mueller-Limmroth, (1982) have aptly described the qualities an operator must display, and which may be contributing to the psychological stress reported in this study. A cashier must have the following abilities:

1. - manual dexterity while keying, in the handling of items and money matters;
2. - good memory for numbers and people and the ability to concentrate on prices, numbers, and signals;
3. - self-dependency, tidiness, organizational abilities, responsibility; and
4. -the ability to interact with customers.

Above all else the operator must be friendly, polite, diplomatic, and possess a high degree of self-control. The cashier operator is usually the only store personnel the customer comes into contact with. This person to person contact is a critical part of the checkout process and usually leaves the customer with an impression of the store and may be decisive as to whether the customer will return or not (Strasser and Mueller-Limmroth, 1982). Essentially the cashier operator is the public relations officer of the supermarket store. Consistant in all check stands and work methods, both environmental and psychological factors seem to be contributing to the physiological and behavioural changes taking place in cashier operators in response to stress. Similar changes were observed by Martin and colleagues (1980), indicating increased incidence of physical complaints due to constrained postures as well as some changes in satisfaction.

All Symptoms Combined

When all health complaints are combined, the work method P+B has significantly more problems than P-B (Figure 12). This is primarily due to the one-sided loading of the upper limbs, and operating in a perpetual flexed position to reach and bag the articles. Such postures have been identified as stressing the shoulder and neck muscles, including the lower back. In addition, standing for long periods leads to increased strain of the skeletal and circulatory system, leading to increased problems and illnesses of the feet and legs. A workstation not designed for the human being can lead to high requirements being placed on body posture, movements, and mental ability (Maeda et al., 1980; Tichauer, 1978; Grandjean, 1980; Armstrong and

Langolf, 1983).

The quality of performance of a system is determined in part by its 'quality of design' and 'conformance' (Bailey, 1982). If the quality of design is not defined in terms of potential users, or if there is a lack of conformance to the human performance requirements, the quality of performance will be adversely affected.

VIII. CONCLUSION

Ergonomic improvements involving workstation heights and layout, and work procedure, are necessary to prevent localized fatigue and ill health to operators. Manual materials handling jobs should be designed so that task pace, distance travelled, object weight, and vertical lift heights are minimized. Asymmetric loading of the upper limbs should be avoided, and also continuous loading of the legs. The decisive factor in easing the strain of a job and thereby minimizing the demands on a person is the opportunity to change body positions.

The major areas that need to be addressed in future check-stand designs include upper limb loading, repetitive wrist flexion/extension, lower limb symptoms; back pain symptoms and psychological stress. Task analysis supports the theory that P-B is a preferred work method, decreasing total time spent keying (memorizing prices) and in transistion (standing around waiting for the customer to extract the money), two activities which have a negative impact on work efficiency.

Some time-motion study engineers would argue that P+B is faster, requiring less total time to process a customer, by avoiding the double handling of products. However, close analysis will show that double handling in P+B is unavoidable due to the unsuitable sequence in which customers unload their buggies, usually presenting soft articles and awkward package sizes first. In fact, due to the fatigue and health problems experienced by cashier operators in the P+B work system, it is very conceivable that overall this is a more costly checkstand healthwise and less efficient requiring longer periods for processing customers. Recommendations for improving checkstands include:

1. the opportunity to work in a variety of body postures which reduce the load of repetitive, one-sided activity and encourage circulatory activity;
2. occasional opportunity should be provided for sitting (though continuous sitting is not advisable); and
3. reaches and heights of work surfaces should adhere to well established ergonomic principles.

Furthermore, this study has demonstrated that both task and posture analysis are necessary in determining, identifying, and targeting problem areas which require ergonomic solutions. It is necessary to obtain a comprehensive view of a situation, otherwise the wrong problem may be addressed.

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D. CONCLUSIONS AND RECOMMENDATIONS - STUDIES B AND C

Summarizing the findings of study B indicates that present checkstands are not designed in consideration of either: (1) ergonomic principles, such as limiting arm reaches to 44 cm and keeping work surface heights at or slightly below elbow height; or (2) anthropometric measures of cashier operators. Usually work patterns included excessive reaches and working above elbow height. Questionnaire responses identified the following problems amongst respondents:

Headaches	47.0%
Neck pain	37.5%
Shoulder pain	49.0%
Arm pain	33.0%
Wrist pain	28.0%
Low back pain	68.0%
Leg swelling	27.0%
Hip pain	29.0%
Thigh pain (R)	23.0%
Feet pain	45.0%

Leg edema was evident, and postural fatigue pattern was specific to the lower back, left shoulder, and right hand after a day's work. W.C.B. wage-loss claims identify over-exertion due to lifting as the most prevelant cause in this industry usually resulting in back strains.

Study C attempts to determine whether checkstand design (cash register type) or work procedure (bagging during or after keying) is associated with health problems amongst operators. The results suggest that it is not the cash register but rather the work procedure, in particular pricing and bagging in one continuous motion, which is associated considerably more with lower limb problems and when all symptoms are combined.

The above results support the following recommendations for the future design of checkstands:

1. limiting arm reaches to 44 cm or less;
2. reducing working height surfaces to 100-105 cm;
3. providing a sit-stand stool for posture variability and for minimizing postural, especially lower back and feet, fatigue/pain;
4. designing left and right handed check-stands, and train the cashier operators to be ambidextrous, to avoid stressing one side of the body only;
5. eliminate pricing and bagging in one continuous motion, especially in a stooped posture; and
6. incorporate some means for the customer rather than the cashier operators to lift bagged grocery bags.

Some of these recommendations have been recently incorporated in a prototype check-stand which I have assisted in developing, in conjunction with the Retail Clerks Union, W.C.B.; and industry.

APPENDIX A - RULES FOR AND SAMPLE CALCULATION OF TYNAN'S (1981) ERGONOMIC COMPOSITE SCORE (ECS) FOR CHAIRS

1. Seat Height - has to adjust from 370-520 mm.
   a. if height adjustment <370 mm score=0;
   b. if height adjustment >520 mm score=0;
   c. if height adjustment is smaller than the range 370-520 mm, add the larger of the two deviations to the ergonomic composite score.
2. Seat Depth
   - has to fall into the range of 380 - 420 mm
   - if seat depth is smaller or exceeds range, calculate feature relative to the nearest standard value.
3. Seat Width - has to fall into the range of 400 - 450 mm
   - if seat width is smaller or exceeds range, calculate feature relative to the nearest standard value.
4. Seat angle - has to adjust from -5 degrees to +10 degrees.
   a. if seat angle adjustment <-5 degrees score=0;
   b. if seat angle adjustment >+10 degrees score=0;
   c. if seat angle is smaller than the range of -5 degrees to +10 degrees, add the larger of the two deviations to the ergonomic composite score.
5. Backrest width - has to be within the range of 300 - 360 mm
   - if backrest width is smaller or exceeds range, calculate feature relative to the nearest standard value.

6. Backrest height - has to be within the range of 230-300mm
   - if backrest height is smaller or exceeds range, calculate feature relative to the nearest standard value.
7. Backrest Height Adjustment - has to adjust from 0-80 mm minimum.
   a. if height adjustment <=0 score=0;
   b. if height adjustment >80 mm, score=0;
   c. if height adjustment is smaller than the range 0-80 mm, add the larger of the two deviations to the ergonomic composite score.
8. Backrest Horizontal Adjustment - has to adjust from 350-500
   a. if horizontal adjustment <350mm score=0;
   b. if horizontal adjustment >500mm score=0;
   c. if horizontal adjustment is smaller than the range 350 - 500 mm, add the larger of the two deviations to the ergonomic composite score

Comments:

1. The other information - base number, type of adjustment cranks, and adjustment location were noted for discussion and importance with respect to using adjustments.
2. Only where dimensions have adjustment ranges does the larger of the two scores become important.
3. Dimensions which were fixed (e.g. backrest width), had to satisfy but not exceed the maximum range.

SAMPLE CALCULATIONS OF ERGONOMIC SCORE

ECS Sample calculation using Tynan's Method for evaluating seat pan.

Dimensions	Prototype Chair	Standard Chair	N.F. Weighting Factor 100/(max.std.-min.std.)
Seat height	420-510	370-520	0.67
Seat depth	390	380-420	2.5
Seat width	380	400-450	2.0

			Tynan's Ergonomic Composite Score
Seat height:			
Standard:	370	520	
Measured:	420	510	
	50	10	
	x 0.67	x 0.67	
ECS =	33.51	6.70	33.5
(use the larger of the two scores)			
Seat depth: falls within standard			0.0
Seat width:			
Minimum standard		400	
Measured		380	
		20	
		x 2	
		40	40.0
			73.5

APPENDIX B - RULES FOR AND SAMPLE CALCULATION OF MODIFIED ERGONOMIC COMPOSITE SCORE (MECS) FOR CHAIRS

1. Seat Height - has to adjust from 370-520 mm.
   a. if height adjustment <370 mm score=0;
   b. if height adjustment >520 mm score=0;
   c. if height adjustment is smaller than the range 370-520 mm, add both deviations to the ergonomic composite score.
2. Seat Depth - should not exceed minimum value of 380 mm as the seat otherwise impinges on the lower leg of the lower percentile of users resulting in thigh and calf compression and irritation. Calculate feature relative to the seat depth of 380 mm.
3. Seat Width - excessive seat width has no negative health effect on the individual, but it may interfere with the table. Too small a seat width does not provide adequate seat support. Calculate feature relative to maximum acceptable seat width of 450 mm.
4. Seat angle - has to adjust from -5 degrees to +10 degrees
   a. if seat angle adjustment <-5 degrees score=0;
   b. if seat angle adjustment >+10 degrees score=0;
   c. if seat angle is smaller than the range of -5 degrees to +10 degrees, add the both deviations to the ergonomic composite score.

5. Backrest width - has to be 360 mm. If backrest width is not contoured and exceeds 360 mm it will interfere with elbow movements. Too small a backrest will not provide adequate support. Calculate feature relative to 360 mm.

6. Backrest Height - should be 300 mm to provide adequate lower back support. Calculate backrest height relative to 300 mm.

7. Backrest Height Adjustment - has to adjust from 0-80 mm minimum.

   a. if height adjustment <=0 score=0;

   b. if height adjustment >80 mm, score=0;

   c. if height adjustment is smaller than the range 0-80 mm, add both deviations to the ergonomic composite score.

8. Backrest Horizontal Adjustment-has to adjust from 350-500mm

   a. if horizontal adjustment <350mm score=0;

   b. if horizontal adjustment >500mm score=0;

   c. if horizontal adjustment is smaller than the range 350 - 500 mm, add both deviations to the ergonomic composite score

SAMPLE CALCULATIONS OF MODIFIED ECS

MECS Sample calculation using Modified Method for evaluating seat pan.

Dimensions	Prototype Chair	Standard Chair	N.F. Weighting Factor 100/(max.std.-min.std.)
Seat height	420-510	370-520	0.67
Seat depth	390	380-420	2.5
Seat width	380	400-450	2.0

			Modified Ergonomic Composite Score
Seat height:			
Standard:	370	520	
Measured:	420	510	
	50	10	
	x 0.67	x 0.67	
MECS =	33.51	6.70	40.2
(add these two together)			
Seat depth:			
Standard:	380		
Measured:	390		
	10		
	x 2.5		
	25.0		25.0
Seat width:			
Standard:	450		
Measured	380		
	70		
	x 2.0		
	140		140.0
			205.2

APPENDIX C - RULES FOR CALCULATING TYNAN'S ERGONOMIC COMPOSITE SCORE (ECS) FOR DESKS

1. Keyboard height - must exceed range for score=0
2. Screen height - must exceed range for score=0
3. Viewing distance - must exceed range for score=0
4. Desk width - measurement must fall within (or exceed) range for score=0
5. Desk depth - measurement must fall within range for score=0
6. Leg clearance height - must exceed range for score=0
7. Depth - must fall within or exceed range for score=0
8. Width - must fall within or exceed range for score=0

APPENDIX D - RULES FOR CALCULATING MODIFIED ERGONOMIC COMPOSITE SCORE (ECS) FOR DESKS

1. Keyboard height - must exceed range for score=0 to accomodate the 5th - 95th percentile of operators otherwise calculate high and low deviation.
2. Screen height - must exceed range for score=0 to accomodate the 5th - 95th percentile of operators, otherwise calculate high and low deviation.
3. Viewing distance - must exceed range for score=0 to accomodate the 5th - 95th percentile of operators, otherwise calculate high and low deviation.
4. Desk width - must meet or exceed minimum width of 1200 mm for score=0.
5. Desk depth - must meet or exceed maximum depth of 900 mm leg clearance for score=0.
6. Leg clearance height - must exceed range for score=0 to accomodate both short and tall operators, otherwise calculate high and low deviation.
7. Leg clearance depth - must meet or exceed maximum depth 460mm for score=0, so that taller operators can comfortably place their legs in front of them.
8. Leg clearance width - must meet or exceed maximum width 600 mm for easy ingress and egress, for score=0.

APPENDIX E: DEVELOPMENT OF RECOMMENDED ERGONOMIC STANDARD (cm)

	Panero & Zelnik 1979	Grandjean 1980	British Standard 3893, 1965	Eastman Kodak Co. 1983	Recommended Ergonomic Standard
SEAT					
Height	36-51	38-53	42-50	46-61	37-52
Depth	39-41	38-42	38-42	41	38-42
Width	43-48	40-45	40	43	40-45
Angle	$0-5^{o}$	$0-6^{o}$	$0-5^{o}$	$+10^{o}$ Mandel, 1981	$-5^{o}-+10^{o}$
BACKREST					
Height	19-25	30	17-25	15-23	23-30
Height adjustment	8	10	7	7	10
Width	25	32-36	36	30-36	30-36
Horizontal adjustment	-	40-50	31-46	30-43	35-50

APPENDIX F - DEFINITIONS OF THE CHAIR AND DESK DIMENSIONS MEASURED IN FIGURES 5 AND 6

The methods of measurement of the dimensions shown in Figures 5 and 6 and given in Tables 5 and 6 are described in this section.

<u>Figure 5 and Table 5</u>:

a. seat height - The seat pan is adjusted to either its maximum or minimum height. Seat height is measured from the floor surface to the upper surface of the seat pan.

b. seat depth - The depth is measured from the front edge of the back edge of the seat pan.

c. seat width - Width is measured from side-to-side of the upper surface of the seat pan.

d. seat angle - The seat angle is measured from the horizontal. A rearward decline is a negative angle and a rearward incline is a positive angle.

e. backrest width - Width is measured across the front of the backrest and at the centre of backrest height.

f. backrest height - It is measured along the mid-line of the posterior side of the backrest, from the top edge to the bottom edge.

g. backrest height adjustment range - is measured from the seat pan to the base of the backrest at maximum and minimum setting.

h. backrest horizontal adjustment - Is measured from the front seat edge to the upright back edge.

Figure 6 and Table 6:

a. keyboard height - is measured from the floor surface to the height of the keyboard's home row.

b. screen height - is measured from the floor surface to the top side of the VDT screen.

c. viewing distance - is measured from the front desk edge to the surface of the screen allowing enough space for a keyboard during minimum viewing distance.

d. work surface width - is measured from side edge to side edge of the whole table.

e. work surface depth - is measured from the front edge of the keyboard to the back edge of the screen surface at the maximum depth adjustment possible.

f. leg clearance height - is measured from the floor surface to the lower desk edge.

g. leg depth - is measured from the keyboard edge to the closest obstructing surface.

h. leg width - is measured from side to side between obstructing stabilizer bars or legs.

APPENDIX G - QUESTIONNAIRE USED IN OFFICE STUDY

Your health: The following questions concern your health in very general terms. Please answer all questions.

1. What is your age? ______________ years

2. How tall are you? ______________ inches

3. How long have you been in the workforce? ______________ years

4. How many years have you been a typist, word processor and/or typist? ______________ years

5. At which workstation do you work?
   1=book trucks 2=printed paper
   3=separate room ______________

6. During the average workday, approx. how many hours do you work:

   a) standing in one place ______________ hours

   b) sitting ______________ hours

   c) moving around ______________ hours

   (Total number of hours should add up to the number of hours you work during an average workday minus your lunch time).

7. Are you presently experiencing any of the following symptoms: 1=yes 2=no

   a) skin rashes and/or itchy skin ______________

   b) swollen or painful muscle joints ______________

   c) lower back pain ______________

   d) pain or stiffness in your arms ______________

   e) pain or stiffness in neck and/or shoulder ______________

   f) tearing or itchy eyes ______________

   g) loss of feeling in the fingers or wrists ______________

   h) stiff or sore wrists ______________

   i) pain or stiffness in the legs ______________

8. Within the past 5 years has a doctor ever told you that you have: 1=yes 2=no

a) arthritis or rheumatism ____________

b) glaucoma of the eyes ____________

c) colitis (inflamed colon) ____________

d) cataracts ____________

e) hemorroids ____________

9. On the job, do you have any problems with your eyesight while working with your terminal?

1=yes 2=no ____________

If yes, please describe problem: ____________________

____

9(a). Do you wear corrective lenses? 1=yes 2=no ____________

If yes, please answer b-e.

b) at work do you wear special glasses while working with your VDT? ____________

c) do you wear glasses (not bifocals) ____________

d) do you wear bifocals or trifocals ____________

e) do you wear contacts ____________

Your workstation: The following questions examine your immediate work area, i.e. the VDT.

10. While you are working at your VDT, about how often are you looking at the following:

1=never
2=rarely/infrequently
3=sometimes
4=fairly often
5=often

a) the display screen ____________

b) the keyboard ____________

c) the material being keyed-in ____________

11. Does your VDT contain a special filter to reduce glare, enhance contrast etc?

1=yes 2=no 3=don't know ______

12. Considering the current set-up of your VDT, as it is adjusted, how bothersome are each of the following:

1=no bother or problem
2=occasionally bothersome
3=often bothersome
4=very often bothersome
5=constantly bothersome

a) glare from the keyboard ______

b) glare from the table top ______

c) reflection off the VDT screen ______

d) the distance of the keyboard from you ______

e) the distance of the screen from you ______

f) the height of the screen ______

g) the height of the keyboard ______

h) noise from the VDT ______

i) noise from the printer ______

j) heat from the VDTs ______

k) leg room ______

l) the tilt(angle) of the VDT keyboard ______

m) the tilt(angle) of the VDT screen ______

n) the focus or sharpness of the letters or numbers on the screen ______

o) placement of the source document ______

p) ability to read the source document ______

q) printing quality on source document ______

r) work-surface area ______

s) static electricity effects ______

13. What changes would you like to see made to make work with the VDT's more efficient, comfortable, or convenient, if any changes are necessary.

____

____

____

____

____

Your work environment: The following questions deal with the place in which you work, going beyond your workstation.

14. In general, would you say that as a workplace environment your office is:

1=very pleasant
2=somewhat pleasant
3=just adequate
4=somewhat unpleasant
5=unpleasant

______

15. Indicate the extent to which you are bothered in your work by any of the following:

1=rarely, never
2=occasionally
3=sometimes
4=fairly often
5=very often

a) odors, fumes or smells ______

b) dust ______

c) cigarette or other tobacco smoke ______

d) crowding ______

e) noise ______

f) temperature level ______

g) lighting ______

h) drafts ______

i) fluorscent lights ______

j) natural light (windows) ______

k) xerox machine ______

16. Is the lighting of the background areas around your workstation at all bothersome?

1=yes   2=no   ____________

If yes, explain possible source of irritation   ____________

____

____

17. In regards to the following elements of your workplace environment, how do you feel about:

1=much too high   4=somewhat low
2=somewhat high   5=much too low
3=correct

a) the level of lighting in your office   __________

b) the noise level in your office   __________

c) the temperature of your office during summer   __________

d) the temperature of your office during winter   __________

e) overall level of distraction in your office   __________

f) the humidity in the air   __________

18. Is the supply of fresh air:
1=good
2=inadequate   3=no fresh air at all   __________

19. Considering office noise, how do you feel about the following source:

1=most disturbing   3=rarely disturbing
2=somewhat disturbing   4=not at all disturbing

a) conversation   ____________

b) office machines   ____________

c) telephone   ____________

d) movement back and forth   ____________

e) traffic noise   ____________

f) other, please specify: ________________________________

CHAIR ELVALUATION: The following section is specifically concerned with the chair you are presently occupying. Please answer all questions.

1. Your height in inches: _______inches

2. Your workstation area: ________
   1=book trucks
   2=printed paper
   3=separate room

3. How do you rate the chair with respect to individual parts of your body?

   1=comfortalbe 2=so,so 3=uncomfortable

   a) neck ________
   b) shoulder ________
   c) upper back ________
   d) lower back ________
   e) buttock ________
   f) upper leg ________
   g) lower leg ________
   h) arms ________
   i) overall ________

4. How do you rate the chair when you lean back? ________
   1=comfortable 2=so,so 3=uncomfortable

5. How do you rate the chair when you lean forward? ________
   1=comfortable 2=so,so 3=uncomfortable

6. How do you rate ease of chair adjustability? ________
   (e.g. adjusting height, backrest etc.)

   1=easy 2=somewhat awkward 3=very awkward 4=not possible

DESK EVALUATION: The following section is specifically concerned with the desk, table you are presently working on. Please answer all questions.

7. How do rate the desk with respect to your working space?
   1=adequate   2=so,so   3=inadequate

   a) leg room ________
   b) range of table adjustability ________
   c) ease of table height adjustment ________
   d) range of table tilt(angle) ________
   e) ease of table tilt adjustment ________
   f) range to adjust keyboard distance from you ________
   g) keyboard armrest ________
   h) work surface area ________
   i) matt of table-surface (to reduce glare) ________
   j) storage for personal things ________
   k) overall rating ________

8. Do you use the adjustable screen tilt with the NEW table?

   1=yes   2=no   3=not applicable ________

9. Is it possible to slide the chair under the desk, or is the width of the leg space too small?

   1=yes   2=no ________

10. How do you rate the table with respect to individual parts of your body?

   1=increased comfort
   2=no change
   3=greater discomfort

   a) neck ________
   b) arms ________
   c) legs ________
   d) overall ________

WORKSTATION USAGE EVALUATION

Subjects Name: ______________________________

Mark an X along the scale

1. How often did you work at workstation A?

0	25	50	75	100
never		sometimes		always

2. How often did you work at workstation B?

0	25	50	75	100
never		sometimes		always

3. How often did you work at workstation C?

0	25	50	75	100
never		sometimes		always

4. How often did you work at workstation D?

0	25	50	75	100
never		sometimes		always

5. Do you recall which chair you preferred?

   Yes - which one? ______________________________

   No.

6. Do you recal which table you preferred?

   Yes - which one? ______________________________

   No.

CHAIRS AND TABLES CONTINUED

7. Do you think it necessary to be able to adjust your chair?

8. Do you think it necessary to be able to adjust your table?

Cashier-Operator Survey

DO NOT USE THIS BOX
[ ][ ][ ] [1]
1 2 3 4

1. In which supermarket are you presently working? [ ] 5

   1)Super-Valu
   2)Safeway
   3)Woodwards
   4)Other, please specify____________________

   Location of supermarket:____________________

   ____

2. Date of birth: [ ][ ] month [ ][ ] year

3. How tall are you?

   1)less than 5feet
   2)5'0" - 5'2"
   3)5'3 -- 5'4"
   4)5'5" - 5'6"
   5)5'7" - 5'8"
   6)5'9" - 5'10"
   7)5'11"- 6'0"
   8)taller than 6feet [ ] 10

4. How long have you been working as a cashier operator? (Please indicate total number of months). [ ][ ] months

5. Have you worked on any of the following cash registers? (Please indicate the number of months you were on one cash register or the other).

   1)electronic scanner [ ][ ] months
   2)NCR 255 [ ][ ] months
   3)Sweda touch-checker [ ][ ] months
   4)mechanical cash register [ ][ ] months
   5)Other, please specify____________________ [ ][ ] months
   6)Other, please specify____________________ [ ][ ] months

13-24

6. How many hours do you work on average per week? (Please indicate the minimum and maximum number of hours that you would possible work during any given week).

Maximum ☐☐ hours

Minimum ☐☐ hours

or, Regular full-time ☐☐ hours

25-30

7. How many hours during an average work week do you work on the express counter?

Maximum ☐☐ hours

Minimum ☐☐ hours

31-34

8. What kind of cash register are you presently operating?

1)electronic scanner
2)NCR 255
3)Sweda touch-checker
4)mechanical cash register
5)Other, please specify________________________ ☐

35

9. Do you find that the cash register buttons are placed at the correct height for you?

1)too high
2)too low
3)all right ☐

36

10. Do you feel any pain in your hand, arm and/or shoulder when you push the register buttons?

1)yes
2)no
3)sometimes ☐

37

11. Do you feel any pain in your hand, arm and/or shoulder when you close the cash-register till?

1)yes
2)no
3)sometimes ☐

38

12. Do you find the cash register noisy?

1)yes
2)no
3)sometimes ☐

39

13. Is the cash register set at an angle so that while you are scanning or pricing the groceries you are:

1)facing the customer
2)slightly turned toward the customer (45^{o}angle)
3)facing the food floor and customer is on your left side
4)have your back slightly towards the customer

☐ 40

14. Do you find the cash register price-display, irritating to the eyes?

1)yes
2)no
3)sometimes

☐ 41

15. Do you find that the customer-counter is the right height for you?

1)too high
2)too low
3)all right

☐ 42

16. Do you find that the customer-counter is the right width for you?

1)too wide
2)too narrow
3)all right

☐ 43

17. How do you move the groceries forward, with a:

1)foot pedal
2)knee pedal
3)thigh/hip pedal
4)electronic eye
5)with your hands
6)other, please specify________________________

☐ 44

18. Do you find the "pedal" to be the right height for you?

1)too high
2)too low
3)all right
4)question does not apply to me

☐ 45

19. Do you find that the turn-stile or conveyor belt brings the groceries close enough to you?

1)yes
2)no

☐ 46

20. When you "bag" which do you use most of the time?

1)the bag-well
2)the customer-counter
3)a hook which holds the plastic bags

☐ 47

21. If you don't use the bag-well, why not?______________________

____

22. If you use the bag-well do you find its height:

1)too high
2)too low
3)all right
4)I don't use the bag-well

☐ 48

23. How often do you have a wrapper helping you?

1)always - 100% of the time
2) 75% of the time
3) 50% of the time
4) 25% of the time
5)never - 0% of the time

☐ 49

24. When you load the grocery bags into the buggy do you:

1)grip the TOP of the bag with your hands?
2)grip the BOTTOM of the bag with your hands?

☐ 50

25. Do you find the buggy too deep, to load into for your height?

1)yes
2)no

☐ 51

26. Does your back hurt when you lift the bags into the buggy?

1)yes
2)no
3)sometimes

☐ 52

27. Do you find you have adequate working space?

1)yes
2)no

☐ 53

28. Are there protruding objects in your work area (handles, knobs etc.) on which you hurt/bruise yourself?

1)yes - please specify______________________

____

2)no

☐ 54

29. Do you find that working surfaces cause glare?

1)yes
2)no

a)cash register ☐
b)cash register read out ☐
c)customer-counter ☐
d)floor ☐
55-59

30. Do you find the working environment to be:

a)hot ☐
b)cold ☐
c)noisy ☐
d)drafty ☐
e)bright ☐
f)dark ☐
60-66

31. Do you have fatigue mats?

1)yes
2)no
3)sometimes - please specify when________________________________

________________________________ ☐ 67

32. Do you USE the fatigue mat?

1)yes
2)no

☐ 68

33. How thick is your fatigue mat?

1) 2 inches or more in thickness
2) 1-2 inches
3)less than 1-inch
4)extremely worn
5)I don't have one

☐ 69

34. What kind of shoes do you wear to work?

1)high-heeled pumps
2)white-flat Oxfords
3)strap sandals
4)other, please specify________________________________

☐ 70

35. How high is your shoe-heel?

1)less than 1-inch
2) 1-2 inches in height
3)more than 2-inches in height

☐ 71

36. Do you feel your earnings are:

1)good
2)satisfactory
3)unsatisfactory

☐ 72

37. Do you find the work schedule (the organisation of hours you are required to work):

1)very pleasant
2)pleasant
3)unpleasant

☐ 73

38. Do you find your job:

1)very intresting
2)intresting
3)somewhat intresting
4)boring

☐ 74

39. How do you feel about your fellow workers during working hours?

1)generally they are friendly
2)generally they are unfriendly
3)generally I have very little contact with them

☐ 75

40. What kind of an understanding do you have with your head cashier supervisor?

1)generally a good one
2)generally not such a good one
3)indifferent

☐ 76

41. If you had a friend inquiring about your job would you:

1)recommend the job
2)not recommend the job

☐ 77

42. What kind of work-day do you prefer:

1)when it is very busy
2)busy
3)not busy at all

☐ 78

DO NOT USE THIS BOX 2

43. Do you suffer from any of the following:

1)yes
2)no

a)general fatigue
b)stiff shoulder
c)headache
d)low back pain
e)diarrhea or constipation
f)sleeplessness
g)dizziness
h)pale complexion
i)loss of weight
j)nausea
k)varicsoe veins
l)spidery surface veins
m)swelling of legs

5-17

44. Do you find it is painful to maintain your working posture?

1)yes
2)no
3)sometimes

18

45. Do you find that you become more irratable on work-days?

1)yes
2)no
3)sometimes

19

46. Do you experience remarkable fatigue after the end of a work-day?

1)yes
2)no
3)sometimes

If 1 or 3, please specify when ______________________________

20

47. During an average work eek do you feel any dullness and/or pain in:

1)right side
2)left side
3)both
4)neither

a)neck ☐
b)shoulder ☐
c)arm ☐
d)elbow joint ☐
e)wrist joint ☐
f)hand ☐
g)finger ☐

21-27

48. During an average work week do you feel any numbness (lack of feeling) in your:

1)right
2)left
3)both
4)neither

a)arm ☐
b)hand ☐
c)finger ☐

28-30

49. During an average work week do you feel any tremor in your:

1)right
2)left
3)both
4)neither

a)hand ☐
b)finger ☐

31-32

50. During an average work week do you feel any dullness, pain or bruising in:

1)right
2)left
3)both
4)neither

a)hip joint ☐
b)thigh ☐
c)knee joint ☐
d)ankle joint ☐
e)feet ☐
f)toes ☐

33-38

51. Do you notice any changes in your ability to work during mensturation?

1)no - none at all
2)slightly
3)some
4)quite a bit
5)yes - alot

☐
39

52. Do you find you are given adequate rest periods during a work day?

1)yes
2)no
3)sometimes

☐ 40

53. How many children do you have?

1)one
2)two
3)three
4)four
5)five
6)none

☐ 41

THANK YOU VERY MUCH FOR COMPLETING THIS QUESTIONNAIRE.

Ulrika Wallersteiner

APPENDIX I

EVALUATING Bodily Fatigue and Soreness

Name:______________________________________ Time:_________

1. Please indicate your current level of overall well-being on a scale from:

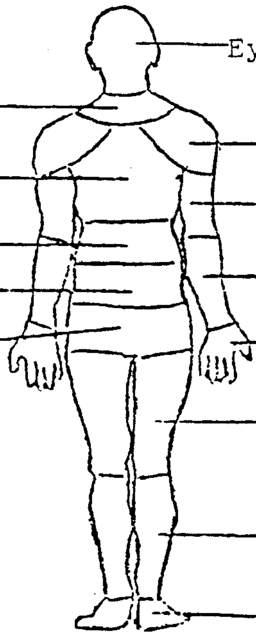
1	2	3	4	5	6	7
feeling very-well		feeling alright		not feeling so well		feeling terrible

(Circle the appropriate number.)

2. Using the following fatigue/soreness scale:

1	2	3	4	5	6	7
none		barely noticeable		moderately noticeable		very noticeable

Please indicate on the diagram below how each area of your body feels to you at the present time. Fill in all the spaces with the appropriate number. Indicate even the slightest feelings of fatigue.



Eyes:____

_____:Neck

_____:Upper Back

_____:Mid Back

_____:Lower Back

_____:Buttock

Shoulders-Right:____ Left:____

Upper Arms- Right:____ Left:____

Lower Arms- Right:____ Left:____

Hands- Right:____ Left:____

Thighs- Right:____ Left:____

Legs- Right:____ Left:____

Feet- Right:____ Left:____

3. Do you work on the VDT terminals at any time during your work week? 1=yes 2=no ________

4. How many hours did you work on the VDT today? ________ hours

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