The evaluation of HSRC seating and work-station facilities

Report PERS-431

A.P. Golding

NATIONAL INSTITUTE FOR PERSONNEL RESEARCH

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A.P. Golding, M.Sc., Environmental Studies Division

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ABSTRACT

The management requested an evaluation of the health risks of present HSRC seating facilities. A preliminary study of 70 workers revealed that many workstations were inadequate from an ergonomic point of view and that many of these people were suffering from complaints which could be occupationally related.

The aim of the study was to establish whether such complaints were due to previous musculoskeletal disorders or injuries or whether they were due to postural stress as a result of workstation design. A number of subjective and objective techniques were used in assessing a sample of 37 workers selected from four occupational groups.

Examinations of the subjects by physiotherapists indicated that 68% of the clinical symptoms reported were not related to previous disorders or injuries. Of the clinical problems 86% were reported to be occupationally aggravated or related. Other techniques measuring subjective comfort, workstation dimensions and posture of subjects over time suggest that an interventionist approach is required to improve the situation.

A number of recommendations have been made including workstation redesign, work reorganisation (in some instances), promotion of fitness and an organisational health programme. These are all options which need to be prioritised by a committee appointed for evaluating the costs and benefits to the HSRC.

EKSERP

Die bestuur het 'n evaluering aangevra van die gesondheidsrisiko's van sitfasiliteite wat tans by die RGN in gebruik is. 'n Voorlopige studie van sewentig werkers het aan die lig gebring dat baie werkstasies vanuit 'n ergonomiese gerigspunt ontoereikend was en dat baie van die werkers gebuk gegaan het onder kwale wat beroepsverwant kon wees.

Die doel van die studie was om vas te stel om sulke kwale aan vorige muskuloskeletale afwykings of beserings toe geskryf kon word en of hulle die gevolg was van houdingstres was spruit uit werkstasie–ontwerp. 'n Aantaal subjektiewe en objektiewe tegnieke is gebruik om 'n steekproef van 37 werkers wat uit vier beroepsgroepe gekies is, te beoordeel.

Ondersoeke van die proefpersone deur fisioterapeute het aan die lig gebring dat 68% van die kliniese simptome wat aangemeld is nie met vorige afwykings of beserings verband gehou het nie. Daar is gemeld dat 86% van die kliniese probleme met die beroep verband gehou het of daardeur vererger is. Ander tegnieke wat subjektiewe gerief, werkstasie–afmetings en houding van proefpersone oor tyd meet, laat die gedagte ontstaan dat 'n intervensionistiese benadering nodig is om die situasie te verbeter.

'n Aantaal aanbevelings is gemaak wat die herontwerp van werkstasies, die herorganisasie van werk (in sommige gevalle), die bevordering van fiksheid en 'n organisatoriese gesond–heidsprogram insluit. Hierdie is almal opsies wat in volgorde van belangrikheid geplaas moet word deur 'n komitee wat aangestel moet word om die koste en voordele vir die RGN te evalueer.

OVERVIEW OF REPORT

HSRC management requested an evaluation of chairs to determine whether these were suitable for prolonged use by members of staff without health risks. Preliminary interviews revealed that seating and health problems did exist. It was then apparent that two alternative approaches could be adopted. The first would be directed specifically at eradicating problem chairs and evaluating ergonomically designed alternatives with a view to purchasing those which were most comfortable. The second would be holistic and directed at factors influencing health rather than at seats *per sé*. As back pain is a problem which is becoming increasingly significant and costly to society, and as the holistic approach would incorporate, amongst other things, an analysis of workstation design (including seating), it was thought preferable to adopt this second alternative.

The disadvantage of this option is its complexity, necessitating detailed data–analysis. The result is a long report.

Research into work–related musculoskeletal disorders has expanded at a tremendous rate over the last 10 years with the increased documented incidence of neck and upper limb disorders. It is agreed that the aetiology of such problems is multifactorial and the relative importance of different causative and moderating variables is still unknown (Hagberg, 1984; Jonsson *et al*, 1988). It is commonly believed that the pathophysiological mechanism involved is acute/chronic muscle or connective tissue strain (or fatigue). In spite of intensive experimental research, the exact process whereby strain leads to tissue damage is unknown.

According to Hagberg and Wegman (1987) *the proportion of common disorders attributable to occupational exposure is high. This indicates that it should be possible to prevent a relatively large proportion of these cases.* Many intervention projects have been undertaken, based on a simplified model (Kilbom, 1988) for the development of work-related disorders. Factors which influence the risk of developing a disorder can be divided into:

1. Individual capacity: the worker's physical characteristics and personality, health and skill.
2. Physical work demands:
   a. Workstation and tool design
   b. Work organisation: work duration and pauses, speed, force, monotony and repetitiveness of work.
3. Psychosocial factors: relations with supervisors, management and work colleagues, communication issues, heavy or variable demands on productivity, wage structure, sick leave and workers' compensation system.

In the model, individual capacity, physical work demands and psychosocial stress act to cause imbalance and musculoskeletal stress. The body's response to this is musculoskeletal strain, perceived as pain or fatigue. If no action is taken to intervene in the process chronic disorder will eventually result.

Alternatively if action is taken to rest the area affected or the job is so redesigned to eliminate fatiguing conditions then the stressed area recovers.

Most intervention studies focus on work design, either by improving only the workstation (Aaras, 1987; Itani *et al*, 1983), by improving the work organisation, ie mainly the working hours and duration of pauses (Edgren, 1986), or by influencing both of these factors (Itani *et al*, 1979; Ohara *et al*, 1976; Ong, 1984). From a purely theoretical point of view interventions directed at only one risk factor are preferable, as they permit conclusions regarding the effectiveness of that method of intervention.

In the present study workstation redesign is considered as the principal method of intervention.

Regarding health complaints, clinical examinations by two student physiotherapists on the 37 subjects revealed that 78% suffered from neck problems, 57% from lower back problems, 8% from upper back problems, and 19% from headaches. Significantly 68% of these problems were not related to any known previous trauma or pathology. Additionally, 86% of these problems were reported by subjects to be occupationally aggravated or related.

These findings agree with the earlier statement of Hagberg and Wegman (*ibid*) that the proportion of disorders attributable to occupational exposure is high and that a large proportion of these should, in principle, be preventable.

Other techniques used in the study included subjective discomfort ratings using a questionnaire administered 6 times daily over 14 days, measurement of anthropometric and workstation dimensions and video recording of subjects' postural behaviour over time. *Analysis suggested that workstation design, constrained working posture and task-related factors contribute towards causing muscular fatigue.*

The four occupational groups studied — data-typists, typists, programmers and researchers — were selected on the basis of the relative constraint of their working posture. *The findings bore out the hypothesis that increased postural constraint is accompanied by increased likelihood of musculoskeletal problems.*

Postural constraint is influenced by task demands. In the case of data-typists the constraint is high because of the fixed position required for the operation, the work pace and the workload. The head is held stationary in a twisted position, and the right hand types at a fast rate. With typists there is less constraint because the work pace is slower but the head is still twisted for copy typing. In programming a fair proportion of work does not involve using a keyboard and work pace is determined by the individual worker. In research tasks the work provides for a good deal of postural variety though some staff are already becoming virtually full–time VDT users.

The nature of sedentary occupations leads to poor muscle tonus and low muscle strength unless combatted by a dynamic and healthy lifestyle. *It is therefore advocated that an intervention program to reduce musculoskeletal stress should be regarded as part of a larger managerial policy aimed at organisational health, fitness and productivity.* Occupational health is the first step in the equation and follows logically once occupational safety has been recognised as important for the welfare of employees. Corporate policies such as this have been demonstrated to be cost–effective in reducing the incidence of cardiovascular disease as well as disorders of the musculoskeletal system (Stamper, 1987).

The main recommendations of this study involve workstation redesign. Recommendations are made on an individual basis where the most necessary changes have been outlined. These vary from minimal changes such as moving equipment, to major alterations (for example, the computer console in the data–typing pool). Provision of footrests, document holders and chairs are typical suggestions.

Work reorganisation is considered likely to be necessary in the case of data–typists because of the onerous nature of the task as well as the contorted postures required whilst working. Greater task variety and a revised work—rest regime would be the main features of such reorganisation.

The success of any intervention also depends on whether health education is used as a tool in creating awareness of (a) how to use and adjust furniture, and (b) the importance of pauses and the relationship between postural variety and comfort.

Clearly the evaluation of the results of the intervention are of key importance, if only from an academic viewpoint, since the success of the intervention technique depends on its efficacy in leading to the expected change in work posture and on whether this change is sufficient to influence the development of the disorder. Owing to the variable clinical history of disorders the results of any intervention must be studied over a period of time. Repeated evaluations or constant monitoring of the prevalence of problems over several years is necessary.

If this is applied to the organisation as a whole it becomes evident that the only cost–effective manner of operating such a program is to employ an occupational health professional with appropriate facilities who is able to monitor the overall health of employees and perform continuous audits on sickness records. Such a person (for example, an occupational health nurse) would also have the expertise to be able to liaise with doctors and other specialists about specific health problems and refer members of staff to them. The responsibility for health education would also fall within her scope. The advantage to be gained is that the cost of employing such a professional would outweigh the cost of sick leave and lost productivity (if evidence from the literature is to be believed).

Originally the project proposal stated that modifications to existing workstations might be possible but that, if not, then a further phase of evaluating a range of seats with the subjects would be advocated. It is now apparent that in some cases modifications to workstation layout will be sufficient but that in others alternative seats and desks are required. In each case a phase of evaluating the effectiveness of the implemented solutions/intervention will be necessary to conclude the study.

The implications of the findings of the report are that the relationship between seats and health is not straightforward. In view of this background the actual steps to be taken in respect of seating for all HSRC staff are not clearcut. And yet it is this information which is needed for decision-makers at this stage. At the outset of the study one suggestion was to acquire a range of seats, carefully matched to workstations and users, which can be evaluated over a period. However, there is obviously a limitation on the scale of such a program if it is to be undertaken in a methodical way. Detail about furniture requirements, budgeting plans and costing is necessary before any scheme is decided upon. There is no evidence to date that conventional strategies of bulk purchase of seating or buying expensive furniture will guarantee user comfort.

This overview has perhaps shown how much broader the area of research has become since the investigation was first initiated. There are still several other issues, such as the place of the VDT in health complaints, which dovetail into this area. These are beyond the scope of this present study but require separate and urgent investigation.

The report's findings are based on a small sample, statistically speaking, but it is effectively 37 case studies. Preferably much larger samples are required for an epidemiological approach of this nature. At this stage it may be considered as a pilot study which has yielded useful information on the relationship between workstations, tasks, work postures and musculoskeletal problems.

It is hoped that the report contains sufficient detail to permit management to decide on which recommendations it should act and that the reasons for the length of the report are understood. If there should be too much repetition this is only a device to assist in bridging across sections which are somewhat diverse.

1. INTRODUCTION

Following a series of complaints about seating, the management of the Human Sciences Research Council requested an evaluation of chairs to determine whether these were suitable for prolonged use by members of staff without health risks. In a preliminary investigation into the extent of the problem 70 workers were interviewed at their workstations. The findings suggested that many chairs and workstations were ergonomically inadequate, that few people had been educated in postural awareness, that concentration on work tended to exclude personal considerations of seating or health, and that many workers suffered from complaints which could be task related.

The aim of the present study was to establish which health complaints were likely to be due to chronic musculoskeletal disorders or old traumas and which complaints were linked to bad working posture and/or workstation design.

A secondary aim was to develop a diagnostic system (using several techniques) which would be accurate, reliable and quick. This could then be used in a variety of occupational settings as an interventionist strategy to reduce problems.

1.1 Some findings from the preliminary study

The questionnaire included questions on seating and workstations, tasks and health. Concerning seating, an important finding was that 55% of staff could not put their feet on the floor whilst using the backrest without feeling pressure under the legs. This confirmed observations of excessive seat and desk height; seat height often being raised to reach the desktop, and suggested that some people were not getting sufficient back support.

Task analysis revealed that those whose job was essentially 100% keyboard work felt a greater need for additional rest breaks than other staff who had greater postural variety. The majority of typists used glasses and more than 50% suffered from visual discomfort. No typists had document holders so their necks were in a twisted position, looking down at the documents they copied from. Most of this group felt their job pressurised them.

With regard to health complaints amongst the sample as a whole, neck, shoulder and back problems were found to occur quite frequently together with headache and physical fatigue.

This summary reflects the role of the task and the workstation in determining what work posture is adopted. Several respondents answered that it was not the workstation in itself which they felt caused the complaint but rather the job. It seems that improved workstations might only be a partial solution; work reorganisation may also be necessary in some instances.

1.2 Concepts underlying the study

Two main concepts underlie the methodology of this study; 'fitting the task to the man' and 'constrained posture'.

1.2.1 Fitting the task to the man

The aim of ergonomics is basically to achieve the optimum human performance in any activity. 'Optimum' in this context means the best balance between health, safety, well–being and efficiency. These factors share a symbiotic relationship. One way of arriving at an effective synthesis is to 'fit the task to the man' rather than make the man 'fit the task'. The Greek philosopher Protagoras said, 'Man is the measure of all things'. Yet most man–made things have been designed with only one ideal, average, person in mind which has been to the detriment of everyone else.

Generally speaking Man is able to perform optimally in any activity provided the activity does not exceed his physical or mental capacity. When these limits are exceeded then the chance of human error is increased. Aeroplane collisions and nuclear disasters are well known examples which are often attributed to loss of vigilance or faulty decision–making. Lesser errors can be due to a mismatch between worker and machine; the computer and its novice user is a battlefield in which, luckily, no one gets hurt. However, Africans who have to operate heavy manufacturing machinery designed for German users are often in danger of losing their limbs, because of the difference in size between the two racial groups. This example is concerned with physical capacity.

In office environments error is not such a crucial factor and the emphasis is on optimising productivity and health. The approach used by ergonomists is to assess how workstation dimensions fit the dimensions of the user in order to reduce the postural stress which might result from a 'misfit' between these two.

1.2.2 Constrained posture

Biomechanically posture may be defined as the relative spatial orientation of the segments of a person's body, requiring an overall balance of forces between the body and its surroundings (Grieve and Pheasant, 1982). As human beings never stand or sit completely still this means that gravitational forces are constantly being opposed by muscular activity or by passive tensions in soft tissues. Such activity is referred to as postural or static work. The mechanical loading placed upon the body by virtue of its posture is referred to as 'postural stress' and the body's responses to the stress 'postural strain'.

A key factor in the causation of postural stress seems to be constrained or fixed posture. Whereas dynamic muscular work is characterised by a rhythmic alternation between contraction and relaxation of muscles in which oxygenated blood is pumped into the muscle and waste products removed, static muscular work is characterised by a tense, prolonged state of contraction.

In constrained positions the blood supply is obstructed and the toxin known as lactic acid builds up between the muscle bundles of the back and shoulders (which are the main muscles employed in maintaining static postures). The by–product of lactic acid is a fluid which causes a sensation of fatigue. If insufficient rest is allowed, an overused muscle may become distended by the fluid and fibrous material can accumulate, causing pain in the area concerned. Alternatively, repeated exertion may cause muscles to become hypersensitive, resulting in muscle spasm (Oborne, 1982).

According to Grandjean (1987) postural efforts, if repeated over a long time, are associated with an increased risk of:

1. Inflammation of the joints (arthritis),
2. Inflammation of the tendon sheaths (tendinitis),
3. Inflammation of the attachment points of tendons,
4. Symptoms of chronic degeneration of the joints (chronic arthroses),
5. Painful induration of muscles,
6. Intervertebral disc troubles.

It follows that one would expect to find more symptoms in workers whose posture was constrained than in those whose task allowed freedom of movement. In Sweden there has been a move towards the introduction of so–called 'pause gymnastics' for office workers whose tasks are repetitive and demand static muscular work.

Prolonged sitting leads to curvature of the spine and to a slackening of the abdominal muscles. Postural efforts are then made increasingly without the support of those muscles which should be assisting in protecting the spine.

In this connection it has been demonstrated that low muscle strength is related to the incidence of musculoskeletal disorders in relatively strenuous occupations, but this has not been tested in sedentary jobs (Kilbom *et al*,1986). However, strengthening the muscles responsible for maintaining posture by training them is the main feature of all rehabilitation programmes and it follows that all–round muscular fitness and a sensibly active life style inhibit degenerative processes to a large degree.

1.3 General background

1.3.1 The impact of Information Technology

Why are postural complaints such as backache only gaining attention now? Many problems of older generations of workers were never addressed because of lack of knowledge and the attitudes to work, job satisfaction and health prevalent in society. Compared to the fatal occupational diseases found within primary sector industry the niggling aches of typists may have appeared to be trivial. Today these aches assume a new significance with the advent of the computer which has transformed the structure of Industry in developed economies, together with the tasks of office workers. This has made many people keyboard users and the incidence of 'typists' complaints has escalated.

An important consequence of the introduction of visual display terminals (VDTs) at workplaces is the integration of operators in a man–machine system. The space of the worker's action is restricted and movements are limited. The position of the head is imposed by visual angle and visual distance; the position of the hands is determined by the keyboard and source documents. Many jobs have a repetitive character with demands on vigilance. All these elements create 'constrained postures' which are characterised by a restriction of free movements and long–lasting static postural efforts. Such static efforts may produce painful fatigue in the muscles concerned which is short–lived and reversible. However, if the static load is repeated daily over a long period of time, tendons and joints are affected and permanent aches will appear. Studies of this phenomenon have revealed that inadequate workstation design can generate or aggravate such physical impairments.

Now that most office workers are becoming VDT users overuse of the keyboard is becoming a common phenomenon, resulting in the growth of a number of medical syndromes such as 'Repetitive Strain Injury'. Use of VDTs is giving some people eye strain because of the visual demands it imposes on the eyes. Related headaches are also common but it is difficult to isolate those produced by visual work from those produced by neck tension through having to sit in constrained postures or stress.

This breed of complaints first occurred in Japan — the home of Information Technology — where new tasks were made possible by the fast response times of modern computers. The task which has been documented more than any other is that of the data–entry operator where keying speeds of up to 13000 strokes per hour have been observed (Ong, 1984). (This compares with 3500 characters an hour for typists.) In Japan medical practitioners coined the term 'Occupational Cervicobrachial Syndrome' to refer to disorders affecting the neck, shoulders and arms of VDT workers.

So the 'Why only now?' question posed at the beginning of this section can be answered largely by referring to the effects of Information Technology — computing and tele-communications — which is transforming society. The influence may be gauged by the fact that in 1986 national guidelines for seating at VDTs were being prepared for Australian schools (*Taskforce*, 1986). For years medical experts have been bemoaning the poor postures given to children in the classroom for them to carry about for the rest of their lives. Now it seems the computer has (indirectly) brought home the message that prevention is better than cure.

1.3.2 Ergonomics and furniture

In the past chairs were manufactured so that 90% of people could sit in them. This meant that tall and short individuals were not accommodated. The next answer was to make chair height adjustable – a demonstration of the difficulty of fitting the chair to the user. More recently furniture manufacturers have been using advertisements which stress the 'ergonomically–designed features' of their wares.

At present Ergonomics is a bit of a 'buzz–word' which tends to be used whenever it sounds fashionable or can be used to sell a product. **Some** chairs have been well researched but comparatively few. There is no such thing as THE ergonomic chair. It depends on who is using it and in what context. This naturally conflicts with the demands of mass–production and the move towards standardisation. Unfortunately the human body does not come in standard sizes. Hence bulk purchasing of furniture may cut short term costs, but the loss to an organisation in the long term because of cutting corners in this way is believed to outweigh such gains. Once a company starts buying computers for its staff then they all have to have new suites of furniture to go with them and this can obviously be expensive. (Especially when employees still suffer from backache!)

For a period after the introduction of the adjustable chair there were still problems with chair and desk incompatibility and one solution was for shorter individuals to use footrests beneath their feet, although this inhibited foot movement and could be cumbersome at times. The solution was obvious and was synonymous with the growth in automated office systems – making the desk height adjustable also. Such desks also had facilities for the cables from computers, printers, telephones, fax machines etc.. Old desks would have been dysfunctional in such a situation with all their drawers obstructing easy access under the workspace. Drawers were dispensed with or relocated elsewhere. Chair design should hopefully evolve towards a stage of refinement where ideally one should not be aware of its existence.

1.3.3 Musculoskeletal disorders in the workplace

Musculoskeletal injuries and disorders in the workplace are at epidemic proportions (Pope, 1987). The total cost of disability, suffering and economic loss is enormous. In the USA musculoskeletal conditions rank first amongst disease groups in the cost of total lost earnings and represent 90% of compensation payments (Machaver, 1987). Low back pain affects 85% of all workers in their life and is the most frequent cause of restricted activity in workers under 45 years of age. Low back pain is second only to the common cold as the cause of lost time from work. The prevalence and clinical course of occupational disorders have not yet been scientifically shown to be affected by prevention efforts (Coleman, 1983). Because of this, more effort is being devoted to assessment of task–related factors in the workplace in the hope that this will contribute to effective prevention.

There are many obstacles to understanding musculoskeletal disorders. Practically all of us are unaware of our body posture until it is too late. Degeneration of tissues and spine is such an insidious process that we hardly notice the transition from being free of aches to when we are never without them. Research into spinal mechanisms, disc nutrition and the healing process is still in its formative stages. At present no treatment appears to be more successful than the spontaneous improvement of back pain (Roland and Morris, 1982). Though various therapies have a capacity to hasten the resolution of symptoms in some patients they do not affect the long term prognosis (Pope, *ibid*).

It is difficult to pinpoint the cause of a musculoskeletal disorder as a specific chair used at work. It is generally accepted that the postural habits acquired during the school years establish standards for later life and the longer these early habits are held the more difficult they are to change (Floyd and Ward, 1969). If a healthy attitude towards posture was taken at schools, together with posture–promoting classroom furniture, then the perennial problems we experience would be more restricted to complaints as a result of injuries. The success of back schools testifies to the importance of health education in promoting correct posture.

According to Troup (1965) only a small proportion of low back disorders can be attributed to trauma. The majority of problems are idiopathic (the cause is obscure). Low back pain causation cannot simply depend on when the pain first developed. The aetiology of most problems is multifactorial – seats leading to poor posture, decreased muscle strength leading to strains on soft tissues, accumulation of 'minor' traumas or 'wear and tear' of supporting structures, gradually putting more strain on the spine itself. In this situation it is a common occurrence that a 'stick can break the camel's back' (quite literally): a subject in the present study sneezed whilst watching television and suffered a prolapsed disc.

1.3.4 Biomechanical aspects of sitting and work posture

Whilst there are several advantages to sitting, such as improved stability and low energy demand, there are potential biomechanical and physiological hazards. When standing erect the lumbar spine is lordotic but when sitting it has a tendency to flatten or even become kyphotic (see Figure 1). This is because sitting typically results in the pelvis being rotated backwards, which changes the angle of the lumbo–sacral joint. The backward position of the pelvis puts the spine into a state of kyphosis which, in turn, increases the pressure within the discs.

The lower back: Studies performed on disc pressures in the lumbar spine indicate that pressure is lowest in the prone position. When standing the load on L3 is approximately 330 Newtons (Andersson, 1987). As the hip angle is reduced from 180 degrees towards a seated posture so the disc pressure increases. On a seat with a backrest inclination of 130 degrees the pressure is 200 N, if it is 80 degrees the pressure is 480 N. Measurements taken during seated office work gave figures of 470 N for writing whilst leaning at a desk, 550 N whilst typing, and 350 N whilst leaning back relaxing.

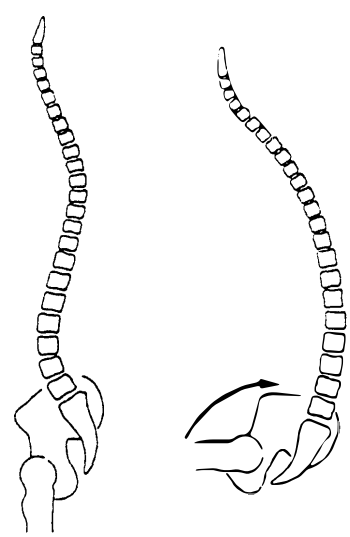
Measurements of muscle activity using the EMG revealed amplitudes of 5 microvolts at 130 degrees and 18 microvolts at 80 degrees.

The implication of these findings is that the normal chair angle of 90 degrees imposes a postural load upon both the spine and the muscles supporting it which is hazardous in the long term.

FIGURE 1. ROTATION OF THE PELVIS WHEN CHANGING FROM A STANDING TO A SITTING POSTURE

Left: Standing upright.

Right: Sitting down involves a backward rotation of the pelvis, turning the lumbar lordosis to a kyphosis.
(After Grandjean, 1987)



The shoulders: Shoulder posture is determined by worksurfaces and armrests when sitting. If the work surface is placed above the height of the elbows the shoulders have to be abducted, flexed or elevated. In each case stresses are imposed on the joints as well as the muscles in the shoulder/neck area. Hagberg *et al* (1986) found that shoulder elevation (hunching) resulted in increased EMG activity in the trapezius muscles, while in abduction the increase was mainly in the deltoid muscles. In each case the static load on the muscles exceeded the recommended level of 2% of the maximum voluntary contraction (MVC) for long term work with a mean of 4%.

The effect of forward arm postures on the shoulder muscles was studied by Chaffin (1973) who found a linear relationship between muscle fatigue and arm angle/horizontal distance from the body. The larger the angle or distance the earlier fatigue developed.

The neck: Stress on the cervical spine results mainly from the position of the head, which in turn is influenced by the visual requirements and the posture of the trunk. Neck forward flexion occurs when the head has to be flexed to view the screen, keyboard, or document. Neck rotation occurs because of a need to view a poorly placed screen or document. In both cases the muscles have to increase their activity to maintain equilibrium. Chaffin (*ibid*) found that the cervical extensor muscles fatigued quite rapidly when the neck flexion angle exceeded 30 degrees.

Static loading: The work at many workstations is static in nature and organised in such a way that movements are restricted and head and hands are in fixed positions. Grieco (1986) maintains that the emerging phenomenon of 'postural fixity' is a function of work organisation, which cannot be resolved solely by biomechanically correct workstation design. High workloads, work pace and psychogenic stress are thought to increase tension and lead to muscular loads which result in postural fatigue.

Work technique: Some individuals do not develop problems as much as their colleagues, although they are performing the same work. A longitudinal study by Kilbom and Persson (1987) revealed individual differences in work technique, perceived stress, sick leave, productivity and previous work to be important risk factors for deterioration in neck/shoulder disorders.

1.4 Approach adopted in the HSRC seating study

It can be seen from the above sections that the problem of seating and health is complex. One way of looking at the issue would be to consider seating in relation to tasks, investigating what is required for different occupations and surveying furniture on the market. This approach is relatively simple and avoids any evaluation of health risks, except in so far as it is possible to tell that chairs will be unsuitable by looking at them and trying them in the showroom. Given the complexity of seating and health problems, such an approach is probably the wisest to adopt in many situations. A similar approach is used by many commercial organisations where bulk purchase of furniture is constantly taking place.

However, little is known about whether such a policy is actually reducing the postural complaints of workers, as no research has been performed in this country. The HSRC is in a position to perform research and the view has been expressed that the widespread incidence of occupational back pain merits a broader study than one which concentrates on seating alone.

Hence the present study was designed to examine seating and health of workers from a variety of angles – both objective and subjective – in order to arrive at a balanced conclusion. This approach used ergonomic, paramedical and psychological techniques of observation and measurement. The investigation is an in–depth case study of a small sample of 37 subjects. Therefore the conclusions derived must be treated with some caution if readers should wish to make any generalisations.

2. METHODOLOGY

2.1 Design

The design of the study was based on results from the preliminary interviews conducted in October 1987 and upon a review of methods adopted in studies overseas. In such studies seat comfort has been evaluated using very small samples (usually students). On the other hand, musculoskeletal disorders have been investigated using large groups of workers within commercial organisations, typically comparing data–entry workers with other workers using VDTs. These sample sizes have been adequate from a statistical point of view: a group of six subjects is enough to employ when comparing chair ratings, and a hundred subjects is sufficient to evaluate effects of workstations on workers' health.

However, the HSRC is a research organisation with a predominance of researchers. Thus it differs from any large business concern in its manpower requirements. The preliminary interviews which covered every occupational category nevertheless established that those people seemingly most at risk were those which would have been predicted from the literature – the data–entry operators.

A sample of 37 subjects from four occupational categories was selected, according to the degree of postural constraint imposed by their tasks, and mainly from among the 70 subjects interviewed previously. Unfortunately from a statistical point of view the size of the groups was too small to enable strict comparisons to be made. In any event only the quantitative data from the subjective ratings could be analysed statistically: the more objective physical examinations, anthropometric/workstation measurements, and postural assessments can, at best, only be analysed with the aid of descriptive statistics. With these qualifications in mind it is suggested that any extrapolations of the findings beyond the sample be made only tentatively.

2.2 Subjects

A sample consisting of 7 data–typists, 5 typists, 8 programmers and 17 researchers took part in the study during January 1988. The sample included 30 females and 7 males. This was partly due to the nature of the occupations. The mean ages and standard deviations of the groups were as follows: data–typists 30.83 years (7.20); typists 33.60 (7.89); programmers 26.33 (12.40); and researchers 32.67 (8.35).

There was one outlier in the programmers, a woman of 51 years of age, and when she was excluded the figures were reduced to 21.40 (2.90). Comparisons of the groups using Student's t test revealed significant differences between this adjusted value for the programmers and those of the other groups ($p < .01$).

As the programmers were younger their periods of employment were correspondingly shorter than any other group. The consequence of this is that age–related and/or occupation–related problems may be expected to be minimal for the programmers with the exception of the older subject.

2.3 Apparatus

Equipment was built to measure anthropometric and workstation dimensions. Two rigs incorporating vertical and horizontal rules were assembled for taking anthropometric measurements together with an adjustable stool. A tape measure and protractor were also used when measuring workstations, as well as measurements and angles of the subjects *in situ* whilst working.

Two video cameras were used to record subjects' postures and postural changes over time.

A questionnaire with two sections was devised for the subjective recording of general comfort and discomfort for specific body areas: the first was a rating scale, the second a manikin with over a dozen parts of the body shown together with a further rating scale (see Figure 2).

Physical examination by physiotherapists included a computerised subjective assessment in which subjects were asked to pinpoint and describe their complaints. Firstly a diagram of the human body in its sagittal and coronal planes was shown to the subject, who was asked to rate the importance of the complaint(s) from A to Z (see Appendix 1). Secondly, the subject was asked a series of questions about the complaint(s) on a personal computer. The resulting printout of questions and responses provided the physiotherapist with a focus for the clinical examination.

2.4 Techniques and procedure

The methods used in evaluating workstations and health were:

1. Measurement of anthropometric dimensions of subjects,
2. Measurement of workstation dimensions,
3. Measurement of general subjective comfort,
4. Measurement of discomfort in different body areas,
5. Assessment of posture and posture change over time,
6. Physical examination of subjects by physiotherapists.

FIGURE 2. THE SUBJECTIVE QUESTIONNAIRE

NAME DATE TIME

GENERAL COMFORT RATING

Please rate your feelings *now*. Mark the scale.

I feel completely relaxed

I feel perfectly comfortable

I feel quite comfortable

I feel barely comfortable

I feel uncomfortable

I feel restless and fidgety

I feel cramped

I feel stiff

I feel numb (or pins and needles)

I feel sore

I feel very painful

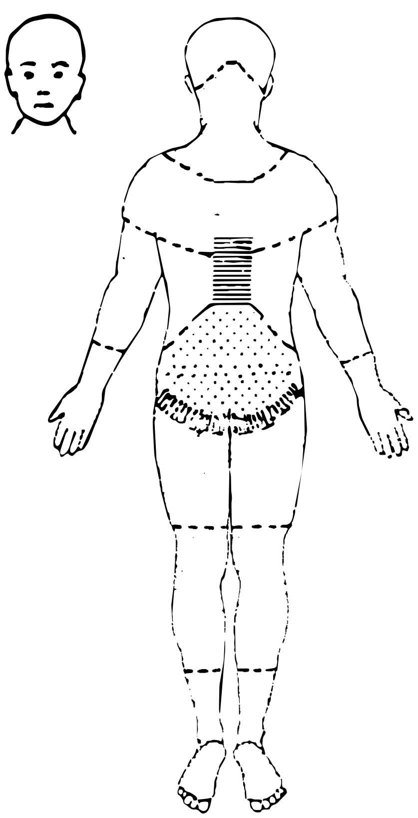
BODY PART DISCOMFORT

Please look at the figure. Do you feel discomfort in any part of your body? YES/NO.

If YES, mark the uncomfortable parts of your body on the chart in order of importance from A to Z.

For each body part which you have mentioned please rate the discomfort using the scale:

SCALE:
1. Just noticeable discomfort
2. Moderate discomfort
3. Quite bad discomfort
4. Severe discomfort
5. Almost unbearable discomfort



2.4.1 Physical examination and anthropometric measurements

Two student physiotherapists performed clinical examinations for their thesis project. They were advised by two physiotherapists who also attended to supervise examinations on two afternoons. The students will from now on be referred to as physiotherapists.

Subjects first completed a subjective assessment on the personal computer, whilst the physiotherapists dealt with another subject who had finished this phase. The subjective assessment sought to establish in which areas of the body the subject had complaints, whether these were experienced constantly or intermittently, the severity of pain, the kinds of activities (or non–activities) which aggravated the pain, the typical duration of pain and the form of activity (or non–activity) which alleviated the pain.

Before the examination subjects' weight and anthropometric measurements were taken. Subjects received a printout of their responses to take to the physiotherapists. It was found that the printout sometimes needed to be embellished with a little more detail: some responses were contradictory and sometimes subjects were unsure as to when they first started experiencing a complaint. Often a question about injuries did not elicit a response until later when the subject would suddenly announce that she had a car accident, fell on her head when young etc..

The contradictory nature of some responses was a characteristic found frequently from one technique to another. This issue is discussed later.

2.4.2 Posture assessment

Subjects' working posture was recorded by means of video cameras. Initially recordings lasted up to two hours. However, when replaying the tapes recorded over the first week it was apparent that the 'repertoire' of subjects' postures was exhausted in a shorter period. After this the recordings lasted an hour. In filming a sideways view was always attempted, in order to gain as comprehensive a perspective as possible. Obtaining a proper picture of the position of a subject's limbs in relation to the workstation is difficult without using two cameras. This would have been expensive and impossible within the time limits set by the study. As it was the two cameras were fully employed recording different subjects.

2.4.3 Measurement of workstation dimensions

The measurement of workstation dimensions was performed with the help of a researcher from the Environmental Studies Division.

2.4.4 Measurement of subjective comfort

The questionnaire measuring subjective comfort was completed by subjects six times throughout the day – twice before morning tea, twice between tea and lunch, and twice in the afternoon. On each occasion a blank questionnaire was presented to the subjects, in order to reduce the effect of memory and a stereotyped form of response. Two interns from IPER administered the questionnaire – one with the IPER staff on the 7th and 8th floors and one with the staff on the Lower Ground Floor, largely in the Computer Centre. The interns changed positions halfway through the study in order to control for any bias that might have arisen through familiarity with the subjects.

The questionnaire consisted of an 11–point 'General Comfort Rating' scale ranging from the statement 'I feel completely relaxed' up to 'I feel very painful'. The instruction was to 'Please rate your feelings *now*' and the subject could mark the scale either by a statement or at intermediate points. Thus someone might prefer to mark the scale in between 'I feel quite comfortable' and 'I feel barely comfortable'.

The 'Body Part Discomfort' section began by asking whether subjects felt discomfort in any part of their bodies. If the answer was positive then they were asked to mark the parts in order of importance from A to Z (much the same as in the physical examination) and then to rate the discomfort on a 5–point scale based on the psychophysical notion of a threshold of a 'just noticeable difference' (see Figure 2).

The questionnaires were understandably the largest part of the study with 6 x 14 working days equal to 84 potential questionnaires completed by each subject over the entire period.

3. RESULTS AND COMMENTARY

3.1 General Comfort Ratings

The General Comfort Rating scale (GCR) was the first section of the questionnaire. It was developed by Shackel *et al* (1969) to compare the comfort of different types of chairs as perceived by users. Seat comfort was being measured rather than user comfort so that the employment of the GCR in the context of the present study, where the user's comfort was the prime consideration, was not entirely appropriate. For instance, the statement 'I feel cramped' is more fitting to describe one's reactions to a chair than to describing one's own physical sensation of comfort.

However, the GCR has been used many times (which suggests it is reliable) and no other scales have been employed more than once or twice. Two of the original statements were altered; 'I feel sore and tender' was changed to 'I feel sore', and 'I feel unbearable pain' was changed to 'I feel very painful'. As most of the responses fell into the 'I feel quite comfortable' end of the scale it is thought that the GCR was suitable for its purpose in providing a very global view of the subject's comfort at that time.

Table 1 presents a summary of all GCRs for the entire period of the investigation.

The pooling toward the lower (more comfortable) end of the scale will be evident from examining the mean values. There also appear to be differences between individuals and between groups. Maximum ratings are generally reflections of single instances of greater discomfort, though, as will be seen later, a few subjects do experience discomfort more or less continuously.

Most of the analyses of the GCRs were performed by Dr Koortz of ISR and the graphs and statistical analyses which he has provided are included in the text and appendices.

The first hypothesis which was considered was that of postural fatigue. The role of cumulative postural fatigue in the aetiology of musculoskeletal disorders is well documented in the literature and previous studies have demonstrated its progression during the day (Corlett and Bishop, 1976). Figure 3 charts the mean GCRs for each group across the working day for the entire 14 days. There is a small but gradual increase in discomfort from time 1 to time 4, an indication of a decrease after lunch at time level 5, and then a rise in discomfort until time 6. It is noticeable that, for the data–typists especially, the fatigue builds up very quickly early in the day from time 1 to time 2.

Page's trend test was performed on this data (see Appendix 2) and the value of L was found to exceed the critical table value at the one percent level of significance. It can therefore be concluded that there is a general postural fatigue effect for all four groups during the normal working day which is statistically significant. This confirms the findings of Corlett and Bishop (*ibid*) who demonstrated that perceptions of postural discomfort are linearly related to the time of exposure to that posture.

TABLE 1. GENERAL COMFORT RATINGS FOR ALL SUBJECTS

	mean	SD	max	min
PROGRAMMERS	1.64	0.67	9	2
EF	2.13	0.84	9	2
SO	2.00	0	2	2
TG	2.07	0.32	3	1
ID	1.53	0.73	4	1
HF	1.67	1.04	4	0
CC	0.37	1.15	5	0
JH	1.90	0.80	7	0
JR	1.48	0.50	2	1
RESEARCHERS	2.01	1.19	5.25	0.75
GS	1.70	1.20	5	0
RR	0.27	0.51	2	0
IP	0.44	0.56	2	0
JGS	1.92	1.14	9	1
DM	2.42	0.69	4	1.50
DZ	2.47	1.24	5	0
HO	2.20	0.72	5	1
JL	2.22	1.02	7	0
EL	1.05	0.87	2	0
JB	2.05	0.22	3	2
NC	2.76	2.35	10	1
SC	1.11	1.16	4	0
HB	3.13	1.82	7	1
KH	0.25	0.57	2	0
GH	1.90	1.55	6	0
MV	2.81	1.00	5	1
GP	2.10	0.86	5	1
DATA–TYPISTS	2.77	1.31	6.43	0.86
AC	2.39	0.71	5	2
AP	3.75	3.21	10	0
MC	2.16	0.85	7	0
LB	2.15	0.85	7	2
KF	2.94	1.98	7	0
CN	3.99	1.37	6	0
AD	2.05	0.22	3	2
TYPISTS	2.67	0.90	6.20	0.80
AK	6.95	1.05	9	3
VM	1.31	0.72	5	0
EL	2.04	1.10	5	1
BO	2.07	1.30	10	0
MN	1.00	0.35	2	0

SCALE:				
	0	completely relaxed	6	cramped
	1	perfectly comfortable	7	stiff
	2	quite comfortable	8	numb (pins & needles)
	3	barely comfortable	9	sore
	4	uncomfortable	10	very painful
	5	restless & fidgety		

FIGURE 3. GENERAL COMFORT RATINGS OVER TIME

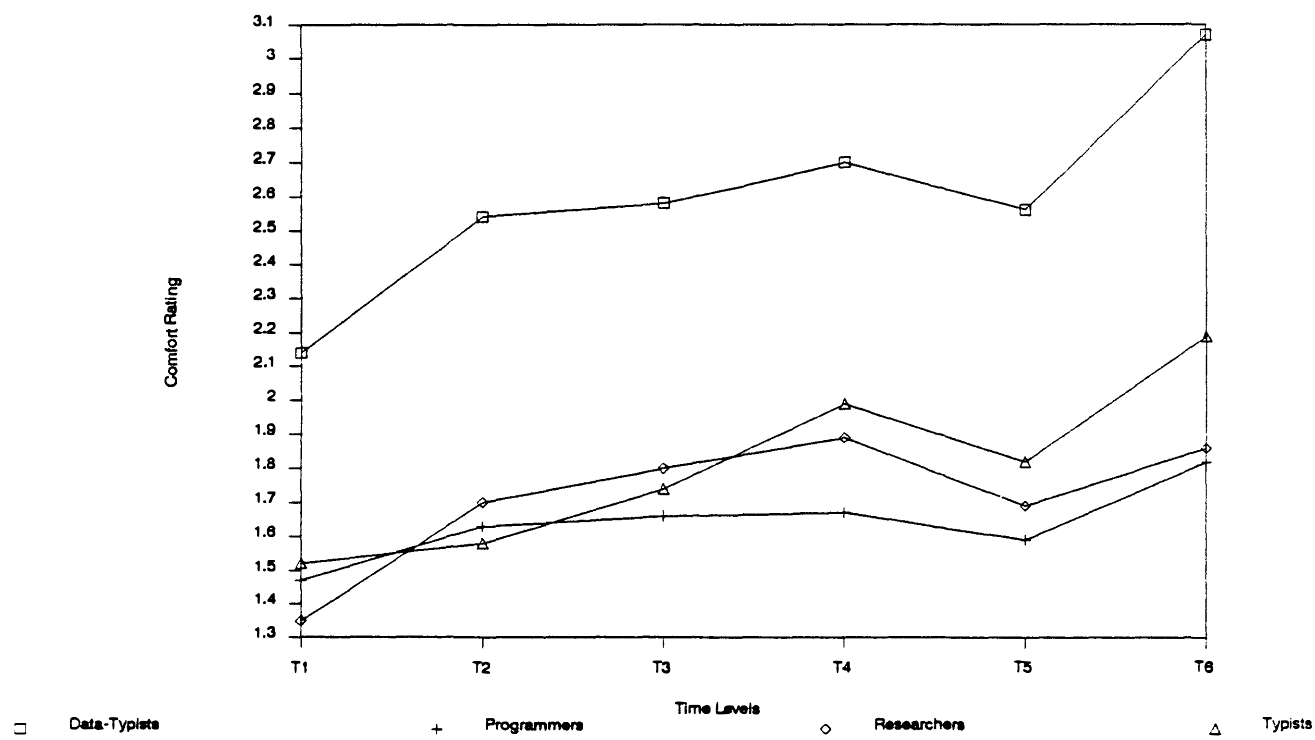


Figure 3 also shows that the 30 minute lunch break provided does not act as an adequate recovery period especially for the typist and data–typist whose work posture is more fatiguing than that of the researcher and programmer. Figures 4–7 describe the mean Discomfort Frequency scores for each group (the average number of times subjects gave a response of 'Yes' to the question 'Do you feel discomfort?'). These show the effect of a lunch break for the programmers and researchers but suggest the greater discomfort of typists and data–typists is not markedly reduced by the break. Discomfort appears to taper off as the afternoon progresses for these subjects which may indicate that fatigue has slowed down the pace of work.

When examining the graphs there is no indication of any slight reduction in fatique because of tea breaks which might be expected. This could be due to the fact that people 'recharge their batteries' by passive relaxation at tea–time, whereas they tend to be much more active at lunch–time – going shopping, walking within the building. Such a change creates postural variety and quickly recycles oxygenated blood into the muscles and removes toxic waste products.

In comparing groups it is noticeable that the data–typists are apparently much less comfortable than the other groups. It should also be noted that typist AK who was always uncomfortable has been excluded from the graphs because she was atypical. Her mean GCR was 6.95 (Table 1). Her inclusion would place the typists above the data–typists in Figure 3.

FIGURES 4–7. FREQUENCY OF DISCOMFORT OVER TIME

FIGURE 4. DATA-TYPISTS

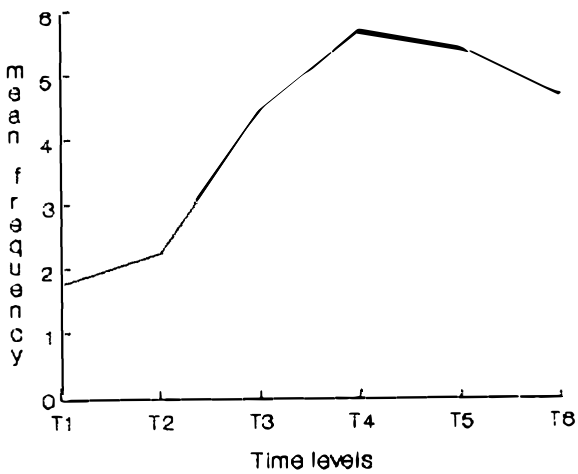


FIGURE 5. TYPISTS

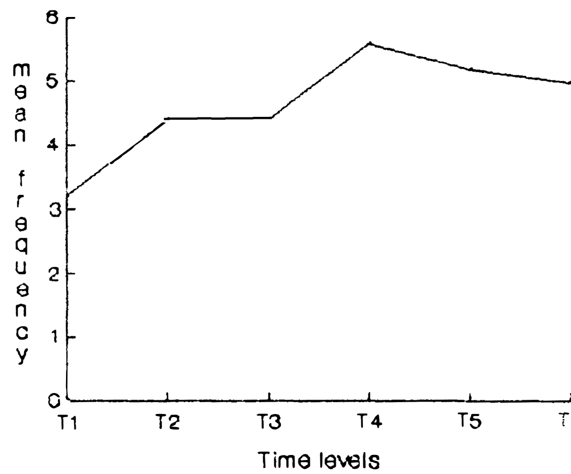


FIGURE 6. PROGRAMMERS

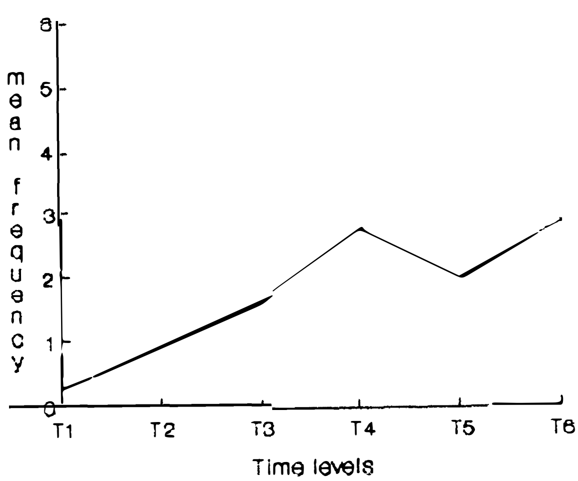
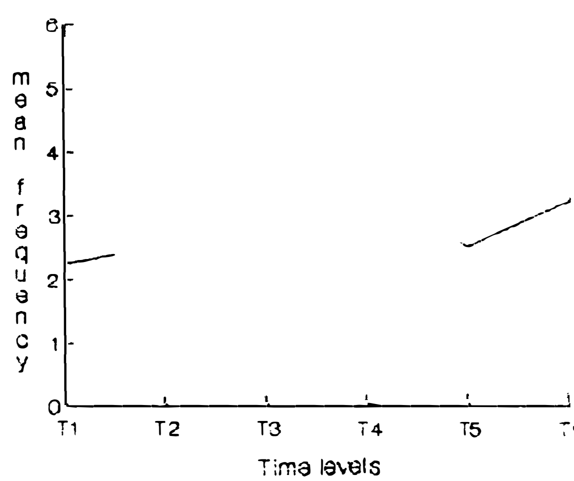


FIGURE 7. RESEARCHERS



It is a frustrating fact that in attempting to correct for abnormalities which bias mean values the exclusion of a subject for one reason results in the mean being distorted by another subject for another reason. This is more the case in the analysis of body part discomfort. The means are biased mainly because of the small group sizes. This point has to be emphasised to qualify the conclusions drawn from comparisons between groups which must remain tentative at the moment.

Viewing the responses towards the GCR scale it was notable that certain statements were hardly ever used by subjects. These were 'I feel cramped' and 'I feel numb (or pins and needles)'. This could be because the occurrence of such states was rare or because the statements themselves were not as meaningful as others. It was also found that one subject could similtaneously feel 'quite comfortable' and 'stiff' whilst another felt 'stiff' most of the time or else 'sore'. Clearly there is a certain overlapping of meanings for different people. This finding was confirmed when the responses to the Body Part Discomfort section of the questionnaire were examined.

As all the responses to the different techniques were analysed it became clear that a holistic perspective reveals quite a degree of uncertainty about how subjects perceive themselves and their sensations. If they can state that they feel 'quite comfortable' and yet have 'moderate' or 'quite bad discomfort' in some body parts what is this telling us? On the surface two explanations could be offerred: firstly, there is a social pressure not to dwell on one's aches and pains. Secondly, people may not wish to admit to themselves that they are uncomfortable, especially if the sensation is more or less constant, so they deny it or fail to recognise it. The meaning of pain, suffering and locus of control is being researched at present by medical practitioners.

In comparing the GCRs from this study with those of the previous studies using this technique it is noticeable how chair design has improved. For instance, in the Shakel *et al* study of 1969 (*ibid*) mean values for 10 chairs varied from 1.5 to 4.0 whereas 13 years later Drury and Coury (1982), evaluating a single chair, found means of 1.5 for typists and 2.0 for terminal users. Drury and Francher (1985) later evaluated an unconventional office chair where the means for typists and terminal users were 2.0 and 3.0 respectively. So the findings of the present study fit in quite well and suggest the majority of subjects are feeling 'quite comfortable' for most of the time.

However, there may be a form of 'regression to the mean' effect where it is all too easy to say that you feel quite comfortable. The GCR results should therefore be treated with caution.

3.2 Body Part Discomfort Ratings

Body part discomfort (BPD) rating was a technique first adopted by Corlett and Bishop (*ibid*) for assessing the postural discomfort of workers operating spot welding machines. It was later refined by Drury (Drury and Coury, *ibid*; Drury and Francher, *ibid*) in the evaluation of chair comfort. The first question asked whether subjects felt discomfort in any part of their body (Figure 2). If the answer was 'No' then no further questions were asked. If the answer was 'Yes' then the subject rated the uncomfortable areas in alphabetical order and gave each a discomfort rating according to the 5–point scale provided.

3.2.1 Body Part Discomfort Frequency

The percentage of occasions on which a 'Yes' response was given to the question on discomfort was considered as the 'Body Part Discomfort Frequency' (BPDF). Answers to the second question provided a measure of 'Body Part Discomfort Severity' (BPDS).

The issue which was first addressed in the data analysis was whether GCR and BPD were measuring the same thing. Did those subjects who felt more or less comfortable in the former ever say that they had discomfort in a specific body area? Two Chi–squared tests were performed on all responses at time 1 and time 4 – times when fatigue or discomfort were low and high respectively. The 2 x 2 contingency table was designed so that scores up to and including a GCR of 2 were considered 'comfortable' and scores of 2.5 to 10 'uncomfortable'. The rows were the 'Yes' and 'No' responses to BPD. At both times there was a high degree of association ($p < .001$) between GCR and BPD, despite the fact that there were some subjects whose responses were apparently contradictory, as has already been mentioned.

TABLE 2. ASSOCIATION BETWEEN GCR AND BPD

		Time 1				Time 4	
		GCR				GCR	
		0–2	2.5–10			0–2	2.5–10
BPD:	'yes'	30	41	BPD:	'yes'	70	93
	'no'	301	12		'no'	220	7

The 'contradictory' cells in Table 2 are 30 and 12 for time 1 and 70 and 7 for time 4. It is evident that discomfort has increased over time but it is interesting that for time 4 there are as many as 70 subjects who feel generally comfortable although they have an area of discomfort.

FIGURE 8. BODY PART DISCOMFORT FREQUENCY

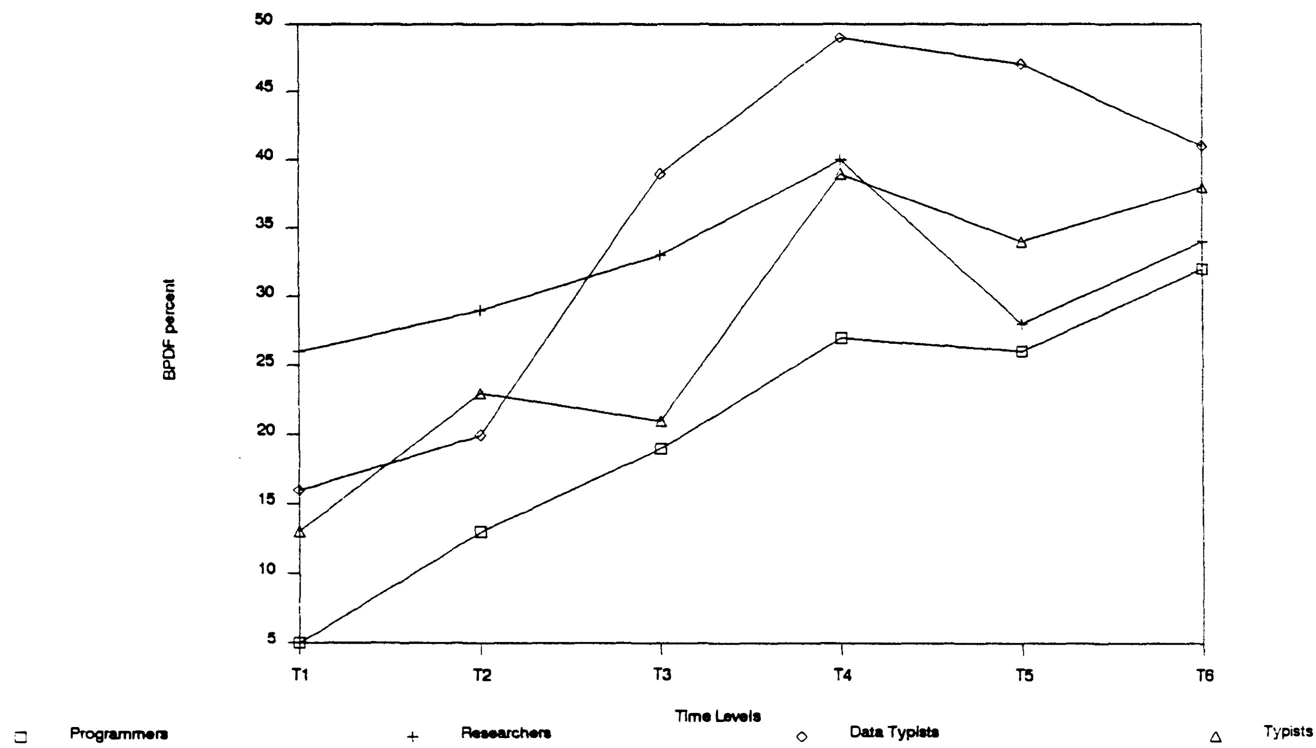


Figure 8 depicts the number of occasions on which subjects gave a 'Yes' response to the question 'Do you feel any discomfort in any part of your body?' expressed as a percentage of the total number of occasions. Again there is a temporal trend as with the GCR, indicative of postural fatigue. Although some of the percentages may seem high it must be remembered that this is for the duration of the study. A subject may have responded 'Yes' to the question on 1 out of 12 occasions. This is 8%. Another individual, on the other hand, may have responded 'Yes' 14 times on 14 occasions — 100%. So the weighting of the mean has to be seen in this light. A full breakdown on each subject is included in Appendix 3.

3.2.2 Body Part Discomfort Severity

If subjects had answered 'Yes' to the first question then they were instructed to specify the area(s) in which they experienced discomfort, weighting their importance from A to Z. The hypothesis in the Corlett and Bishop (*ibid*) study was that if more areas were felt to be painful then it was probable that the intensity of pain would be greater than if only one area were affected. In the present study it was realised after a pilot session that this method was not wholly appropriate, since the degree of postural discomfort experienced by office workers was obviously considerably less than that of spot welders whose job involved standing and operating a foot pedal all day.

An alternative scale (Roland and Morris, 1983) of measuring the intensity of discomfort was used (see Figure 2). It was thought that the statements from 'Just noticeable discomfort' (1) to 'Almost unbearable discomfort' (5) would prove more easily quantifiable and be more meaningful for the subjects. The A to Z weighting idea was retained, partly to discriminate between two or more areas given the same discomfort rating – it was frequently found that aches were quite widespread and crossed over the boundaries delineated in the body diagram.

Table 3 and Figure 9 show the mean BPDS scores for subjects by occupational group. Table 4 and Figure 10 show the mean BPDS scores weighted by the number of body parts affected similtaneously.

It is evident that there is little difference between the graphs for the researchers and programmers but those of the typists and data-typists confirm that these subjects tend to experience discomfort frequently in more than one area. The scores need to be viewed in conjunction with the body part discomfort frequency percentages, since the scores in the above tables reflect the mean severity of discomfort when discomfort was present. This was nil in some cases and always in others. In conclusion, as these figures are means for the duration of the study, it does appear that there are some subjects who regularly suffer from quite bad discomfort or even severe discomfort.

TABLE 3. BODY PART DISCOMFORT SEVERITY (MEAN SCORES)

Time level	T1	T2	T3	T4	T5	T6
DATA-TYPISTS	1.70	1.70	3.19	2.67	3.00	3.47
TYPISTS	1.83	1.91	1.67	1.72	2.37	2.80
PROGRAMMERS	1.00	1.38	1.55	1.79	1.82	1.45
RESEARCHERS	1.31	1.32	1.69	1.83	1.59	1.72

FIGURE 9. MEAN BODY PART DISCOMFORT SEVERITY

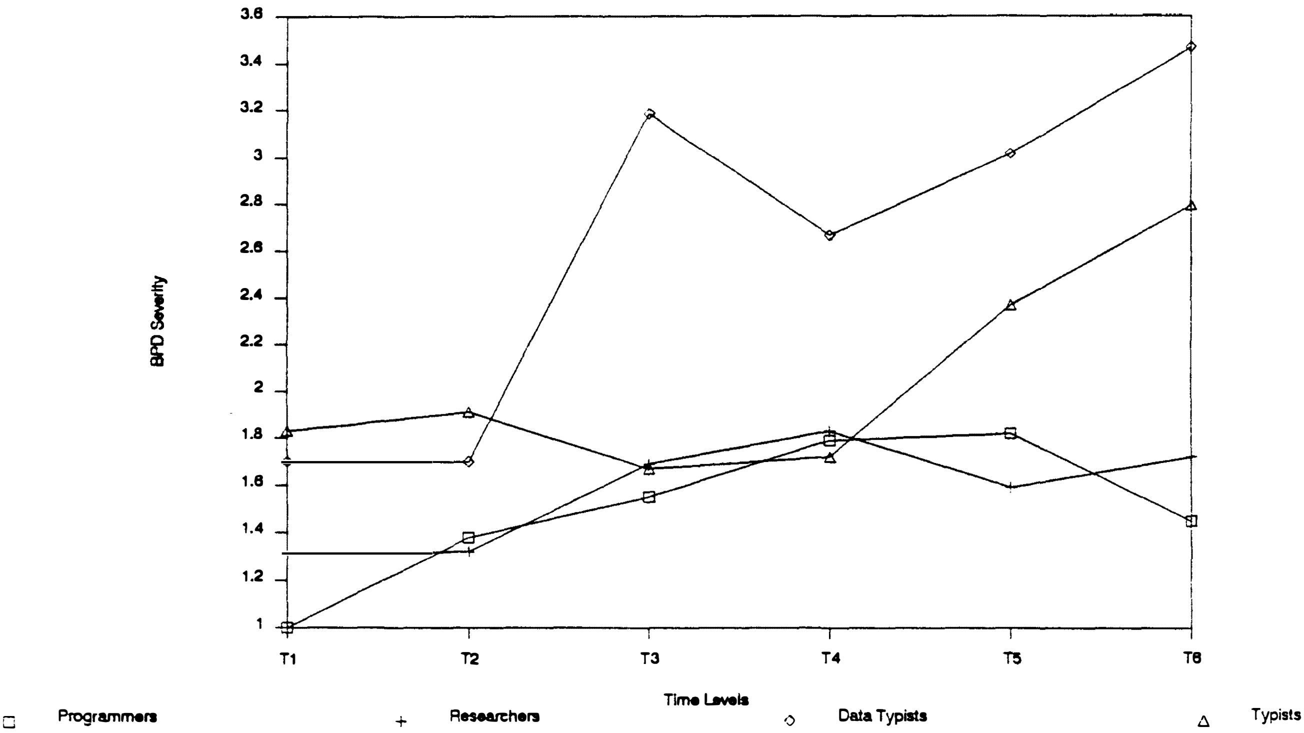
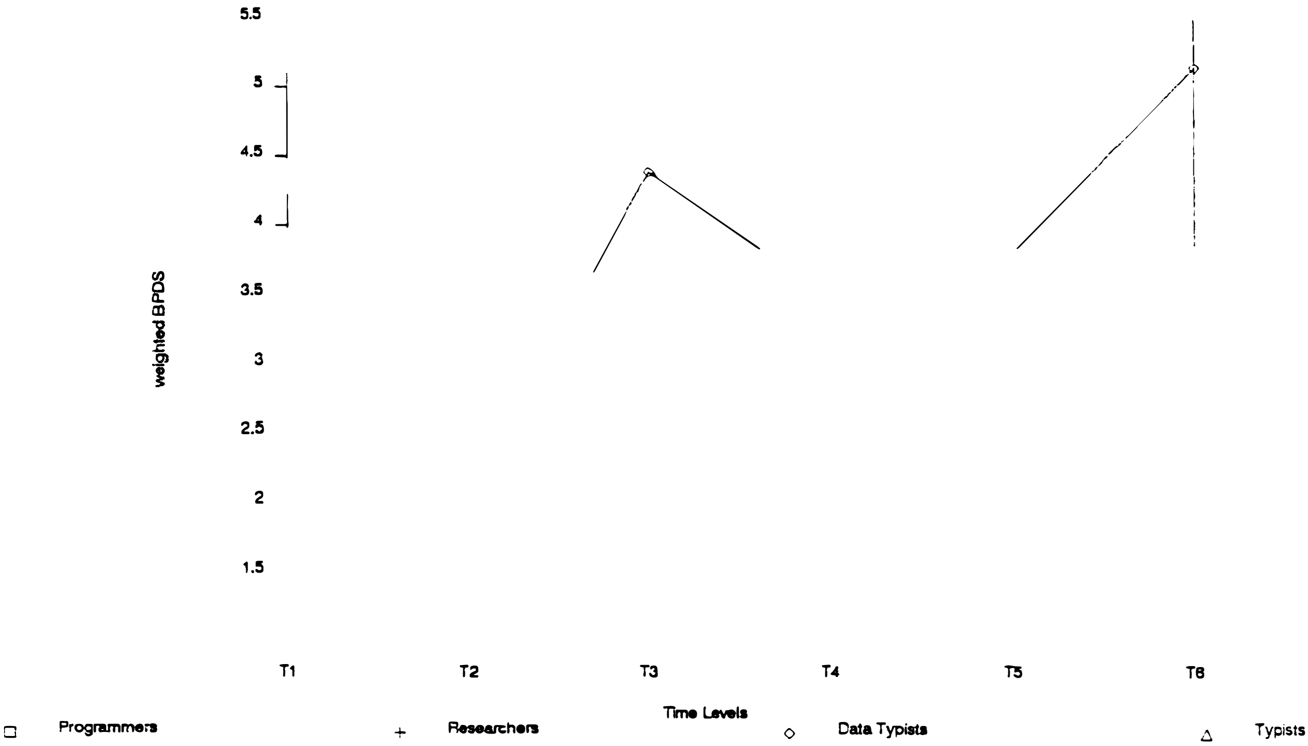


TABLE 4. BODY PART DISCOMFORT SEVERITY (MEAN WEIGHTED SCORES)

Time level	T1	T2	T3	T4	T5	T6
DATA–TYPISTS	2.00	2.00	4.38	3.48	3.79	5.13
TYPISTS	1.83	2.11	1.67	2.23	3.44	3.80
PROGRAMMERS	1.00	1.50	2.05	2.31	2.24	1.65
RESEARCHERS	1.52	1.48	1.95	2.13	1.94	2.37

FIGURE 10. MEAN WEIGHTED BODY PART DISCOMFORT SEVERITY



3.2.3 Body parts in discomfort

From a physiotherapeutic angle perhaps the most interesting information to be gained from the questionnaire is exactly where subjects experience discomfort. This can be used in conjunction with the more objective findings from the physical examination. From an ergonomic perspective such information can point to where there may be deficiences in workstation design.

Figure 11 shows the overall picture for subjects throughout the study. It is apparent that neck and lower back ache are the main sources of discomfort for the subjects as a whole. The other areas affected are the right and left shoulders, the upper back, and the frontal part of the head. Right and left thighs were also affected to a lesser extent. The total number of occasions on which discomfort was registered was expressed as a percentage of the number of times the questionnaire was administered. Percentages for each body area and occupational group are shown in Figure 12. It is evident that there is great variability in symptoms between groups.

FIGURE 11. BODY PARTS IN DISCOMFORT

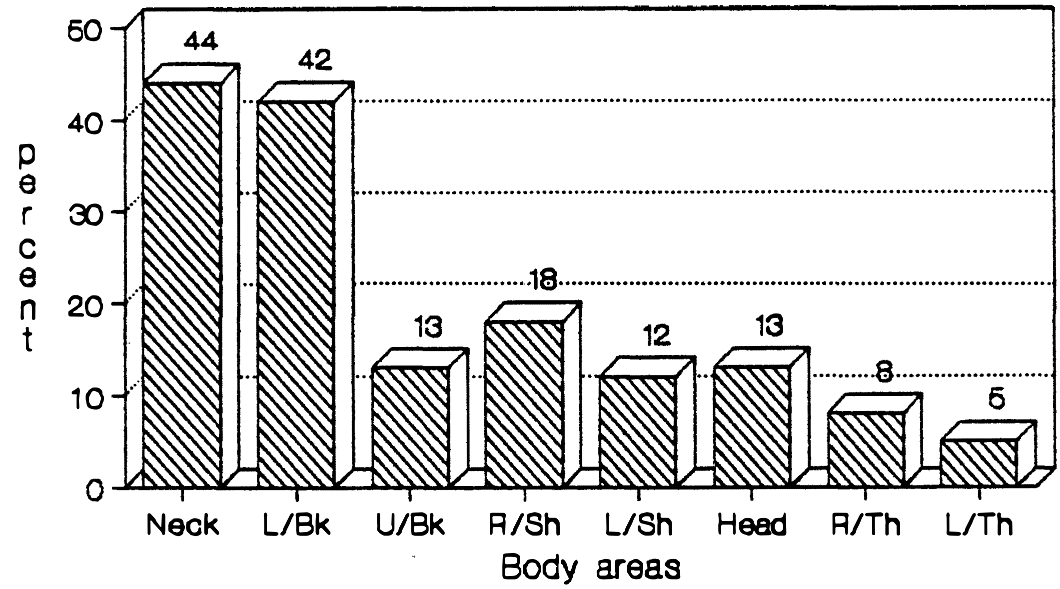


FIGURE 12. BODY PARTS IN DISCOMFORT BY OCCUPATION

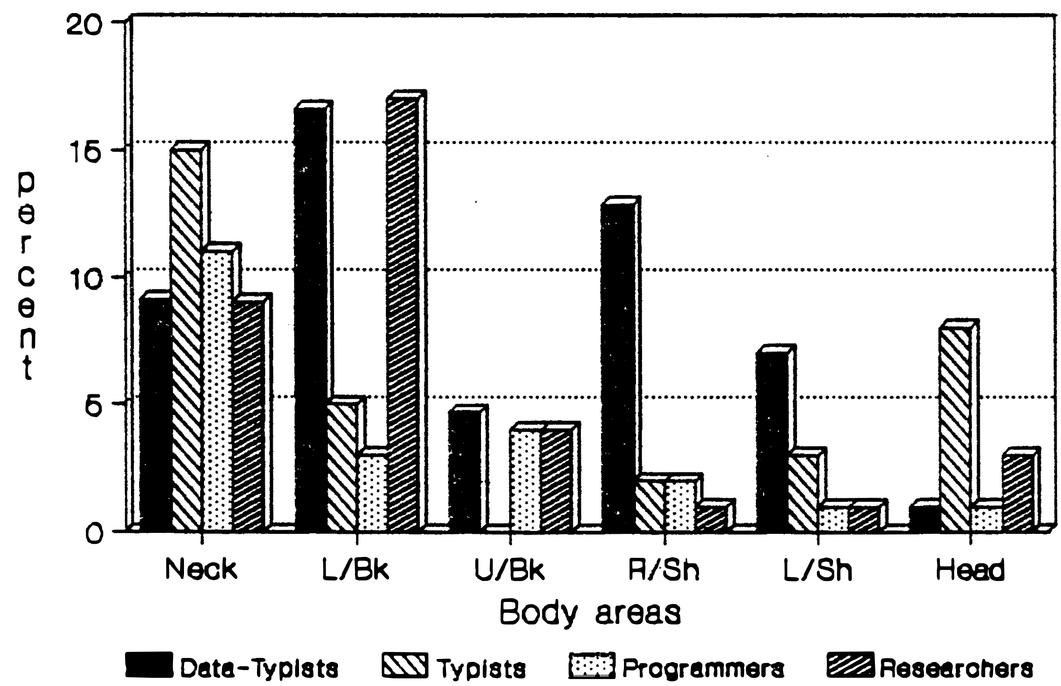


TABLE 5. DISCOMFORT BY BODY AREA (FROM DATA–TYPISTS SCORES)

	NECK	L/BACK	U/BACK	R/SH	L/SH	F/HEAD	B/HEAD
LB	11	7	1	1	1	7	0
AC	0	25	1	0	0	3	0
MC	6	1	0	7	0	0	0
KF	0	0	17	2	1	0	16
CN	12	0	1	43	26	0	0
AD	2	1	0	0	0	0	0
AP	8	37	0	2	2	0	1
TOTALS	39	71	20	55	30	10	17
OCCASIONS	428	428	428	428	428	428	428
PERCENT	9	17	5	13	7	1	4

Table 5 is an example of how the figures were derived for the graphs. It is evident from this that there is also great variability within groups. Even a cursory glance at this data reveals the tremendous weighting of the figures because of one or two subjects' responses. For instance, in the table above, subject CN experienced discomfort in her right shoulder on 43 occasions out of a total of 55 for the group and in her left shoulder on 26 times out of 30. Low back pain is experienced regularly by two subjects (AC and AP) and upper back pain mainly by one subject (KF). Of these subjects five are experiencing discomfort on a daily basis (LB, AC, KF, CN and AP), one has pain almost daily or occasionally (MC) and one occasionally (AD). In this context 'almost daily' means every second day and occasional means once a week.

Thus it is difficult to make assertions about the different groups from such profiles but the overall picture is similar to the findings of the earlier interviews which cited the locus of complaints in the neck and lower back. This was confirmed in the physical examinations of the cervical and lumbar spine. Many of the symptoms concerning the shoulders and some of those concerning the head are the result of referred pain from the neck. A smaller but significant proportion of complaints among data–typists and researchers involved discomfort in the underside of the thighs because of ischaemia and pressure in that area. Other symptoms were also in evidence – aches in the arms and hands of data–typists and typists, and aches in the legs and feet – but these were more isolated and are therefore not included in the figures.

3.3 Physical examination

The brief of the study was to determine which health complaints were likely to be due to chronic musculoskeletal disorders or previous trauma and which were linked to bad working posture and/or workstation design. The aim of the physical examinations was to answer the first question and exclude problems related to pathology, trauma or anatomical abnormalities. These examinations were also an important source of data about those problems which appeared to be a result of working posture.

The examinations by physiotherapists incorporated a subjective assessment, determining area, severity and type of pain. In this case (which is not customary) the assessment was performed using a computerised questionnaire, designed on an indirect questioning basis. This was followed by the objective assessment (based on the Maitland principle) which included:

1. The physical posture and postural abnormalities;
2. The range of body movements and their relationship to pain, stiffness and spasm;
3. Neurological examination of sensations, reflexes and muscle power;
4. Palpation — to determine any soft tissue spasm, thickening, temperature change and the range, pain and stiffness of the accessory movements of other joints under consideration.

The rest of this section relies heavily on the project report submitted by the physiotherapists. In their study the term 'clinical' was defined as being symptoms confirmed on objective examination and/or complained of in the computerised subjective assessment. (Thus the use of the term 'clinical' does not, in itself, imply a particular type or severity of disorder.) The use of 'Pathological' was confined to conditions caused by disease, degenerative processes and disc lesions. 'Trauma' referred to injuries, either to bony or soft structures.

Differentiation of clinical symptoms

Figure 13 illustrates which of the reported symptoms were related to previous trauma and/or pathology and which were not. Seventy–eight percent of subjects experienced discomfort in the neck region. Sixty–five percent of these had no known trauma and/or pathology (Clinical). All of the subjects who complained of upper back symptoms, and sixty–two percent of subjects who complained of lower back symptoms, had no known previous trauma or pathology.

With regard to the terms used in the figure, 'Neck' includes symptoms in the cervical spine, trapezii spasm and rhomboid spasm; 'Upper Back' includes symptoms in the thoracic spine and/or erector spinae spasm; 'Lower Back' includes symptoms in the lumbar spine and/or erector spinae spasm; and 'Head' includes both frontal and occipital headaches.

A summary of the data obtained from the subjective and objective examination for each subject is included in Appendix 6.

FIGURE 13. DIFFERENTIATION OF CLINICAL SYMPTOMS

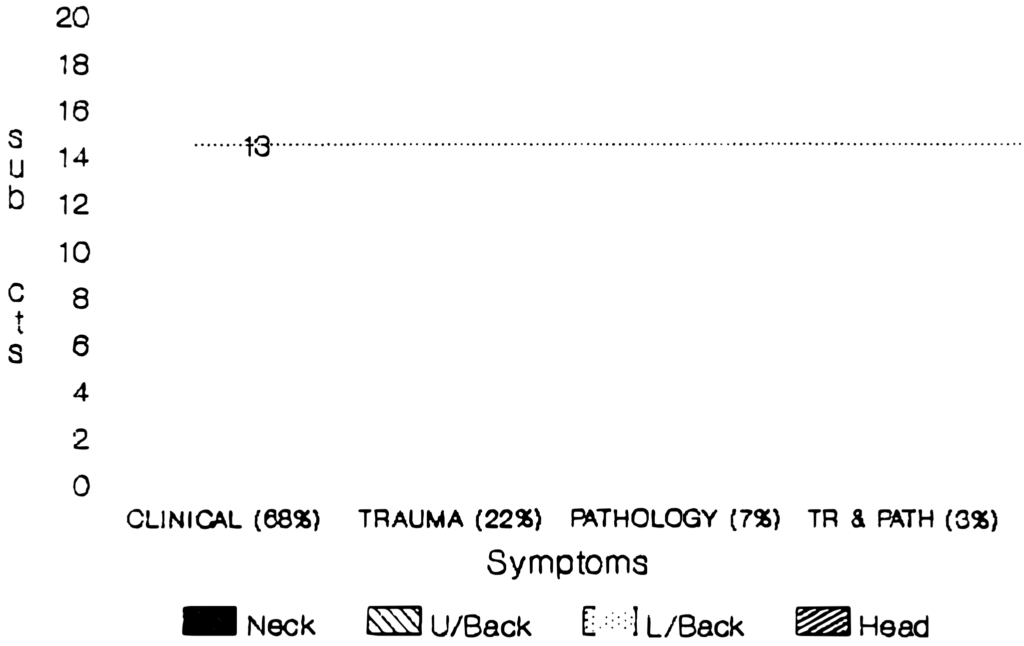


FIGURE 14. SYMPTOMS OCCUPATIONALLY AGGRAVATED

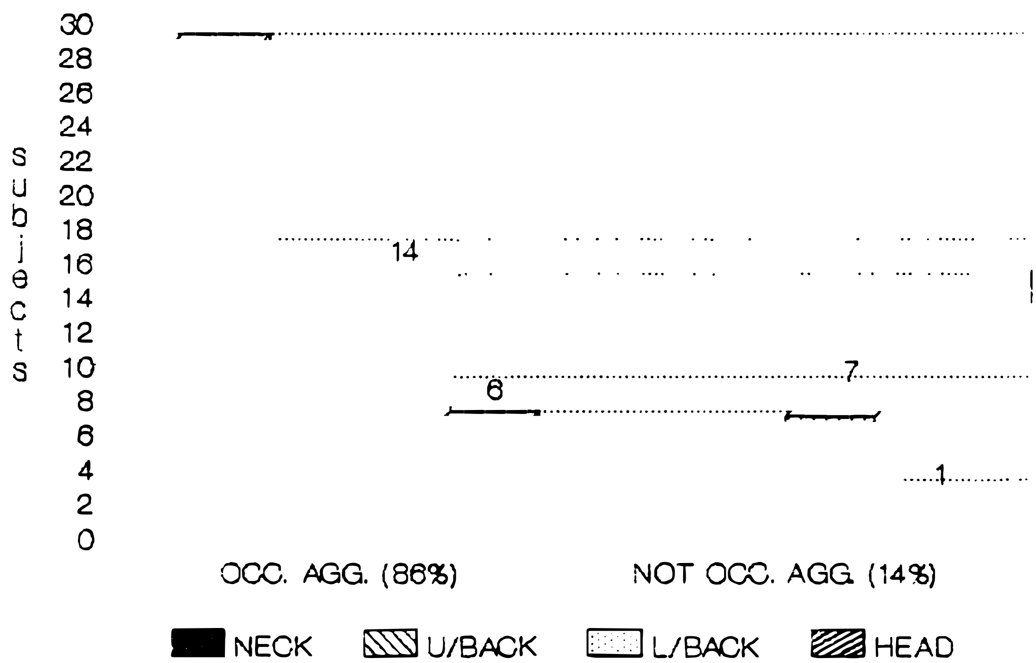


Figure 14 depicts whether the subjects reported their symptoms as being occupationally aggravated or not, as stated in the computerised subjective assessment. (This is within the section which asks what type of activities aggravate the presenting symptom. The question simply asks 'Does your occupation aggravate the problem?')

Eighty–six percent of all reported clinical problems were said to be occupationally aggravated. Ninety–seven percent of the neck problems and sixty–seven percent of the lower back problems were said to be occupationally aggravated. (The physiotherapists' report uses the phrase 'occupationally related or aggravated' for the reason that though the question says 'aggravate', some subjects maintained that their work actually caused the problem when they were asked to state how the complaint first arose.)

In discussing these results the physiotherapists make several points. Firstly, the 68 % of the reported clinical problems not related to previous trauma or pathology must have some other causative factor(s), which might well be constrained postures and/or repetitive movements (Hunting *et al*, 1981; Oborne, 1982).

Secondly, of all reported clinical problems 49% were in the neck region and 36% in the lower back. This prevalence of neck problems is in agreement with studies showing that symptoms occur more frequently in the neck region of data–entry operators (the so–called 'Occupational Cervicobrachial Syndrome').

Thirdly, of the 49% presenting with a neck problem, the majority had associated muscle spasm. There may be some relationship between this and muscular fatigue due to static loading and/or repetitive movements (Oborne, *ibid*).

Fourthly, the subjects who experienced headaches also complained of symptoms in the neck region and presented with findings on objective examination of the cervical spine. However, no attempt was made to direct link neck symptoms and headaches. These headaches may also be related to stress and eye strain as subjects frequently complained of both.

Lastly, most subjects reported their symptoms to be related to, or aggravated by, their occupation. This is based purely on the subject's own opinion and remains to be verified. It is possible that the knowledge that the study was dealing with ergonomic problems biased the subjects' response. (The question in the subjective assessment may also have been influential in leading the subjects. On the other hand, as subjects spend the greater part of their active lives at work, the relatively high response may not be unduly false. Nevertheless, this response must be corroborated by other evidence).

The physiotherapists note the disappearance of two subjects' complaints following a change in their working chairs, which is in agreement with the findings of Ong (*ibid*), that an altered and ergonomically designed workstation helps to minimise the subjects' symptoms. They also observe that a number of people complained of circulatory problems in the back of the thigh which was relieved when they walked around. This illustrates that subjects would benefit from rest periods every hour, which serves to reduce musculoskeletal fatigue and the amount of prolonged static loading. (Indeed one of the simple answers to the health hazards of chairs is precisely that any prolonged static posture such as sitting is likely to be injurious to health, no matter how comfortable the chair may be).

In their conclusion the physiotherapists mention the following avenues for further research:

1. The importance of physical fitness in office workers,
2. The role of a backschool in office working environments,
3. Stress related to physical symptoms,
4. Rest periods and postural fixity as related to clinical symptoms,
5. Headaches – their relationship to stress, neck problems and visual display terminal work.

3.4 Comparison of reports of symptoms

The various reports of subjects' symptoms were compared. This included the responses to the preliminary interviews, the daily Body Part Discomfort responses, and the subjective and objective physical examinations. In 57% of cases there was a good or satisfactory correspondence – no major complaints had been omitted in the preliminary interviews that were present in the daily questionnaires and in the physical examinations – with the exception of headaches. Out of 25 subjects who complained of headaches, only 5 mentioned them in the physical examination. Opinions differ on why this should be.

In 32% of cases there was some correspondence across the reports – new symptoms were mentioned to the physiotherapists which had not been previously mentioned in the interviews. This runs counter to what might be expected since the clinical examination employed indirect questioning mainly whilst the other techniques tended to use direct questions. One instance of a discrepancy was CN who maintained her complaint occurred 'occasionally' in the physical examination and yet who actually experienced discomfort on 78% of the occasions when the questionnaire was administered.

In 11% of the cases there was little or no correspondence between the different reports. Some subjects said they had no symptoms in the interview, yet reported several to the physiotherapists. Another subject complained of minor symptoms in the interview but experienced discomfort quite frequently during the study and reported major problems to the physiotherapist.

A total of 16 subjects (43%) said they had visited their doctor but it was noticeable that these visits were often for other problems such as eyesight.

The findings in this section accord with the experience of professional physiotherapists who find that patients tend to have 'tunnel vision' and cannot see beyond their current frame of reference to appreciate the relevance of past traumas and their style of life for their present symptom.

However, in the study most major complaints were pointed out and examined. The use of several techniques has meant that any discrepancies have been noted and that reasonably accurate profiles of the health of each subject now exist.

3.5 Anthropometric and workstation dimensions

Anthropometric and workstation dimensions are shown in Table 6. Findings are summarised with the aid of diagrams, using the numbers shown in the table to refer to the dimensions. A protocol describing measuring procedure and terms used is in Appendix 8.

The groups have been broken down into researchers who use VDTs, and those who do not. A single person category was created for the data–typist in IPER. Tables of measurements for all categories are included in Appendix 7. Numbered dimensions in the diagrams refer to aspects which were unergonomic.

3.5.1 Data–Typists

There are many points of concern in the data–typist profile and it can be readily seen from the diagrams how the Computer Centre pool subjects differ from the data–typist in IPER (Figures 15 and 16). The chief limiting factor in the pool is the customised computer–console which allows for no individual variation in body size. It is cramped, the screen is too low and is not tilted. Consequently data–typists have to sit well back from the screen and the eye to screen distance is too far, which leads to visual problems. The low screen and document heights, and the lack of armrests mean the neck is overloaded. Typing with the keyboard off–centre and the source document to the left side of the screen necessitates a twisting of the neck and trunk which is hazardous in the long term, since the structure of the intervertebral disc of the spine is most vulnerable to torsional movements. The keyboard is fixed at an awkward and unnatural angle which requires ulnar deviation of the typing hand.

The chairs are too high for some subjects who have to use footrests. Backrests should be higher to support the upper back. New chairs were purchased in August 1987, but interviews in October revealed that 67% of this group were dissatisfied with their chairs. At the time of the study two subjects were using another kind of chair and a third sat in an old visitors chair.

TABLE 6. ANTHROPOMETRIC AND WORKSTATION MEASUREMENTS

	Age
	Sex
	Weight
	Height (without shoes)
Seated on standard stool with shoes on:	
	Eye height
1.	Elbow height
	Knee height
2.	Popliteal height
	Elbow–fingertip length
	Buttock-knee length
3.	Buttock-popliteal length
	Hip breadth
At workstation:	
D.	Upper arm abduction
F.	Forearm angle
E.	Elbow angle
C.	Hip angle
A.	Head inclination
B.	Neck-head angle
4.	Thigh clearance
5.	Eye height (at chair used)
6.	Eye-screen distance
7.	Eye-screen inclination
8.	Eye-document distance
9.	Eye-document inclination
10.	Eye-document deviation
11.	Screen tilt
12.	Backrest angle
13.	Seat tilt
14.	Screen height
15.	Keyboard height (home row)
16.	Desktop height
17.	Backrest height
18.	Armrest height
19.	Seat height
20.	Seat depth
	Seat width
	Backrest width
21.	Desktop thickness
22.	Keyboard thickness
23.	Desk-edge to keyboard

note: All the measurements are in miilimetres or degrees except for age, sex and weight.

The data–typist in IPER (LB) works in a very different situation (Figure 16). Here the screen is too high and the document is flat on the desk to her left. Consequently her head has to move up and down and twist at the same time, which is probably the cause of her postural complaints. Additionally her table is too high and although she has adjusted her chair upward the table–edge is 140mm in thickness so her upper leg is compressed.

3.5.2 Typists

The typists of IPER share similar workstations (Figure 17). The terminal screens are tilted at appropriate angles but the documents are placed flat on the desktop so that the neck is twisted continually. This agrees with the amount of neck problems found in this group. The other feature of the workstation is a high desk (with a fixed footrest) and chairs adjusted to high levels. However, the desk design is old and the position of the footrest disadvantageous from an anatomical point of view. As with the data–typists, chairs lack armrests and the backrests are too low to give support to the upper back.

FIGURE 15. WORKSTATION DIMENSIONS – DATA-TYPISTS

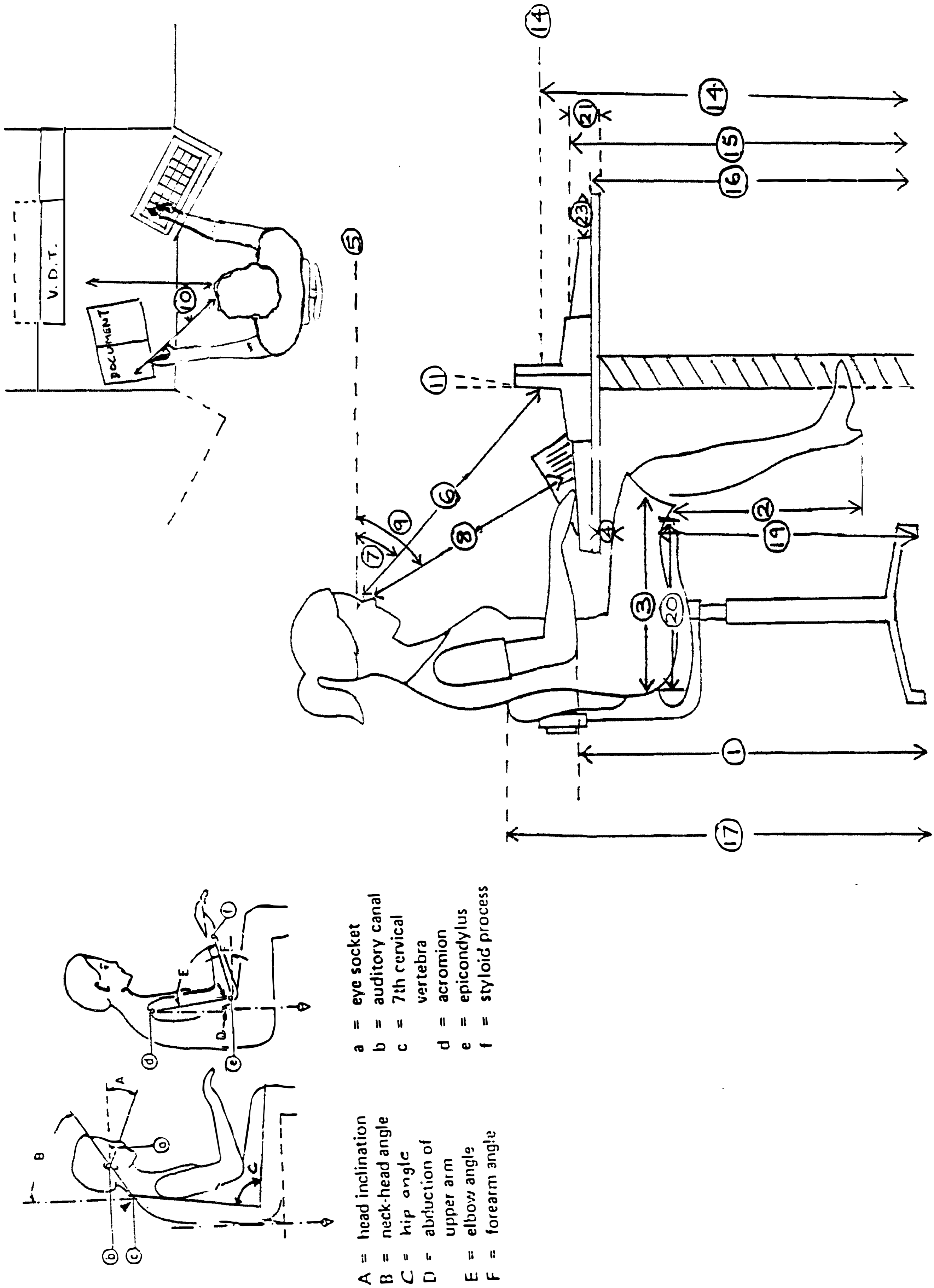


FIGURE 16. WORKSTATION DIMENSIONS – DATA-TYPIST LB

A	–	head inclination	a		eye socket
B	=	neck-head angle	b	=	auditory canal
C	=	hip angle	c	=	7th cervical vertebra
D		abduction of upper arm	d	=	acromion
E		elbow angle	e		epicondylus
F		forearm angle	f	=	styloid process

FIGURE 17. WORKSTATION DIMENSIONS – TYPISTS

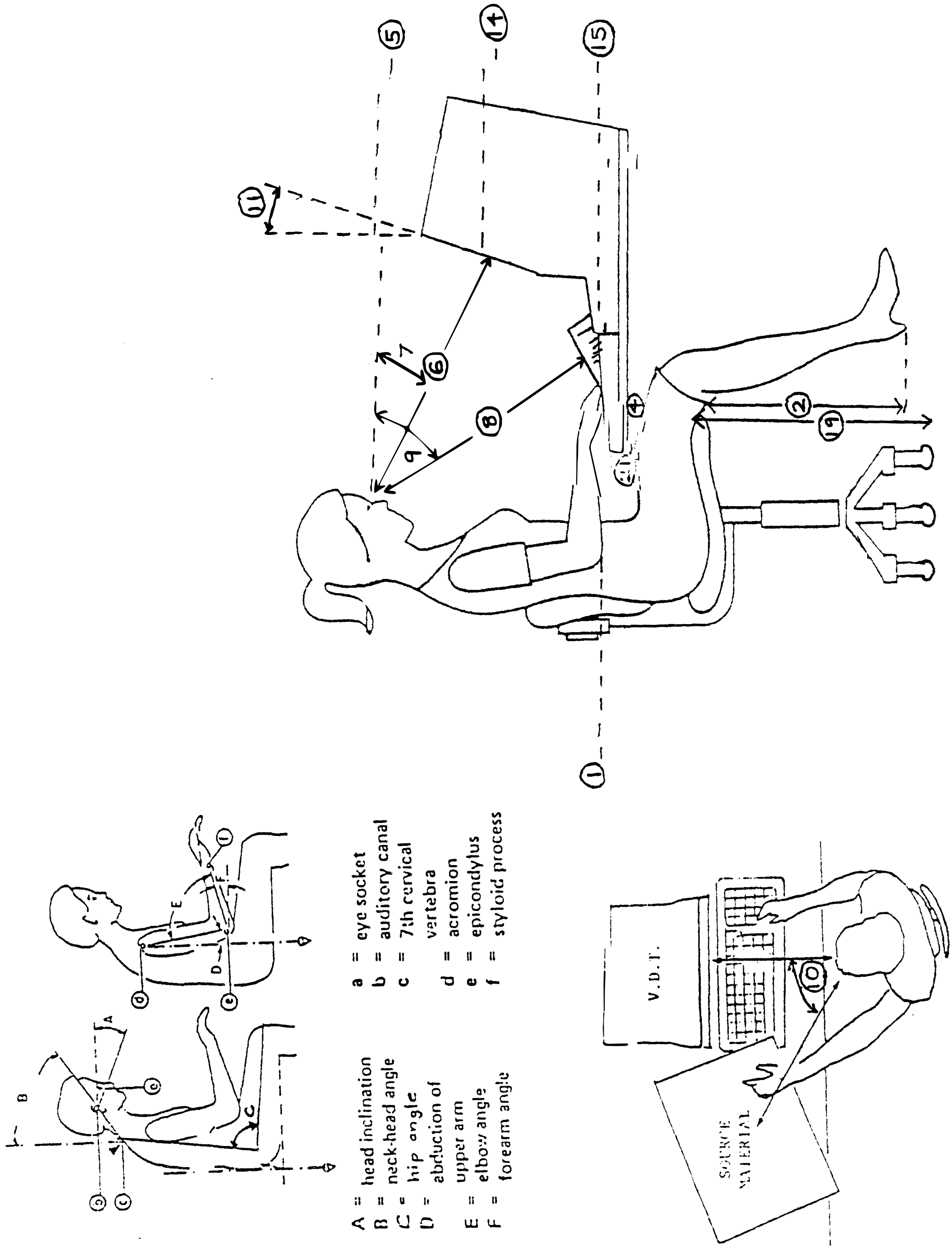


FIGURE 18. WORKSTATION DIMENSIONS – PROGRAMMERS

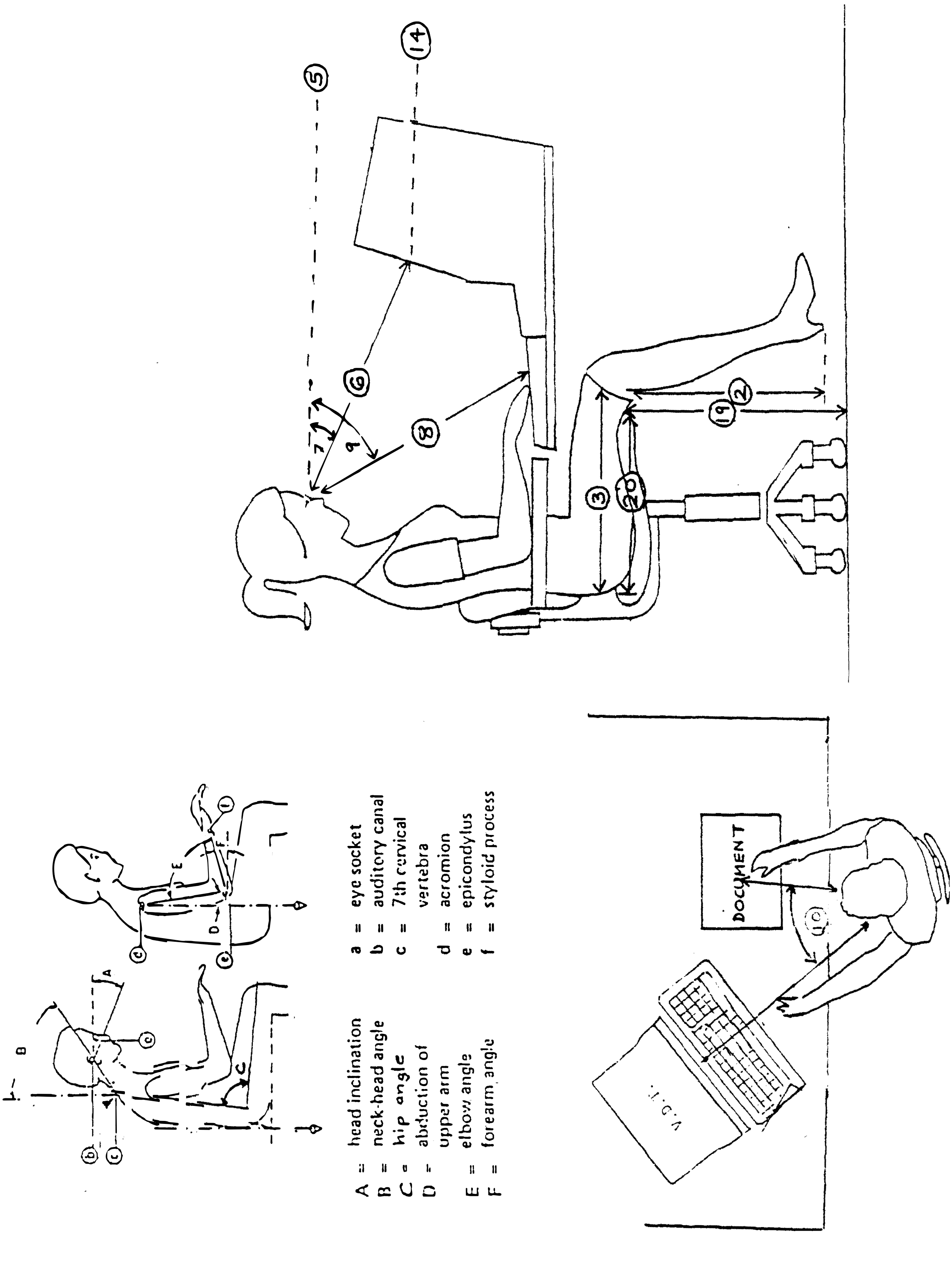


FIGURE 19. WORKSTATION DIMENSIONS – RESEARCHERS (VDT WORK)

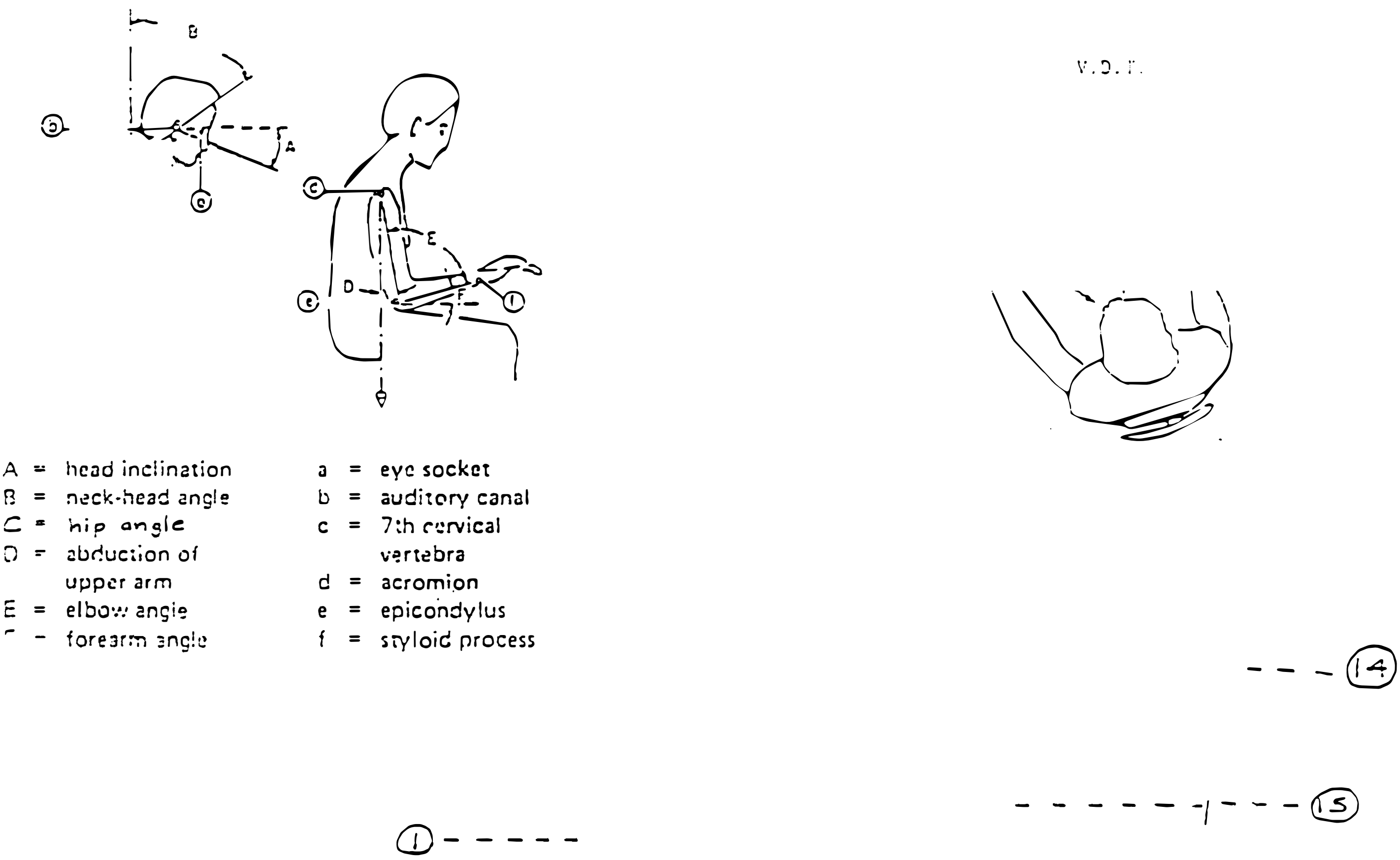
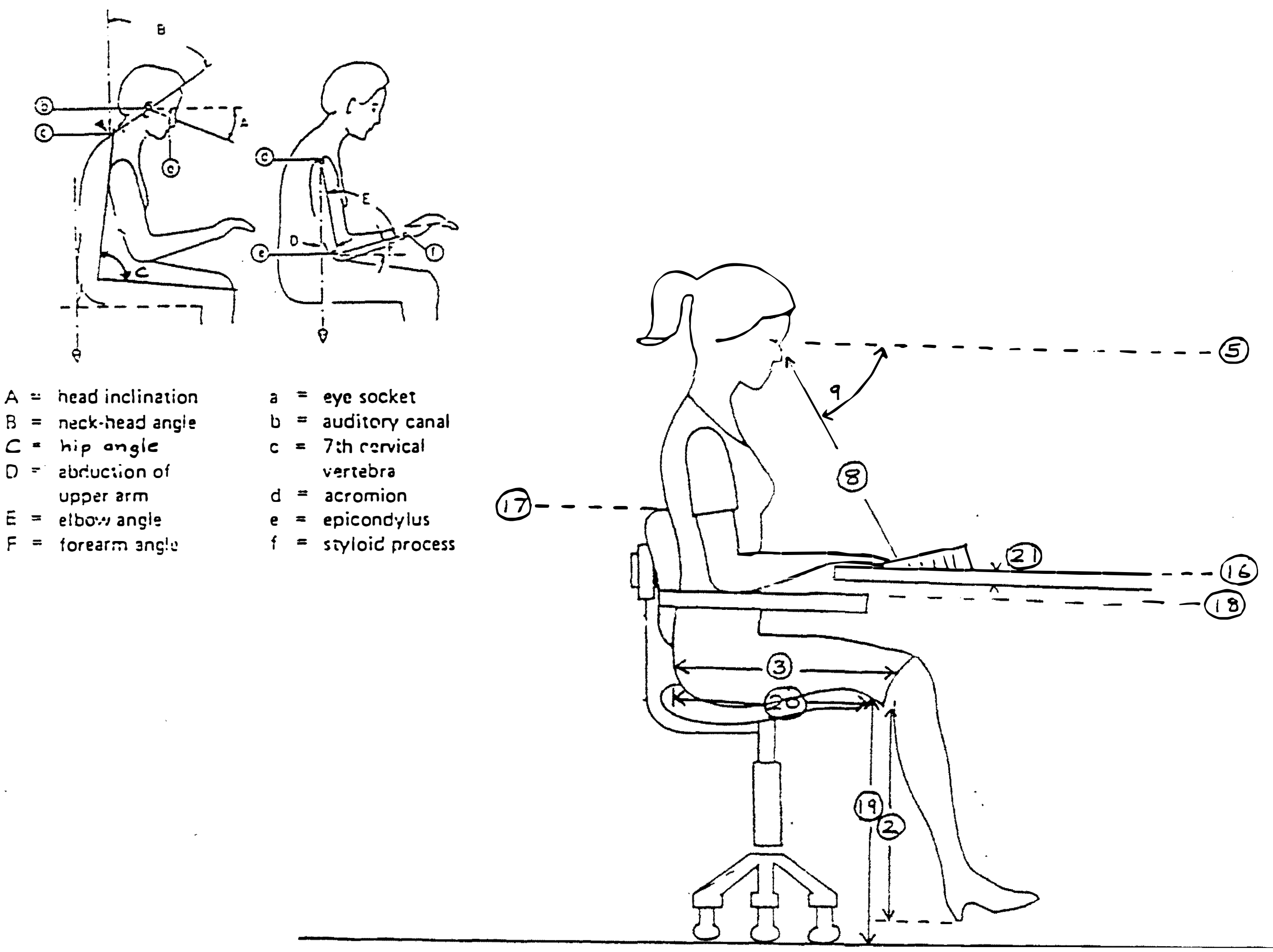


FIGURE 20. WORKSTATION DIMENSIONS – RESEARCHERS (DESK WORK)



3.5.3 Programmers

Here there is an unusual worktop configuration, with the terminal on the far left–hand corner of the desk (Figure 18). The desk space in front is probably required for paper–work. Old desks are not suited to this layout because of drawers either side which prohibit lateral leg movement. Nevertheless the position of the terminal requires the upper body to be twisted towards the left. Even at this early stage of their lives subjects are having neck problems: this emphasises the dangers of adopting a twisted posture, though neck symptoms here could also be due to hunched shoulders and stretching towards the distant keyboard. It was notable that in the interviews 91% of subjects expressed dissatisfaction about their chairs. Apparently since the study was completed new chairs have been purchased.

3.5.4 Researchers

VDT work

The terminal rooms provided for researchers have arguably the most unergonomic workstations of all the groups (Figure 19). The table and seat designs are old and there is a rush amongst staff to get to the best positions before others arrive. The latter have to contend with crushed thighs, bent necks, and screwed–up eyes as a result of screen glare from the windows. Terminals take up most of the space so there is little or no room for documents and keyboards typically hang over the desk edge.

Desk work

The subject is usually crouched over work. On the whole postures are not very good and the workstations do not promote healthy posture (Figure 20). Slumping forward or backward were frequently observed. Seat height, desk height and bent necks were the biggest problems though it was interesting to note that two female researchers had realised the value of tilting the writing surface towards them to decrease the neck angle.

3.5.5 Man–workstation match

Essentially this consisted of a series of comparisons between body dimensions and chair/ workstation dimensions, using means and standard deviations to perform Student's *t* Test in a few cases. Elsewhere dimensions have been compared to recommendations made in ergonomic guidelines (Grandjean, 1987; Cakir *et al*, 1979; Tougas and Nordin, 1987). Anatomical terms can be derived from the numbered diagrams for reference. The data–typist in IPER has been excluded from any statistical comparisons because of the uniqueness of her situation.

Elbow height (1) versus keyboard height (15) : — Keyboards were higher than elbow heights for most subjects ($p < .05$). This may result in hunched shoulders and neck tension and is mechanically inferior to being on–top or level with one's work. Elbow height was also significantly lower than desktop height (16)($p < .05$).

Popliteal height (2) vs seat height (19) : — Popliteal height was lower than seat height ($p < .01$)(even allowing for 20mm of seat compression). Eighty–four percent of subjects have this problem.

Buttock–popliteal length (3) vs seat depth (20) : — Older seats for researchers and programmers were deeper than the recommended depth ($p < .05$) which allows for 50mm between the popliteal crease and the front of the seat. Thus people cannot make proper use of the backrest and the lower back will not be adequately supported.

Upper arm abduction (D) was within reasonable limits for most subjects; only researchers writing exhibited marked angles. This is probably due to desk height being higher than elbow height.

Forearm angle (F) was unsatisfactory; all angles being negative. This is the result of elbow height being below desktop height.

Elbow angle (E) was excessive for programmers, who rested their elbows on the desk in front for support. Forward extension of the upper arm is adverse for the neck and shoulders (Chaffin, *ibid*), confirmed by the fact that 7 out of 8 programmers have neck complaints.

Hip angle (C) varied from 80 degrees to 135 degrees. It was noted that subjects with major low back complaints opened up their hip angle, probably to reduce the stress on the lower back.

Backrest angle (12) / Seat tilt (13) were combined since the key angle is between the horizontal seat pan and the almost vertical backrest. Angles varied from 86–114 degrees. The problem with most chairs is the lack of a provision for the backrest to follow the back when the user bends forward. To do so it would have to tilt forward. Thus although a few of the existing chairs did have angles approximating the 105–115 degrees which is currently recommended, the users only received back support as long as they sat back in the chair, which was a small proportion of the time.

Backrest height (17) was generally too low in the light of recent research suggesting that high backrests are necessary for upper back support. The recommended range is 480–500mm above seat height, whereas the overall mean was 399mm. Two tall subjects previously suffering low back pain acquired chairs with higher backrests and claimed that their problems were now minimal.

Armrest height (18) was generally higher than elbow height for those subjects who had armrests on their chairs. It is thought that armrests are necessary for the support they give to the neck and shoulders, as well as the amount of potential postural variety they introduce into a static situation.

Seated eye height (5) in the subject's chair was markedly lower than eye height measured on the standard stool used when taking anthropometric measurements, even though the stool was in most cases lower than the chair. This paradox can be simply explained by the fact that people sit upright for measurements but slump back into habitual postures in their own chairs. It indicates that people adopt poor postures when sitting at work.

Desktop thickness (21) very often exceeded the recommended value of 30mm or less. Only the desktops of 22mm without a supporting edge were under this figure. The implication of thick desktops (a relic of the past as far as desk design is concerned) is the restriction on the attainable seat height.

Thigh clearance (4) was variable with the worst workstations having no thigh clearance at all between the top of the thigh and the underside of the desk. The recommendation is 100mm. In addition, the distance from table edge to the back wall should not be less than 800mm and the space under the desk should be at least 680mm wide and 690mm high. In these respects the data–typists 'shallow' desks were unsatisfactory and led to subjects being at excessive distances from their work.

Deskedge to keyboard (23) was satisfactory in most instances but was occasionally very poor where no room was left to rest the subjects' wrists or the terminal was actually protruding over the edge of the desk. The recommendations now appearing suggest the incorporation of a specific wrist rest at the front of the desk.

Head inclination (A) varied only slightly among the groups using terminals. The researchers performing desk work had very large values. This parameter may be considered in connection with the Neck–head angle (B) where, again, researchers performing desk work were observed with very large angles. The research evidence shows a relationship between the incidence of stiffness/pain in the neck and shoulders and increased forward–bending of the head.

Screen height (14) : — A test of significance revealed that the data–typists' screens were of much lower elevation than screens elsewhere ($p < .01$). The mean height was 799mm, with the other categories being 1023mm, 1027mm, and 1049mm. The recommended range for screen height is 1000–1150mm.

Eye–screen distance (6) : — The data–typists and programmers means were in excess of the recommended range of 450–700mm, with a range of 460–880mm. This has implications for eyesight.

Eye–screen inclination (7) : – Here, because of the height of their screens, the data–typists again had large angles. The recommended range is 10–15 degrees below horizontal. Whilst the means of the other groups were satisfactory – 15, 10, and 15 degrees – the data–typists' mean was 29 degrees.

Eye–document distance (8) : – Distances were generally much shorter than distances to the screen (they should be the same).

A discrepancy between distance to the screen and to the document means that subjects' eyes are required to adjust their focus frequently. The posture analysis suggests that with typists this can be every 3 seconds. Visual discomfort occurs frequently among these subjects. The discrepancy between screen inclination and document inclination means that head movements are frequent and that, because of the positioning of documents to the side, subjects twist their necks in order to read the material. This is obviously not conducive to a good working posture.

3.6 Posture assessment

In past studies a variety of methods for observing posture over time have been used, the main ones being the recording of posture on film (Branton and Grayson, 1967) and by means of coded forms (Cantoni *et al*, 1984). The former method was used in this study and postures were allotted codes for analysis. A computer program was written to facilitate recording of postures and the time they were held: code letters were keyed into the computer in conjunction with the video playback on a monitor.

The data analysis examined the following variables:

1. Number of changes in posture,
2. Number of body segment movements,
3. Time in each posture,
4. Relationship between work posture and physical symptoms.

Changes in posture refer to fairly gross shifts in the body's centre of gravity, whereas body segment movements refer to minor adjustments. Obviously the latter are more frequent. In practice changes in posture usually concern an alteration of weight in the position of the trunk or legs in relation to the seat. Segment movements concern arm movements or slight head movements.

3.6.1 Frequency of posture change and movement

These indices provide a reasonably good estimation of the degree of postural variety for the various groups studied. Table 7 gives a comparison. LB is the IPER data–typist and Researchers are divided into those filmed at VDTs and at desks.

It seems that the task performed determines postural requirements. Researchers working with terminals have to regulate their posture in accordance with the screen they look at and the keyboard — they change their posture only half as much as their colleagues performing desk work. Yet because their task requires an interaction between screen, document and keyboard, their frequency of head movements is comparable to researchers writing at desks. One subject was performing a series of operations on a calculator and copying the results. He made 87 postural changes, involving shifting the trunk back and forth (1 every 16 seconds), and 498 body segment movements (1 every 2.8 seconds).

The data–typing group is conspicuous for its lower frequency of both postural changes and body segment movements. The comparative immobility of data–typists' postures is due to several factors, the most important of which is the required high speed of execution which is imposed by an apparent simplification of work. The other factor is the concommitant speed of visual information retrieval from the source document, requiring a fixed eye–document distance. The immobility of posture may be assessed by the amount of postural variation within groups. The main posture of data–typists is seated with the head bent down and twisted, looking at the document.

LB, the data–typist in IPER, reveals a different profile. Her posture does not change as much as the typists because of the task, but the positioning of the screen and documents forces her to twist her neck, resulting in many small head movements.

The typists appear to change posture very frequently and this is because of their interaction with screen, keyboard and document. There are several postures: the two main ones are seated, with the head directed at the screen, or head bent down and twisted.

The programmers and researchers display a high degree of variety in their postures.

TABLE 7. POSTURAL CHANGE AND MOVEMENT FOR EACH GROUP

	mean frequency (seconds)	
Category	posture shift	body segment movement
Data-typists	102	13.0
LB	76	3.2
Typists	47	4.2
Programmers	61	6.0
Researchers (VDT)	82	4.6
Researchers (desk)	42	5.4

3.6.2 Time spent in each posture

Coding of Postures

Postures were defined with reference to the position of the head, trunk, shoulders, arms and legs, and were coded as follows:

Head	Free (< 15 degrees below horizontal)			1
	Bent down (> 15 degrees below horizontal)			2
	Bent down with neck twisted			3
	Free with neck twisted			4
	Supported by hand			5
Trunk	Free of backrest and upright	1	(and twisted)	5
	On backrest	2	(and twisted)	6
	Slumped forward/crouched	3	(and twisted)	7
	Slumped backward	4	(and twisted)	8
Shoulders	Rested			1
	Hunched			2
Arms	Rested			1
	Turning pages, manipulating files etc.			2
	Typing			3
	Writing			4
Legs	Free and flat on floor			1
	On footrest or chair castors			2
	On desk footrest			3
	Crossed at ankles			4
	Crossed at knees			5
	Extended			6

The postures were coded in a combined form ie. H2 T3 S1 A4 L1, or simply 23141, to denote a subject writing, head down and trunk crouched, shoulders and legs in their normal (free) position.

In practice, the recording of every subject's leg position was made difficult by lighting conditions so only particular instances will be referred to. The determination of whether a subject's shoulders were in a rested position or hunched was also difficult. Thus only three numbers will be used to describe posture in the tables — that of head, trunk and arms. A general classification for leg position follows after the subject's initials and a note is made of hunched shoulders. Taking the example of data–typist KF in Table 8, the (L2) refers to feet on a box, and the postures are 363 (head bent down with neck twisted, trunk on backrest and twisted, and arms involved in typing), and 361 (as previously but with arms rested).

Data–Typists : –

The work of data–typists consists of copying numerical information (usually from coded forms) directly into the mainframe computer. The forms arrive in batches, held together by elastic bands. The first task of the data–typist is to undo the elastic bands and arrange the forms for suitable access. Once processed the forms are done up for storage. The whole operation or work cycle takes from 6–9 minutes to complete on average. The preparation of forms for processing and storage, takes a short while during which subjects have to stop typing, lift the forms, tie them up and move them to another part of the desk. This usually requires trunk movements and a break from typing. The term used originally for this was a 'natural break' and although this is customarily employed in a different sense it will be retained as 'N'. No filming was performed during tea breaks but occasionally subjects would stand up and wander off with a mug, or some forms, or with nothing (presumably to visit the toilet). This is coded as 'A' for absent.

TABLE 8. DURATION OF POSTURES (PERCENT) – DATA-TYPISTS

	postures									
subject	363	323	383	321	353	361	381	523(1)	N	A
KF (L2)	86					8			5	6
MC (L2)		74		12					7	7
CN (L2)	81					3		2	12	2
AP (L6)			81				4	3	12	
AC (L4)		68		9				5	9	14
AD (L1)	65				18	6			7	4

note: hunched shoulders – AD.

Table 8 demonstrates the emphasis of the head position which is bent down and twisted. Three subjects actually twist the trunk towards the document. AP, a subject with bad neck and low back problems, slumps back in her chair. Her trunk is twisted and she tilts her shoulder down on the left side.

A comparison of these postures with a non–sedentary profile may be of relevance here. Subject AC was involved in other clerical duties during the period of filming in the data–typing pool. In this work postural changes occurred once every 18 seconds, as against 102.5 seconds whilst typing. The percentage of time spent in different postures was as follows: Standing bent down 35, Sitting writing 25, Standing 15, Standing manipulating the copying machine 14, Walking 9, and Carrying loads 2. The 'execution' of these postures was poor, and no doubt led to the discomfort the subject felt the following day in the low back. The data–typist in IPER employed a different combination of postures in her work. Table 9 shows a far greater emphasis on a 'free' or upright head position when looking at the screen.

TABLE 9. DURATION OF POSTURES (PERCENT) – DATA-TYPIST LB

subject	postures 123	323	121	223	N	A
LB (L1)	63	19	7	6	3	2

note: hunched shoulders

Typists :–

The work of typists in IPER is fairly conventional. The crucial factor is that their terminals are linked to a mainframe computer and there are system response delays. The posture where this is evident is 121 (head free, trunk on backrest, and arms rested)(see Table 10). Some quite substantial delays were observed and the designation (D) is used in such instances. As with the data–typists the head is often bent down and twisted in the direction of the source document. However, in this situation the head alternates between screen and document in quick succession and the degree of twisting is greater (in fact the mean angle 'screen–document deviation' is 21 degrees for data–typists and 42 degrees for typists).

TABLE 10. DURATION OF POSTURES (PERCENT) – TYPISTS

subject		postures 123	323	121(D)	321	223	521	224	523	N	A
MN	(L1)	20	49	20			8			2	1
AK	(L3)	27	42	18		6			2	5	
VM	(L1)	44		5	30		6			11	1
BO	(L3)	21		69		4			2		4
EL	(L1)	29	35	18		5			4	3	6

note: hunched shoulders - EL

Compared to the data–typists a greater variety in postures is evident. However, the neck–twisting requirements of the task put a stress on that area, and four of these subjects have a neck problem.

Programmers : –

The task of the programmer includes a large proportion of both desk work and terminal work. Subjects take unofficial rest breaks as and when they feel them necessary and these often take the form of collecting new assignments from the pigeon–holes or walking to a colleague and discussing work, much as is the case with researchers. This is not the case with either data–typists or typists who seldom have such 'postural' breaks. The actual workstation layout for programmers appears to be unique, and may be due to the lack of desks available. The terminals are placed on the far left corner of the desk so that printouts and other paperwork can be located in front. It means that subjects adopt an unusual posture, leaning their arms across the desk towards the keyboard. This must be borne in mind when looking at Table 11, since it is difficult to make such distinctions within such a limited coding system without it becoming large and unweildy. Even so it has been necessary to combine several postures because of the greater variety and only the position of head and trunk is considered.

TABLE 11. DURATION OF POSTURES (PERCENT) – PROGRAMMERS

		posture									
subject		23/7	14/6/8	11/5	53/7	13/7	24/8	47/1	21/5	N	A
ID	(L1)	62	6	4			16				12
SO	(L1)				31		19	39			11
TG	(L3)		5	68	27						
EF	(L5)	35	24	18			19				4
HF	(L3)	5	7	9	23	49	1		2	4	
JH	(L5)	10	40		24	7	1		9		9
JR	(L1)	4	47	3	16	14			5	6	5

note: hunched shoulders - SO, TG, EF, HF, JH, JR.
Subject CC was filmed for a short period so this video was not analysed.

The figures in the table become confusing: for example 14/6/8 refers to three categories of posture where the head was free (1) and the trunk was slumped backward (4), on the backest and twisted (6), or slumped backward and twisted (8). There are clearly a number of different postures adopted for similar tasks. Six of these subjects showed signs of neck problems in the physical examination and no doubt the hunched shoulders as a result of the workstation design served to aggravate such problems.

Researchers : –

In this study it is possible to see the emergence of a comparatively new phenomenon – the 'Terminal Researcher'. The rather morbid undertones of this term should not be taken too literally, but the video analysis suggests that the physical work being done by this new category towards maintaining a stable posture is unlike that of the traditional researcher and is more likely to result in postural problems related to the static nature of the task. Table 12 shows the lack of variation in postures for the researchers doing VDT work, and may be contrasted with Table 13 for researchers doing deskwork where a much greater variety of postures may be observed.

TABLE 12. DURATION OF POSTURES (PERCENT) – RESEARCHERS AT VDTs

		postures											
subject		12	14	32	22	28	11	15	23	33	21	N	A
GS	(L1)	70					6	6	13			5	
GP	(L1)	36		36	24						3	1	
KH	(L4)	85					6	5				4	
GH	(L5)		55	13		21	1	2		6			2

note: hunched shoulders - GS, GP, KH

Table 13 shows three groups of postures predominating; head bent down and trunk free or trunk free and twisted (21 and 25), head bent down and trunk slumped forward or trunk slumped forward and twisted (23 or 27), and lastly, head bent down with trunk either on the backrest, slumped backwards, or slumped back and twisted (22, 24 and 28).

TABLE 13. DURATION OF POSTURES (PERCENT) – RESEARCHERS AT DESKS

		postures									
subject		11/3/5	12/4/8	21/5	23/7	22/4/8	31/3	51/5	53/7	52/4/8	N/A
JL	(L1)		9	33	45			5	8		
JB	(L1)			27	30	4	39				
IP	(L1)	5	4	1	25	39		2	13	1	10
RR	(L1)			15	39	10			21	2	13
JGS	(L3)			18	54	10					18
DZ	(L1)			13	37	25		1	12	12	
ELM	(L4)			5	7	67				8	13
HO	(L3)			10		19		11		45	15
NC	(L4)	15	21		8	10		9	9	13	15
SC	(L1)	3			46	20			23	7	1
HB	(L3)			29	41	18				2	10
DM	(L3)	9	1	12	31	11	3	1	19	9	4

note: hunched shoulders - IP, RR, JGS, HO, NC, SC, DM

One person, not included in the study, was filmed because of her novel workstation. She found that a lectern, placed on her desk, was the solution to her neck and back problem. She supported her head by her arm, acheiving an upright posture, and had a larger hip angle than normal.

3.6.3 Relationship between work posture and physical symptoms

The relationship between inadequate work postures and pain has been discussed by van Wely (1969). His table of posture and pain (Table 14) was developed from studying the symptoms recorded in an industrial medical officer's surgery and the postures which gave rise to them. Many of these are precursors of disease, whilst others indicate the existence of damage. The warning provided by the discomfort is to be seeen in many cases as an indicator of an inadequate match between the person and his work or workstation.

According to Corlett and Bishop (*ibid*), "This calls for a change to the job rather than the worker".

TABLE 14. BAD POSTURES VERSUS PROBABLE SITES OF SYMPTOMS (After van Wely, 1969)

Bad posture	Probable site of symptoms
Standing (awkward stance)	Feet, lumbar region
* Sitting without lumbar support	Lumbar region
* Sitting without back support	Erector spinae muscles
* Sitting without good footrests of the correct height	Knees, legs and lumbar region
* Sitting with elbows on a work surface which is too high	Trapezius, rhomboideus and levator scapulae muscles
Upper arm hanging unsupported out of vertical	Shoulders, upper arms
Arms reaching upwards	Shoulders, upper arms
Head bent back	Cervical region
* Trunk bent forward; stooping position	Lumbar region, erector spinae muscles
Liftingheavyweights with back bent forward	Lumbar region, erector spinae muscles
* Any cramped position	The muscles involved
Maintenance of any joint in its extreme position	The joint involved

* Common postures observed in the HSRC study

Although some of these types of posture are not in evidence with sedentary working populations, this table serves as an example of the role of poor posture in the aetiology of disorders. The postures preceded by asterisks denote positions commonly adopted by subjects in this study. It is relatively easy to note the grosser features of a subject's posture on film but the finer distinctions are probably missed by most people who are not used to dealing with posture on a daily basis and here the experimenter includes himself. To endeavour to eliminate some of the subjective bias that must inevitably creep into observations made by one person, it was arranged for the physiotherapist who is acting as consultant in this project, to view as many of the video films as possible and to give an opinion.

The videos of 22 subjects were watched by the physiotherapist who generally made fairly quick conclusions. A summary of her observations, together with the actual results from the physical examinations are included in Table 15.

TABLE 15. SUMMARY OF OBSERVATIONS ON POSTURE BY PHYSIOTHERAPIST

subject	posture	site of symptoms probable	site of symptoms actual
KF	Static but good posture, low backrest support		UB, LB, Thighs
AC	Poor posture, lordosis, kyphotic upper back	Low back, UB, N/Shs	LB, Thighs Neck, F/Head
CN	Kyphotic, too low for desk	Neck/Shs	N, Shs, Thighs
AP	Poor overall posture	N, Shs, LB	LB, Neck
VM	Screen too low for bifocals	Neck, eyes	N, LB, Thighs
AK	Neck twisted	Neck	N/Shs, L/Arm
BO	Lordosis, shoulder depression	LB, Neck	LB
MN	Good posture, seat correct		Neck
EL	Active posture but hunched shoulders – desk too high	Neck	N, Head, LB
EF	Chair too low	Neck	Neck
TG	Hunched – desk too high	Neck/Shs	Neck/Shs
HF	Chair too low	Neck/UB	UB, N/Shs, H
SC	Hip angle closed – both chair and desk too low	LB, Neck	LB, LSh
HB	Chair too big and low	Neck	LB
NC	Desk and chair too low, needs higher backrest	Neck	LB
JL	Desk high, chair shallow		N, LB, Thighs
JH	Good posture but desk high	Neck	Neck/Shs
GH	Support for UB but not LB, desk in way of legs	Low Back	N, LB Front Head, LB
JGS	Hunching shoulders – chair too low to reach desk	Upper Back	UB, N/Shs
DZ	Nice position, but low		N/Shs
DM	Chair too low	Neck	N/Shs, LB
SO	Chair too low	Neck	N/Shs

The correspondence between the observations of the physiotherapist and the actual results from the physical examinations are direct in 16 of the 22 cases. That is, where a probable site of a symptom was low back, then this symptom was revealed in the examination. A further two cases might be deduced indirectly, ie. where the only comment was that the chair was low or the desk high the neck would be a probable site. It should be emphasised that if muscle fatigue is eliminated most shoulder aches and headaches result from a problem in the cervical spine.

It is interesting to see how the physiotherapist's comments generally begin with an observation on the subject's 'natural body posture' – whether he or she sits correctly with the head aligned according to the centre of gravity. Then the comments become more generalised and dependent on the way in which the workstation arrangement determines posture externally – 'nice position, but low'. Thus there is an interdependency between the individuals' postures, the tasks which they are doing and the tools (including the workstation) which they use to accomplish them.

4. DISCUSSION AND RECOMMENDATIONS

4.1 Overview of findings

The present study's results corroborate the very useful in–depth findings of the preliminary questionnaire/interview which evaluated seating, workstations, tasks and health.

With regard to health the questionnaire showed that of the 70 subjects, 40% suffered from neck problems, 37% back problems, 31% shoulder problems, 38% headaches, and 42% fatigue.

The physical examinations on 37 subjects in the present phase revealed that 78% suffered from neck problems, 57% from lower back problems, 8% from upper back problems, and 19% from headaches. (It should be noted that shoulder problems were all manifestations of neck symptoms and were therefore included under that category by the physiotherapists. As alluded to in the Results section, many subjects did not present with headache problems during the physical examination but had mentioned them during the three week test period).

A rider to these findings is that the location of the hip socket in relation to the lumbar vertebrae in females increases the lifting stress in the back muscles by up to 15% more than in males (Tichauer, 1978). Other factors also seem to make the female body susceptible to postural stress and injury. Thus the fairly widespread prevalence of complaints in this sample may be partly explained.

To what extent is it possible to determine the effect of seating and workstation design on musculoskeletal disorders from the data presented here? The physical examinations show that 65% and 62% of subjects with neck and lower back problems, respectively, had no known previous trauma or pathology. This does not mean that, *ipso facto*, all these problems are due to sitting in awkward postures at work. Many problems are the result of a lifetime of poor postures which have gradually stressed certain parts of the body until they 'ungracefully retire' and put all the burden on the spine. Nevertheless the data here on individual cases does suggest that some problems are almost certainly due to workstation design and postural stress.

The fact that 97% of neck problems were said to be occupationally aggravated or related suggests that improvement could be expected in this area with a redesign intervention. In this connection a study by Slovak and Trevers (1988) is interesting. Sixty–seven percent of neck problems, 78% of low back problems, and 63% of headache problems were work related. The subjects performed VDT work in varying degrees. In the category using VDTs from 10–50% of the day the mean number of symptoms was 0.45, whereas the figure for the 60–100% category was 1.26. The study identified the 80–100% group as a priority target for remedial action.

The data on individual cases is included in the text rather than in an appendix in order to demonstrate how the findings present themselves for each person. It is intended that the reader may gain a good impression of from perusing some of the cases.

Individual cases

Subjects' initials, with occupation and age in brackets, are given together with their profiles.

LB (DT)(20) has a chronic neck/shoulder disorder which developed since starting computer work. Twisting her head to the left to read source documents is a particular action which causes pain. The VDT screen affects her eyes and results in headaches. Her upper back symptoms are intermittent but probably referred from the neck. Pressure at the back and front of the thighs is due to the chair being too high and the desk edge too low, thus impeding circulation. Other complaints include swollen feet and aches in fingers, wrists and arms, which occur only whilst typing. There is no history of trauma or pathology and the subject's low age weighs against the symptoms being due to the ageing process. Her problems seem to be related to her occupation and the design of her workstation, which induces an incorrect sitting posture.

AC (DT)(42) has a chronic low back problem related to a previous accident and an intermittent neck complaint which started in 1987. Both problems are aggravated by sitting in her work chair and occupation in which her neck is often bent. The muscle spasm present in the examination suggests that this is due to her poor work posture. Wrist pain is due to overuse in her occupation and numbness under her thighs is caused by the work chair.

MC (DT)(28) has an intermittent problem which affects her neck, right shoulder and right arm. This began a year ago, only occurs at work and becomes worse with a heavier workload.

KF (DT)(34) has intermittent problems affecting her upper back, lower back, right wrist and thighs. She has had these symptoms for 10 years, since she started typing. The pain in her thighs is especially bad and due to the chair.

CN (DT)(30) had a motor vehicle accident 15 years ago, which is probably the origin of her neck and shoulder problem. However, only her occupation and posture seem to aggravate the problem.

ID (P)(22) has only been employed for six months. Since then she has developed a minor low back complaint due to her chair and workstation, which encourages a slumped forward posture.

SO (P)(19) has experienced her neck problem since starting work in the Computer Centre.

TG (P)(19) injured her lower back when very young but her present neck/shoulder problem started a year ago after joining the HSRC.

EF (P)(24) has an intermittent neck/shoulder problem, which is likely to be due to her poor posture, sitting with outstretched arms unsupported.

HF (P)(26) had an accident three years ago but the symptoms have worsened since joining HSRC. The subject was observed using an old chair in a poor posture during the filming.

JH (P)(27) has had neck/shoulder stiffness since school days but finds this is aggravated by the work chair. She is fit and swims every day. She attributes her daily headaches to the job itself.

JR (P)(22) injured her back at school, and suffers from low back, neck/shoulder pains and headaches. These are aggravated by work and aerobics.

IP (R)(27) suffers intermittently from a lower back injury. His neck problem and pain behind the thighs occur only at work and are related to his posture and his chair.

JGS (R)(25) had a series of problems throughout her spine, including frontal headaches. The physical examination suggests that these have an underlying pathology, but all symptoms are aggravated by her occupation and sitting crouched over a desk.

HO (R)(26) had two whiplash injuries which affected his neck, and a lower back problem which was posturally related.

DM (R)(29) had a neck injury in high school which is the origin of his problem. His occupation aggravates it. He has experienced lower back pain for about a year, when he joined the HSRC. Both problems seem severe and he experienced discomfort on all but two of the occasions on which the questionnaire was administered.

ELM (R)(27) had a back problem prior to acquiring a chair with a high backrest. The examination showed that underlying signs were still present but no longer being aggravated by her work posture.

SC (R)(30) had a episodic lower back problem. Since there is a postural abnormality this would tend to stress various spinal structures. The comment made about this subject's posture on the video by the physiotherapist was that both chair and desk were too low, leading to a closed hip angle which would probably give him low back symptoms. His tendency to slump down on his left side may not help matters.

HB (R)(29) had a minor lower back problem due to poor posture and knee and ankle pain aggravated by aerobics. The latter were due to the strains placed on the joints during exercise.

KH (R)(42) had a lower back operation in 1979 and also suffered from a neck problem and ischaemia under the thighs due to his seat in the terminal room.

MV (R)(28) had a lower back problem due to an earlier injury, and experienced neck and shoulder pain at work. This is probably due to tension, leading to muscle spasm, and poor working posture.

BO (T)(21) started having a lower back problem in mid 1987. This is aggravated by sitting in a slumped position at work and disappears when she starts moving.

EL (T)(34) had a neck problem since she started typing four years ago. The video revealed her shoulders to be hunched as a result of the desk being too high. She suffers from migraine and maintains this is aggravated by long periods in front of the VDT.

MN (T)(33) has experienced a neck problem for the last two years which is generally caused by doing extra typing work at home.

These findings strongly confirm the conclusions voiced in the research literature that the aetiology of musculoskeletal disorders is multifactorial. It is apparent that in a number of the cases described above, occupation (and therefore work posture) plays a significant role in exacerbating the problem.

The number of young staff with symptoms is a particular cause for concern. It was mentioned in Chapter Two that the programmers were significantly younger than any other group and should not be expected to display symptoms by virtue of ageing and degenerative processes. Yet they seem to have as many problems as the other groups.

In this connection it is of interest that neck/shoulder disorders have a period of latency before symptoms related to work posture arise. This period has been quoted as from 6–12 months (Kilbom *et al*, *ibid*), and as early as two months (Bammer, 1986). Many programmers maintained they had their problems only since joining the HSRC. This may be too soon to attribute the problem solely to workstations here. Alternatively, the symptoms may have developed and subjects were unable to pinpoint a more specific date when the complaints manifested themselves. Without more information it is impossible to be categorical about these cases.

4.2 Evaluation of techniques

4.2.1 The preliminary questionnaire/interview

This was an invaluable source of information which provided the present study with several points of departure. For future work, revisions would be necessary – some questions were not very useful, and the section on postural complaints needs to be more specific. In comparing the responses from this section with those of the present study some three months later, it is evident that many people are uncertain about how frequently their symptoms occur. In changed form this type of questionnaire could probably provide enough answers for collecting summary data. A much debated issue in this regard is direct versus indirect questioning. The questions on workstations and tasks were direct whilst the section on complaints asked 'Do you experience any of the following symptoms either during work hours or afterwards?' A pilot questionnaire using a more indirect approach to workstation questions was rejected on the grounds that no one was really aware of any deficiencies in his or her workstation design even if they were obvious, so more specific questions were asked.

According to Slovak and Trevers (*ibid*), "It is well–recognised as a truism of occupational health practice that only a small proportion of problems will be voluntarily reported in any situation". On the other hand in a clinical situation a question such as "Are you feeling fatigue?" is likely to receive a positive reply. The context of the interview thus has an important bearing on the answer to the question.

4.2.2 General Comfort Ratings

As explained in Chapter Three this method was developed for the assessment of seat comfort rather than user comfort so it was not really appropriate in the present context. However, the findings confirmed the trend of Body Part Discomfort and revealed the postural fatigue phenomenon. If new chairs required evaluation then GCR, or a revised version of it, could be useful.

4.2.3 Body Part Discomfort Ratings

This technique was arguably the most effective of all those used, with the exception of the physical examinations. Administered six times a day, it revealed the actual frequency of discomfort, its location and its severity. It showed the build up of postural fatigue over time. In mapping the actual frequency of discomfort over 14 days it showed some of the other subjective responses to be inconsistent in instances of detail. More research into the reasons for the discrepancies would be needed but it is likely that distortion of events by memory and preconceived ideas about the nature and function of assessments are major factors.

4.2.4 Physical examinations

A clinical assessment was essential for the aim of this study; which was to establish which health complaints were likely to be due to past traumas or pathologies. Here examinations were hampered somewhat by subjects' inadequate recall of their health histories. The computerised assessment saved considerable time and has a lot of potential if revised. It was felt that at this stage it could not be regarded as a substitute for direct anamnesis with the physiotherapist.

The examinations revealed more disorders than could have been anticipated from the preliminary interview or the daily questionnaires, thus validating the use of several techniques.

4.2.5 Anthropometric and workstation measurements

The number of measurements could be curtailed to include the key dimensions and angles. The preliminary questionnaire gave a good idea of the workstation problems and just a casual glance was very often sufficient to reveal mismatches between the user and the furniture. However, such observations are not generally regarded as scientifically robust and need to be backed up by actual measurements. Only a few dimensions emerge as critical determinants of work posture — two of these are seat height and desktop height/keyboard height. Seat heights were significantly higher than popliteal (lower leg) height, and desktop heights were significantly higher than elbow height. The consequences of these findings, if generalised, amount to a posture characterised by pressure under the thighs, hunched shoulders or neck tension, and very often an unsupported lower back (depending on the chair and degree of support from the feet in maintaining stability).

4.2.6 Posture assessment

The data gained here confirmed some of the inferences made from the workstation measurements. The assessment was useful in determining postures used by subjects and the amount of changes over time. The differences in the postural requirements of the various tasks were also clearly demonstrated. However, the amount of time spent in analysing the video data was excessive in comparison with the information yielded. Film is perhaps the best way of assessing posture so it is thought that time spent in revising the type of data analysis would be profitable.

4.2.7 A 'better tool'

In the Introduction it was stated that a secondary aim of the study was to develop a battery of techniques which would be 'accurate, reliable and quick'. In terms of the amount of data gained over time the preliminary questionnaire/interview was the best technique — taking approximately half an hour per subject. This could be reduced in size and a section on user/workstation dimensions included. Video film for ten minutes or 'stills' of users at their workstations would provide sufficient data on the type of work postures involved. In this study the examinations by student physiotherapists quite often took an hour per subject (including the computerised subjective assessment) but this time could be halved if experienced students or physiotherapists were employed and the subjective assessment were revised.

Most expensive in terms of time was the subjective comfort rating in the daily questionnaires. There is no way of performing this operation quickly, although overseas evaluations of seat comfort have been completed in two–and–a–half hours with questionnaires every half hour. If the main interest is in obtaining objective data on the frequency of user discomfort over longer periods then the method used in the present study is the most direct. There is no known study which has examined discomfort on a daily basis for this period of which the author is aware. An alternative is for users to keep a daily diary.

Studies of musculoskeletal disorders in organisations have investigated large groups of workers performing the same task, which makes statistical analysis feasible, focusing mainly on symptoms of the neck/shoulders and arms only.

In comparison the present study has perhaps sought to be too exhaustive which has made it rather unwieldy to handle. This is evident in interpreting data from different analyses. Situations vary from person to person so that it is difficult to make general statements. Nevertheless, for each group it seems viable to offer recommendations on solutions to the problems observed.

4.3 Recommendations

4.3.1 Health and fitness

In the project proposal for this study the socio–economic and other advantages were stated to be 'staff health, welfare and productivity'. Few would argue that health, job satisfaction and quality of working life are beneficial. Some would argue that spending time and money to achieve these objectives runs counter to the goal of productivity. 'If workers are too comfortable they will become lazy' is a comment which summarises this attitude. However, there is an increasing recognition that consideration of working conditions and environment can pay dividends in the long term, and that workers who are forever taking sick leave are not being optimally productive.

Westgaard and Aaras (1984) state that, in Norway, musculoskeletal complaints account for 30% of all time lost through sick leave, and that the cost of production lost and sickness benefits amount to approximately one million pounds per thousand workers for this type of illness.

The above reference was found after the author had made a few calculations on the possible costs of sick leave to the HSRC. As no specific figures are known this exercise is just for interest. If the average annual sick leave for employees is assumed to be 8 days, if it is assumed that the HSRC staff complement is 1 000, and if it is assumed that the average salary (including perks) is R25 000, then it could be said that the cost of salaries paid for unproductive time would amount to R1 000 000 per year.

At present there is no way of determining the reasons for sick leave from the Administration Department's files. *It is recommended that a method for the collection of such data would prove useful and should be developed.* The Boeing Corporation began a process of tabulating all injuries, illness and sick leave in 1981 which led to a cost saving of more than six million dollars in the first year of its operation (Stamper, 1987).

Health, fitness, ergonomic workstations and office environment do appear to be conducive to productivity and job satisfaction. At the moment these aspects cover such a wide area that insufficient evaluations have been performed to verify this relationship. For instance, there are many confounding factors: in evaluating the effectiveness of fitness programmes it is generally found that it is the fit and motivated person who joins the classes rather than the individual who is unhealthy (Cox *et al* , 1988). Even though motivated and fit people tend to be more productive. Quite a few studies have confirmed a relationship between these factors and productivity but it depends on how changes are introduced and managed. Employee participation in any decision–making process is regarded as essential for any programme to succeed.

A holistic approach to the issue of employees' welfare is needed. If Maslow's need hierachy can be accepted as valid in general terms, then it can be noted that survival is Man's first need. It could be argued that health care is the next most important need. *It is here that the example of various organisations in this country might be heeded; to employ an occupational health nurse on a permanent basis like other statutory bodies.* This is normally the first step before fitness programmes are devised. The occupational health nurse would be crucial in monitoring any attempt to reduce absenteeism due to sickness, to advise staff on their coronary heart disease risks etc.

An American fitness expert, Dr Smith (The Star), notes ironically that it is mainly women who join aerobics classes because of a fear of heart disease, yet it is men who are the high risk group here. Women are the high risk group for arthritis and leg injuries which can be caused by jumping exercises on unsuitable surfaces. Apparently 70% of instructors and 45% of participants experience injury. Many instructors are gymnasts or dancers who make poor use of the research available on exercise physiology and have little or no knowledge of sports injuries.

The implication is that men need to be encouraged to work in the gym, especially those over 40 years of age. The other implied advice is that if the HSRC is concerned about the health risks of seating then it also ought to be wary of aerobics classes unless there is a fitness expert with paramedical skills who organises what these should include.

Judging from the physical examination, there are a number of staff who are suffering from musculoskeletal complaints who have not sought medical advice. Under the present circumstances it is unlikely that these will do so until it is too late. Treatment could be effected at the HSRC by physiotherapists.

At the educational level the recommendation of the student physiotherapists to begin a 'back school' for staff with problems is a very sound one. Overseas it is quite evident that organisations are taking a major step in the promotion of corporate responsibility for employee welfare at every level. This entails bringing services to the workplace, because there is so little time outside of working hours and such services tend to be costly for the employee. It can be argued that organisations save costs by such measures: it is unlikely that the Japanese would have promoted them if they were not cost–effective.

4.3.2 VDT users

The use of VDTs is increasing amongst staff and much of this study has examined the negative effects of VDT tasks on posture. In the preliminary interviews about half the subjects suffered from visual discomfort. As a substantial number of staff are middle aged and wear glasses this could be due to the phenomenon of decreased visual accommodation which can occur after a period of constant viewing of the VDT screen at the near focus. The build up of static on the screen, speed/humidity of the airflow and decreased eye–blink response with screen viewing are some other factors which influence discomfort. The headaches and dizziness could well be related to VDT work without adequate relaxation for the eyes. *It is recommended that VDT users have their eyes checked regularly and are given a rest from screen work every hour.*

As this is an important health issue it is recommended that an in–house group of researchers monitor those people with problems and give advice on correct VDT use, on the adequacy of the glasses prescribed, and on the visual demands of the task. In addition some subjects commented on the poor quality of the VDT screen they were required to use, maintaining the characters were difficult to see. All these issues require consideration.

4.3.3 Workstation recommendations

Workstation redesign need not be costly. Compared to the outgoings of the HSRC the cost of furniture is rather modest. For instance, if that hypothetical R1m spent on unproductive time were employed to purchase furniture, this would mean that every employee could have a new workstation (at R1 000 each).

However, this investigation is strictly only with reference to the subjects studied here, their workstation arrangements and health complaints. Discussion about the way in which the recommendations might be implemented is given later.

General recommendations

A key factor in this study has been the mismatch between seat height, desk height and subjects' body dimensions. A comfortable height to work at depends on the height of the work surface. For office work Grandjean (1982) recommends a work surface height below seated elbow height. This study showed that most people have been struggling to reach this height.

The best solution is to have desks of adjustable height. Footrests, adjustable in height and angulation are recommended where work surfaces are not adjustable (Kroemer and Price, 1982). Chairs should be adjustable for seat height and depth, lumbar support and tilt tension. Adjustments must be easy to make, especially if several people share the workstation — as in the terminal room. A high backrest is recommended to provide more support than the traditional office chair.

For subjects using VDTs, screen height and tilt should be independently adjustable. The optimum viewing angle of the screen is 10–15 degrees below the horizontal at eye height (Grandjean, 1987), and the optimum viewing distance is between 45 and 70 cm (Cakir *et al*, 1979). A document holder is recommended to minimise neck and upper back stress.

A lower table height is recommended for typing than for writing (Dainoff, 1982) so that the home row of the keyboard is at elbow height. The elevation of the keyboard over the desktop should not be much more than 30 mm and the desktop should be as thin as possible (Kroemer, 1971). A wrist rest immediately in front of the keyboard minimises potentially stressful arm and wrist angles (Kroemer and Price, *ibid*). For long term operation of the keyboard support for the palm, hand, wrist and arm is advocated (Kroemer and Price, *ibid*). Posture and efficiency may be further improved by a split keyboard (Kroemer, *ibid*) (Figure 26).

The rider to these recommendations is that users benefit from the support and adjustability of workstations only in a perfectly upright position (Figure 21). However, the posture mostly observed during reading and writing is one in which the trunk is supported by leaning the arms on the desk (Grandjean *et al* ,1983). The backrest is used infrequently.

In the postural assessment of the 12 researchers performing desk work the backrest was used 31% of the time whilst slumping forward was the more common posture.

This tends to confirm the research findings which suggest that conventional chairs are not generally used in the way their designers intended. The observed deviation from the upright position dictated by conventional chair design relates to the performance of bent–forward work. When fatigue is felt in the abdominal muscles whilst sitting upright the user may either slump forward or backward. In the former case the lumbar lordosis is lost and the passive structures posterior to the spine support the trunk. This posture leads to discomfort in the back and thighs. In slumping backward there is a backward rotation of the pelvis which increases the hip angle and relieves pressure on the abdomen.

Here a chair that permits a forward inclination of the seat pan introduces an alternative to the upright position (Figure 22).

Another alternative is the 'pelvic tilt' concept (Figure 23) introduced by Mandal (1976) and incorporated in the 'Balans' chair manufactured in Scandinavia. Here there is a forward inclining seat pan of 15–30 degrees. The increase in the hip angle rotates or tilts the pelvis anteriorly, leading the lumbar spine to adopt its natural lordosis which would obtain in a upright standing position. This type of chair is in use throughout the schools of Denmark in an effort to promote correct posture in children. However, for adults who have become habituated to conventional chairs the pelvic tilt chair may be found to be uncomfortable, although many find it very comfortable. It has been successful in reducing backache for some users. Certain clinical conditions indicate that it should not be used with other individuals.

There are also many more sophisticated chair designs.

In addition to inclining the seat pan forward the tilting of the work surface also contributes towards reducing the angle the neck is bent. For desk workers this option is viable, as the two examples of researchers observed in this study attest.

Specific recommendations

These are made with reference to individual's workstations, their postures and their symptoms. There are various ways of improving the situation but only the most basic and necessary recommendations have been included.

FIGURE 21. RESTRICTED WORKSTATION WITH 90 DEGREE HIP ANGLE

FIGURE 22. VDT WORKSTATION WITH A 105 DEGREE HIP ANGLE

FIGURE 23. BENT FORWARD WORK ON A PELVIC TILT CHAIR

FIGURE 21

FIGURE 22

FIGURE 23

Researchers : –

GS: This subject's desk was too high, leading to hunched shoulders. Here a footrest and a chair which provides support for the whole of the back are recommended. The table for the VDT was totally unsuitable; having a thick edge, being too high and too small. A proper document holder is required as GS also has a neck problem which is related to VDT work.

RR: This subject's desk was too high, a footrest is recommended. The neck angle observed in this tall subject suggests she would benefit from a tilted work surface.

GP: This subject is mainly involved in VDT work and so priority should be given to improving her VDT workstation. A larger desk at a lower height, a document holder and footrest are required.

IP: This subject complained of pain under the thighs, neckache and backache. His posture, with closed hip angle and large upper arm abduction, indicates that both desk and seat are too high. A footrest is recommended and a chair with low back support. A tilted work surface would also help this subject.

JGS: Here the chair is too low for the desk again and a footrest is suggested. The subject has several problems including headaches, neck, shoulder, upper and lower back complaints. As she is on the tall side it is recommended that a chair with a high backrest be provided.

DZ: A footrest is necessary and a chair with lumbar support and higher backrest is indicated, as the subject has a neck problem.

DM: This subject had severe problems and does not seem to use his backrest very much. His desk is too high and his posture is poor. His situation perhaps needs to be looked at in greater detail; trying different alternatives. He could clearly benefit from 'back school' advice on seating posture.

HO: This subject only used the backrest of his chair for 20% of the postural assessment. Most of the time he was hunched on the writing side and slouched down on the left side; his head was supported by his left arm which rested on the left armrest. A footrest to counteract the high desk and a different kind of chair are indicated.

JL: This subject had a high desk with resultant thigh compression. Although her chair was new and she had expressed satisfaction initially, it is clear that the seat pan is too shallow for her and with her height she requires a high backrest. Due to the amount of forward–leaning work she performs (91%) it seems a seat pan with forward inclination would be more suitable for her. This then dispenses with the need for a footrest.

ELM: This tall subject now has a chair with a high backrest and this is quite satisfactory for her back. However, the desk is still too high and a footrest is recommended.

JB: This subject had no physical complaints. However, the desk was too high for him and a footrest would improve his posture.

NC: This subject's seat and desk are too low. The desk must be raised on blocks and a chair with a higher backrest is required.

SC: This subject is tall and his workstation is correspondingly inadequate. Desk and chair need raising.

HB: The chair was too large and low. The backrest was used very little. A chair with inclined seat pan would be more suitable.

KH: This subject had neck and low back problems. His desktop was too high and he was improvising with a board in front of his backrest, which suggests he was not getting adequate back support. At the VDT he had hunched shoulders as a result of the keyboard being too high and his thighs were compressed by the desk–edge. A pelvic tilt chair at the VDT might be more suitable.

MV: This subject would benefit from a more supportive backrest.

Terminal room workstations:

As already mentioned the tables here were completely unsuitable for VDT work and responsible for hunched shoulders, bent necks and thigh pain. A complete re–think is required here since the old IBM terminals are not compatible with any existing furniture; the keyboards are much too thick, the terminals take up so much space that there is no room for documents. Appropriate chairs, footrests, desks and document holders are required in these rooms.

Programmers :–

Since the study new chairs have been purchased in the Computer Centre. As it is not known how these have changed the situation the recommendations will be based on the data collected.

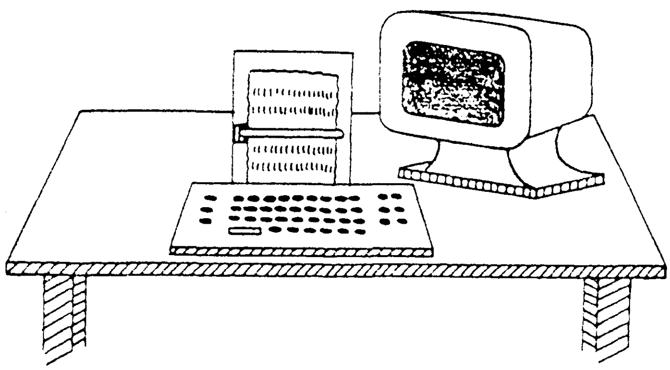
Here subjects only used the backrest for 26% of the time during the video posture assessment. Analysis of workstation dimensions revealed that the chairs being used were too deep to permit proper use of the backrest. In all cases the desk was too high and most subjects had hunched shoulders. In six cases only one desk was made to serve as ordinary work desk and terminal desk. This peculiar layout, alluded to previously, resulted in a twisted posture with arms extended too far forward towards the keyboard. This places stress on the neck, shoulders and upper back. Neck and shoulder symptoms were found in all but one subject. Separate desks for different tasks are recommended and footrests where necessary. Where work involves copying from a document for any length of time document holders should be employed. Chairs with higher backrests would help those with neck problems when sitting back and seats with inclined seat pans would be appropriate in a bent–forward working position.

Typists :–

Here the desks were too high. Some typists adjusted their chairs to compensate and rested their feet on the desk footrests. However, this does not promote good posture. The task demands much neck twisting and neck problems are common. The arrangement of screen, keyboard and source document should be adjusted to the way and frequency these elements are used. Hence, if vision is directly primarily at the document being copied then it is recommended that the keyboard and document holder be positioned in front of the operator and the screen positioned to the side (Figure 24). In this way the document and screen can be viewed with a minimum horizontal movement of the head. Footrests are recommended in all cases.

Subject VM wears bifocals and the low height of the screen requires her to strain her neck to see. Raising the screen would reduce her neck angle. Subject AK, a tall lady, has a chronic neck/shoulder complaint. This would be relieved somewhat if she had a higher backrest. In all cases the provision of armrests and deskrests for the wrists is recommended.

FIGURE 24. RECOMMENDED ARRANGEMENT FOR TYPING
(After Grandjean, 1987)



Data–Typists : –

LB the IPER data–typist has a totally inadequate workstation not unlike that observed in the terminal rooms. A much larger desk at the appropriate height is necessary. A seat with armrests and a high backrests is also recommended as the subject has chronic neckache and several other problems. Much of this is due to the awkward posture adopted. As with the typists an alternative layout with document holder and keyboard placed in front would eliminate the constant need to twist the head.

Recommendations for the Computer Centre data–typing pool are similar for each subject as the workstations are identical, save for two old card–punch machines. It is difficult to know what to recommend here as the whole computer console is integrated. There have already been attempts by subjects to adapt the seating position to the console – new seats and boxes used as footrests. This addresses the issue of seating height but the layout of the console still dictates that subjects sit in constrained postures with bent necks and twisted trunks. For data–entry tasks the ideal position is with the document holder and keyboard placed in front as vision is only directed at the screen occasionally.

The positioning of the keyboard is the most unanatomical aspect of the console (Figure 15) and can be said to constitute a hazard to the healthy functioning of the right arm.

FIGURE 25. POSITIONING OF HANDS OPERATING TRADITIONAL KEYBOARD (After Grandjean, 1987)

The parallel position of the rows requires an inward rotation of the forearms and wrists and a sideways twisting of the hands.

FIGURE 26. ERGONOMICALLY-DESIGNED KEYBOARD (After Ilg, 1987)

Two keyboard halves with opening angle of 30 degrees to avoid sideways twisting of the hands, plus lateral slopes of 8 degrees to lessen inward rotation of arms and wrists.

Much experimental work has been devoted to developing anatomically natural keyboards. The resting position of the arms and hands in a chair or on a table shows that they naturally converge. The typewriter was invented in 1868 as a mechanical device with four parallel rows of keys. Operation requires the hands to be held at right angles to the rows. This means there is an inward rotation of the forearm and wrists and a lateral abduction (ulnar deviation) of the hands (see Figure 25). This posture has long been the cause of inflammation of tendons (tendinitis) in the forearms of keyboard operators. Now that the keyboard is electronic there is no reason why the traditional layout need persist – apart from convention. Experiments with split keyboards (Ilg, 1987) have demonstrated reduced discomfort, less tension and, importantly, increased typing speed. Static muscle load in the shoulders and arms is significantly reduced with such a keyboard design (Figure 26).

After this rather lengthy diversion it may be apparent, on returning to the data–typists' console, that the keyboard is much worse that an ordinary keyboard in that the ulnar deviation is probably doubled. The net result of the contradictory demands placed on the data–typist because of the console layout is a contorted posture. This is not superficially evident at a glance because the contortion is not gross. However, it is quite probable that this contributes towards the rapid build up of fatigue characteristic of this group.

It is recommended that the console be altered but prior to this trials with subjects would be necessary to ascertain the optimum workstation layout.

4.3.4 Recommendations for work reorganisation

Both the preliminary interview, in which several subjects maintained their complaints were not so much due to their chairs but to the work itself, and the physical examination, in which a high percentage of subjects (86%) maintained their complaints were occupationally aggravated or related, suggests that some changes in work organisation or design may be necessary.

Laville (1983) argues that it is the high speed of execution of data–entry which causes the greatest postural immobilisation in data–entry operators. Recent research indicates that because of the static nature of much office work it is not enough to simply design workstations to be comfortable; attention needs to be paid to a work organisation requiring postural changes in order to reduce postural stress.

In enquiring about the data–entry task most information sources have suggested that it is very similar to routine repetitive assembly work in factories and there is little scope for improving on the situation. It would be easy to say, 'this is the job and these are the drawbacks – take it or leave it'. In fact this is not an unfair appraisal of the situation, so why waste time and money on investigating something which is not a viable proposition?

However, some tentative studies have indicated that attention to workstation design and work reorganisation can reduce the adverse effects on health and productivity of data–entry workers even if the essential nature of the task remains unchanged.

Fatigue and productivity are closely related. Ong (*ibid*) showed that workstation and work redesign, including a revised work–rest regime, increased productivity by 2 500 key strokes per hour. Error rate declined from 1% to 0.11%. Physical symptoms were reduced markedly. The work–rest regime incorporated two morning breaks, an hours lunch break and one afternoon break.

Rest clearly helps to reduce fatigue and discomfort. This was evident in the case of one subject with a chronic condition who surprisingly registered 'complete relaxation' in the general comfort rating one afternoon. As this was so completely different from all her other responses a reason for this incongruity was sought, and found. The head of the data–typing pool had not been present at the time.

There is no doubt that stressors such as rigid work procedures, pressure for performance, little operator control over the job, computer system response delays (leading to build up of work), high workload, repetitive work, lack of task variety, boredom and little satisfaction from the end product cause job dissatisfaction, mental fatigue, irritability and psychosomatic correlates such as neck tension. Additionally, in the data–typing pool there are certain other environmental stresses – such as the noise of the copying machine and the illumination. The first can result in loss of concentration, the second in visual discomfort. Job content thus appears to be an important factor in determining the levels of occupational stress and health complaints in workers.

It is therefore recommended that the data–typists' work should be examined to see if there is any way in which it can be redesigned to increase task and postural variety. If this is not possible then additional rest periods should be incorporated. The preliminary interviews revealed that both data–typists and typists seldom had any change in activity. Both groups felt pressurised. Both groups expressed a need for more rest breaks and felt that VDT work required more rest breaks than normal work, principally on the grounds of visual discomfort. Lack of task variety was commonly mentioned.

The other way to combat postural fatigue and stress has already been mentioned – keeping fit or improving fitness. A new development from the USA is called an 'active office system' (Figure 27). Here the subject is walking at slow speed on an electric treadmill whilst word processing. This picture just about encapsulates the problem of the sedentary office worker in a nutshell – especially the problem of the VDT worker. Is THIS the answer?!

FIGURE 27. 'AN ACTIVE OFFICE SYSTEM' (from Edelson, 1988)

4.4 Implementing the recommendations

On the face of it there is a simple solution to reducing work surface heights – saw the legs off the desks. Certainly cutting out the excessive edges of those tables which have thick tops should be simple enough. Before performing any surgery of this kind it is obviously necessary to find out what the best, most comfortable height is for each person. Here it would be useful to construct a desk of adjustable height to perform what are often called 'fitting trials' – fitting the desk to the worker.

On the other hand footrests have been mentioned repeatedly in the recommendations. These devices are apparently commonly used overseas but the author has not, as yet, come across them in this country. It is not sufficient to use cardboard boxes or just any old thing. As mentioned previously footrests have to be adjustable in height and angulation. However, with the practical skills which exist within the HSRC it would no doubt be possible to build these at little cost. Who knows – with a little design input these could be sold as products for office workers!

Inclined work surfaces to reduce the amount of neck-bending would be easy enough to devise.

Document holders with pneumatic operation were available from the Administration Department of the HSRC in October 1987.

Chairs are unfortunately more sophisticated devices than desks. At the outset of this study it was suggested that if the existing chairs were found to be unergonomic then a series of trials should be undertaken with a range of chairs from different manufacturers. This would be on an 'appro' basis as far as possible and for a reasonable period so that several subjects could evaluate the chairs without time pressure.

Gradually, some of the better chairs would be purchased. It was suggested by the consultant physiotherapist that eventually a 'chair library' could be established with staff borrowing chairs for trial and returning them. This is similar in concept to the 'back shops' which exist in Europe where would–be purchasers are allowed to try out chairs, orthoses and other devices for improved spinal health over extended periods. The spin–off from such a chair library would hopefully be an increased interest in postural awareness and a more responsible approach to health.

The specific recommendations for individuals have included details about whether a chair should have lumbar support, high backrest, armrests or whether chairs with inclined seat pan or pelvic tilt would be more appropriate. These are simply considered opinions based on the study findings and the individual is obviously the final arbiter in the matter. Having a wide choice is 'of the essence'. Eventually it should be possible to develop some criteria for the guidance of users and decision–makers at the purchasing end.

This report will be seen to have exceeded the brief of the study in its examination of matters apparently unconnected to seats. Unfortunately better seats in themselves are not the final answer, as many recipients of new seats at HSRC have found.

Grieco (*ibid*) stated that, "the supply of ergonomically designed furniture that reduces postural stress will not in itself resolve all the problems of static seating postures. The next course of action is to intervene in the organisation of tasks and jobs". "For ergonomic chairs to be fully effective the operators should also have the possibility of frequent postural alternatives. Here jobs must be designed so that the work pauses are programmed and are used, from the posture viewpoint, as periods of body 'mobilisation' compared to the period in which work tasks are actually performed". "Health education is necessary so that operators are fully aware of how to use their furniture and are aware of the importance of pauses so as to create conditions of postural alternation. Eventually when this awareness is learnt then the programmed pauses are no longer necessary".

There is thus a priority for the teaching of correct work postures and movements to accompany any workstation redesign. Management must be fully committed to the policy it decides to adopt for that policy to work. If it endorses the avenues advocated in this report then it should seek to reduce high work pressure, perceived stress and be on the lookout for employees with a high occurrence of sick leave. These have been identified as key risk factors in musculoskeletal disorders.

4.5 Evaluating the implementations

It is clear from the analyses that certain factors contribute to the incidence of musculoskeletal symptoms. These are previous trauma and pathology, posture, workstation design and occupation. Both task and workstation influence posture. Changing the design of workstations so as to improve posture is the main tool advocated to promote improvements along with advice on how to make best use of the workstation.

Evaluation of the implemented recommendations would require a further period of monitoring subjects using the questionnaire method and comparing results.

As some of the recommendations might have consequences which are far–reaching (for instance, work reorganisation and revised work—rest regimes) discussion of further evaluation is considered unnecessary at this stage.

5. CONCLUSION

HSRC management originally requested an ergonomic evaluation of the health risks associated with prolonged use of the existing seating facilities. This evaluation revealed that many workstations were inadequate. The present study was devised to distinguish between health complaints due to trauma or pathology and those due to workstation design and working posture. Physical examinations on 37 subjects revealed that 68% of the clinical musculoskeletal symptoms reported were not related to trauma or pathology. Only 2 subjects did not report any symptoms. Of these problems 86% were reported to be occupationally aggravated.

Musculoskeletal complaints are widespread, though not severe, among the subjects. Most problems are due to several factors, including postural stress, workstation design and occupation. Postural stress and workstation design are, to all intents and purposes, inextricable from 'occupation' and other aspects of occupation such as workload, job content and stress combine to increase postural stress.

As the postural assessment revealed, many of the seated postures were static in nature. Good workstation design may not be sufficient in itself but needs to be complemented by an ergonomic work organisation and education in healthy posture.

Interventions to reduce postural stress and the incidence of disorders by workstation redesign, work reorganisation and health education should be seen as part of a larger managerial policy aimed at organisational health, fitness and productivity.

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APPENDIX 1. BODY CHART USED IN PHYSICAL EXAMINATION

Shade in all areas of pain / stiffness / discomfort which you might have and number them in order of importance from A - Z.

APPENDIX 2. PAGE'S TREND TEST ON GENERAL COMFORT RATINGS

occupation	Time 1	Time 2	Time 3	Time 4	Time 5	Time 6
Data-Typists	2.14	2.54	2.58	2.70	2.56	3.07
Programmers	1.47	1.63	1.66	1.67	1.59	1.82
Researchers	1.36	1.70	1.80	1.89	1.69	1.86
Typists	1.53	1.58	1.74	1.99	1.82	2.19
Ranks:	1	2	4	5	3	6
	1	3	4	5	2	6
	1	3	4	6	2	5
	1	2	3	5	4	6
R (sum of ranks):	4	10	15	21	11	23
w (weights):	1	2	3	4	5	6
L (sum wR):	4 +	40 +	45 +	84 +	55 +	138

L = 346

Critical table value at 1% is 331.

CONCLUSION:

As L = 346 > 331, it can be concluded that there is a significant trend across the six time levels of observation. The null hypothesis of no increasing trend with time is rejected.

REMARKS:

The outlier (subject AK) has been excluded.

The values are the means for each occupational group per time level as observed over 14 days.

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APPENDIX 3. BODY PART DISCOMFORT FREQUENCY

PERCENTAGE OF BPD/YES RESPONSES OVER TIME – DATA-TYPISTS

TIME	OCCASIONS	FREQUENCY (PERCENT)							MEAN
		LB	AC	MC	KF	CN	AD	AP	
T1	77	8	9	0	0	23	0	45	12
T2	76	11	23	0	69	85	17	45	36
T3	80	36	45	9	57	100	0	67	45
T4	82	45	50	33	79	100	14	67	55
T5	56	33	64	17	100	100	14	75	57
T6	53	31	55	20	0	58	33		

DATA FOR FULL-TIME AND EXCLUDING A.D.:

TIME	OCCASIONS	LB	AC	MC	AP	MEAN
T1	44	8	9	0	45	16
T2	44	11	23	0	45	20
T3	45	36	45	9	67	39
T4	47	45	50	33	67	49
T5	47	33	64	17	75	47
T6	46	31	55	20	58	41

BREAKDOWN OF (A) INDIVIDUAL FREQUENCIES,
(B) OCCASIONS, and
(C) PERCENTAGES

		T1	T2	T3	T4	T5	T6
LB	(A)	1	1	4	5	4	4
	(B)	12	9	11	11	12	13
	(C)	8	11	36	45	33	31
AC	(A)	1	3	5	6	7	6
	(B)	13	11	12	11	12	12
	(C)	9	23	45	50	64	55
MC	(A)	0	0	1	4	2	2
	(B)	10	11	11	12	12	10
	(C)	0	0	9	33	17	20
KF	(A)	0	9	8	11	1	
	(B)	13	13	14	14	1	
	(C)	0	69	57	79	100	
CN	(A)	3	11	14	14	1	
	(B)	13	13	14	14	1	
	(C)	23	85	100	100	100	
AD	(A)	0	1	0	1	1	0
	(B)	7	6	7	7	7	7
	(C)	0	17	0	14	14	0
AP	(A)	5	5	8	8	9	7
	(B)	11	11	12	12	12	12
	(C)	45	45	67	67	75	58

PERCENTAGE OF BPD/YES RESPONSES OVER TIME - TYPISTS

TIME	OCCASIONS	FREQUENCY (PERCENT)					MEAN
		AK	BO	VM	EL	MN	
T1	61	93	7	15	17	0	26
T2	63	100	8	36	25	8	35
T3	67	100	21	8	33	0	32
T4	66	100	14	57	45	0	43
T5	51	100	15	46	42		51
T6	47	100	15	56	42		53

BREAKDOWN OF (A) INDIVIDUAL FREQUENCIES,
(B) OCCASIONS, and
(C) PERCENTAGES

		T1	T2	T3	T4	T5	T6
AK	(A)	12	12	14	13	13	13
	(B)	13	13	14	13	13	13
	(C)	92	92	100	100	100	100
BO	(A)	1	1	3	2	2	2
	(B)	13	13	14	14	13	13
	(C)	8	8	21	14	15	15
VM	(A)	2	5	1	8	6	5
	(B)	13	14	13	14	13	9
	(C)	15	36	8	57	46	56
EL	(A)	1	3	4	5	5	5
	(B)	11	12	12	11	12	12
	(C)	9	25	33	45	42	42
MN	(A)	0	1	0	0		
	(B)	11	12	14	14		
	(C)	0	8	0	0		

PERCENTAGE OF BPD/YES RESPONSES OVER TIME - PROGRAMMERS

TIME	OCCASIONS	FREQUENCY (PERCENT)								MEAN
		ID	SO	TG	EF	HF	CC	JH	JR	
T1	52	10	0	0	0	0	0	0	33	5
T2	54	0	0	0	29	50	18	9	0	13
T3	82	8	0	31	15	67	0	0	33	19
T4	94	14	0	43	43	83	9	0	25	27
T5	77	0	0	36	31	60	18	10	50	26
T6	84	15	0	38	62	75	9	10	50	32

BREAKDOWN OF (A) INDIVIDUAL FREQUENCIES,
(B) OCCASIONS, and
(C) PERCENTAGES

		T1	T2	T3	T4	T5	T6
ID	(A)	1	0	1	2	0	2
	(B)	10	7	13	14	10	13
	(C)	10	0	8	14	0	15
SO	(A)	0	0	0	0	0	0
	(B)	9	7	13	14	13	14
	(C)	0	0	0	0	0	0
TG	(A)	0	0	4	6	4	5
	(B)	9	5	13	14	11	13
	(C)	0	0	31	43	36	38
EF	(A)	0	2	2	6	4	8
	(B)	9	7	13	14	13	13
	(C)	0	29	15	43	31	62
HF	(A)	0	2	4	5	3	3
	(B)	2	4	6	6	5	4
	(C)	0	50	67	83	60	75
CC	(A)	0	2	0	1	2	1
	(B)	8	11	10	11	11	11
	(C)	0	18	0	9	18	9
JH	(A)	0	1	0	0	1	1
	(B)	11	11	8	13	10	10
	(C)	0	9	0	0	10	10
JR	(A)	1	0	2	2	2	3
	(B)	3	2	6	8	4	6
	(C)	33	0	33	25	50	50

PERCENTAGE OF BPD/YES RESPONSES OVER TIME – RESEARCHERS

TIME	OCCASIONS	FREQUENCY (PERCENT)							
		GS	GP	RR	IP	JGS	DM	DZ	HO
T1	163	33	0	0	0	25	100	25	40
T2	141	83	0	0	0	18	89	11	71
T3	170	20	10	0	0	17	100	36	56
T4	148	22	14	0	0	33	100	67	70
T5	156	14	14	0	0	18	83	62	56
T6	157	25	0	0	0	38	100	54	56

TIME	FREQUENCY (PERCENT)									MEAN
	JL	EL	JB	NC	SC	HB	KH	GH	MV	
T1	45	0	0	71	33	27	0	33	17	26
T2	30	8	0	75	22	40	10	83	0	29
T3	30	17	0	56	23	50	18	100	17	33
T4	70	60	10	43	27	50	22	57	17	40
T5	46	0	0	56	25	44	20	25	0	28
T6	27	33	8	63	43	56	0	63	0	34

BREAKDOWN OF (A) INDIVIDUAL FREQUENCIES,
(B) OCCASIONS, and
(C) PERCENTAGES

		T1	T2	T3	T4	T5	T6
GS	(A)	3	5	2	2	1	2
	(B)	9	6	10	9	7	8
	(C)	33	83	20	22	14	25
GP	(A)	0	0	1	1	1	0
	(B)	8	6	10	7	7	6
	(C)	0	0	10	14	14	0
RR	(A)	0	0	0	0	0	0
	(B)	12	9	10	8	11	11
	(C)	0	0	0	0	0	0
IP	(A)	0	0	0	0	0	0
	(B)	12	8	12	11	11	8
	(C)	0	0	0	0	0	0
JGS	(A)	3	2	2	3	2	5
	(B)	12	11	12	9	11	13
	(C)	25	18	17	33	18	38
DM	(A)	7	8	9	9	5	9
	(B)	7	9	9	9	6	9
	(C)	100	89	100	100	83	100
DZ	(A)	2	1	4	6	8	7
	(B)	8	9	11	9	13	13
	(C)	25	11	36	67	62	54

		T1	T2	T3	T4	T5	T6
HO	(A)	4	5	5	7	5	5
	(B)	10	7	9	10	9	9
	(C)	40	71	56	70	56	56
JL	(A)	5	3	3	7	6	3
	(B)	11	10	10	10	13	11
	(C)	45	30	30	70	46	27
EL	(A)	0	1	2	6	0	4
	(B)	13	12	12	10	11	12
	(C)	0	8	17	60	0	33
JB	(A)	0	0	0	1	0	1
	(B)	8	11	11	10	12	12
	(C)	0	0	0	0	0	8
NC	(A)	5	6	5	3	5	5
	(B)	7	8	9	7	9	8
	(C)	71	75	56	43	56	63
SC	(A)	3	2	3	3	2	3
	(B)	9	9	13	11	8	7
	(C)	33	22	23	27	25	43
HB	(A)	3	4	5	3	4	5
	(B)	11	10	10	6	9	9
	(C)	27	40	50	50	44	56
KH	(A)	0	1	2	2	2	0
	(B)	11	10	11	9	10	10
	(C)	0	10	18	22	20	0
GH	(A)	3	5	5	4	1	5
	(B)	9	6	5	7	4	8
	(C)	33	83	100	57	25	63
MV	(A)	1	0	1	1	0	0
	(B)	6	0	6	6	5	3
	(C)	17	0	17	17	0	0

APPENDIX 4. BODY PART DISCOMFORT SEVERITY AND SEVERITY WEIGHTED BY NUMBER OF PARTS AFFECTED

Explanation: If subjects said they felt discomfort they were required to rate the importance of the parts in discomfort from A to Z and to rate the severity of discomfort on a five-point scale.

SEVERITY OF DISCOMFORT SCALE:

1. just noticeable discomfort
2. moderate discomfort
3. quite bad discomfort
4. severe discomfort
5. almost unbearable discomfort

The scores from this scale constitute 'Body Part Discomfort Severity' (BPDS). Weighted scores have been derived from weighting the BPDS scores by the number of areas affected similtaneously. The rationale for weighting scores is the theoretical presupposition that where there is more than one part affected this weighting of the most painful areas in proportion to the number of levels reported, permits an increased level of pain to be recognised in the scoring (Corlett and Bishop, *ibid*).

Thus we may have someone who experiences level 1 on one occasion and later experiences 3 areas of discomfort at the same level. Without the weighting we could say that the amount of discomfort is just the same in one situation as the other. The system adopted here is that if there are three areas then the weighted scores are 1 x 3, 1 x 2 and 1 x 1 according to which areas were reported as A, B and C in importance.

In the following tables 'BPD/YES' is the total number of times a positive response was given to the first question on discomfort at each time level. 'SUMSEV' is the sum of the scores from the severity scale for each time. 'MEAN' is the average of these scores. 'W/SUM' is the sum of the scores weighted by number of parts affected at the same time. 'MEAN' is the average of the weighted scores.

It should be noted that figures for the group means include those for all subjects but the data used in the text was based on the scores of the full-time subjects only because of the inevitable problems which arise in treating 'mixed' data. In addition typist AK was excluded from the tables and graphs in the text because of her unique amount of problems. As all programmers and researchers are full time the term is not used in these cases.

Data–Typists

SUBJECT	TIME	BPD/YES	SUMSEV	MEAN	W/SUM	MEAN
LB	T1	1	1	1	1	1
	T2	1	1	1	1	1
	T3	4	4	1	4	1
	T4	5	6	1.20	6	1.20
	T5	4	9	2.25	15	2.50
	T6	4	7	1.75	10	2.50
AC	T1	1	3	3	3	3
	T2	3	9	3	9	3
	T3	5	12	2.40	12	2.40
	T4	6	14	2.33	14	2.33
	T5	7	17	2.43	17	2.43
	T6	6	27	4.50	37	6.17
MC	T1	0	0	0	0	0
	T2	0	0	0	0	0
	T3	1	6	6	9	9
	T4	4	15	3.75	20	5
	T5	2	9	4.50	12	6
	T6	2	7	3.50	10	5
CN	T1	3	7	2.33	7	2.33
	T2	11	45	4.09	62	3.65
	T3	14	72	5.14	118	4.37
	T4	14	92	6.57	176	5.03
	T5	1	9	9	18	6
KF	T1	0	0	0	0	0
	T2	9	24	2.67	30	3.33
	T3	8	30	3.75	63	7.88
	T4	11	37	3.36	80	7.27
	T5	1	4	4	7	7
AD	T1	0	0	0	0	0
	T2	1	2	2	2	2
	T3	0	0	0	0	0
	T4	1	2	2	2	2
	T5	1	2	2	2	2
	T6	0	0	0	0	0
AP	T1	5	14	2.80	20	4
	T2	5	14	2.80	20	4
	T3	8	27	3.38	41	5.13
	T4	8	27	3.38	43	5.38
	T5	9	26	2.89	38	4.22
	T6	7	29	4.14	48	6.86

GROUP MEANS:		SEV	FULL-TIME	W/SEV	FULL-TIME
	T1	1.30	1.70	1.48	2
	T2	2.22	1.70	2.43	2
	T3	3.10	3.19	4.25	4.38
	T4	3.23	2.67	4.03	3.48
	T5	3.87	3.02	4.31	3.79
	T6	2.78	3.47	4.10	5.13

Typists

SUBJECT	TIME	BPD/YES	SUMSEV	MEAN	W/SUM	MEAN
AK	T1	12	47	3.92	76	6.33
	T2	12	44	3.67	67	5.58
	T3	14	52	3.71	79	5.64
	T4	13	46	3.54	69	5.31
	T5	13	44	3.38	62	4.77
	T6	13	44	3.38	62	4.77
BO	T1	1	2	2	2	2
	T2	1	1	1	1	1
	T3	3	3	1	3	1
	T4	2	3	1.50	3	1.50
	T5	2	2	2	2	1
	T6	2	5	2.50	8	4
VM	T1	2	3	1.50	3	1.50
	T2	5	7	1.40	10	2
	T3	1	2	2	2	2
	T4	8	14	1.75	20	2.50
	T5	6	8	1.33	16	2.67
	T6	5	11	2.20	17	3.40
EL	T1	1	4	4	4	4
	T2	3	10	3.33	10	3.33
	T3	4	12	3	12	3
	T4	5	17	3.40	21	4.20
	T5	5	17	3.40	21	4.20
	T6	5	17	3.40	21	4.20
MN	T1	0	0	0	0	0
	T2	1	1	1	1	1
	T3	0	0	0	0	0
	T4	0	0	0	0	0

GROUP MEANS:		SEV	FT & EX AK	W/SUM	FT & EX AK
	T1	2.28	1.83	2.77	1.83
	T2	2.08	1.91	2.58	2.11
	T3	1.94	1.67	2.33	1.67
	T4	2.04	1.72	2.70	2.23
	T5	2.53	2.37	3.16	3.44
	T6	2.87	2.80	4.09	3.80

Programmers

SUBJECT	TIME	BPD/YES	SUMSEV	MEAN	W/SUM	MEAN
ID	T1	1	1	1	1	1
	T2	0	0	0	0	0
	T3	1	1	1	1	1
	T4	2	2	1	2	1
	T5	0	0	0	0	0
	T6	2	2	1	2	1
SO	T1	0	0	0	0	0
	T2	0	0	0	0	0
	T3	0	0	0	0	0
	T4	0	0	0	0	0
	T5	0	0	0	0	0
	T6	0	0	0	0	0
TG	T1	0	0	0	0	0
	T2	0	0	0	0	0
	T3	4	10	2.50	19	4.75
	T4	6	13	2.17	22	3.67
	T5	4	9	2.25	11	2.75
	T6	5	11	2.20	13	2.60
EF	T1	0	0	0	0	0
	T2	2	2	1	2	1
	T3	2	2	1	2	1
	T4	6	7	1.17	7	1.17
	T5	4	4	1	4	1
	T6	8	10	1.25	10	1.25
HF	T1	0	0	0	0	0
	T2	2	3	1.50	4	2
	T3	4	5	1.25	6	1.50
	T4	5	12	2.40	20	4
	T5	3	8	2.67	14	4.67
	T6	3	10	3.33	7	2.33
CC	T1	0	0	0	0	0
	T2	2	2	1	2	1
	T3	0	0	0	0	0
	T4	1	2	2	2	2
	T5	2	3	1.50	3	1.50
	T6	1	1	1	1	1
JH	T1	0	0	0	0	0
	T2	1	2	2	2	2
	T3	0	0	0	0	0
	T4	0	0	0	0	0
	T5	1	1	1	1	1
	T6	1	1	1	1	1
JR	T1	1	1	1	1	1
	T2	0	0	0	0	0
	T3	2	4	2	4	2
	T4	2	4	2	4	2
	T5	2	5	2.50	5	2.50
	T6	3	4	1.33	4	1.33

GROUP MEANS:	SEV	W/SUM
T1	1	1
T2	1.38	1.50
T3	1.55	2.05
T4	1.79	2.31
T5	1.82	2.24
T6	1.45	1.65

Researchers

SUBJECT	TIME	BPD/YES	SUMSEV	MEAN	W/SUM	MEAN
GS	T1	3	4	1.33	4	1.33
	T2	5	9	1.80	9	1.80
	T3	2	4	2	4	2
	T4	2	5	2.50	5	2.50
	T5	1	3	3	3	3
	T6	2	4	2	4	2
GP	T1	0	0	0	0	0
	T2	0	0	0	0	0
	T3	1	2	2	2	2
	T4	1	2	2	2	2
	T5	1	1	1	1	1
	T6	0	0	0	0	0
RR	T1	0	0	0	0	0
	T2	0	0	0	0	0
	T3	0	0	0	0	0
	T4	0	0	0	0	0
	T5	0	0	0	0	0
	T6	0	0	0	0	0
IP	T1	0	0	0	0	0
	T2	0	0	0	0	0
	T3	0	0	0	0	0
	T4	0	0	0	0	0
	T5	0	0	0	0	0
	T6	0	0	0	0	0
JGS	T1	3	6	2	6	2
	T2	2	4	2	4	2
	T3	2	4	2	4	2
	T4	3	10	3.33	13	4.33
	T5	2	4	2	4	2
	T6	5	10	2	10	2
DM	T1	7	18	2.57	24	3.43
	T2	8	26	3.25	47	5.88
	T3	9	23	2.56	32	3.56
	T4	9	22	2.44	34	3.78
	T5	5	9	1.80	11	2.20
	T6	9	15	1.67	18	2
DZ	T1	2	7	3.50	9	4.50
	T2	1	3	3	3	3
	T3	4	9	2.25	11	2.75
	T4	6	13	2.17	18	3
	T5	8	20	2.50	28	3.50
	T6	7	21	3	29	4.14
HO	T1	4	5	1.25	5	1.25
	T2	5	6	1.20	6	1.20
	T3	5	9	1.80	11	2.20
	T4	7	14	2	14	2
	T5	5	6	1.20	6	1.20
	T6	5	9	1.80	10	2

Researchers (continued)

SUBJECT	TIME	BPD/YES	SUMSEV	MEAN	W/SUM	MEAN
JL	T1	5	12	2.40	15	3
	T2	3	5	1.67	5	1.67
	T3	3	7	2.33	9	3
	T4	7	15	2.14	17	2.43
	T5	6	13	2.17	15	2.50
	T6	3	10	3.33	12	4
EL	T1	0	0	0	0	0
	T2	1	1	1	1	1
	T3	2	4	2	4	2
	T4	6	10	1.67	10	1.67
	T5	0	0	0	0	0
	T6	4	6	1.50	6	1.50
JB	T1	0	0	0	0	0
	T2	0	0	0	0	0
	T3	0	0	0	0	0
	T4	1	1	1	1	1
	T5	0	0	0	0	0
	T6	1	2	2	2	2
NC	T1	5	8	1.60	8	1.60
	T2	6	16	2.67	16	2.67
	T3	5	11	2.20	11	2.20
	T4	3	4	1.33	4	1.33
	T5	5	8	1.60	8	1.60
	T6	5	9	1.80	9	1.80
SC	T1	3	6	2	6	2
	T2	2	4	2	4	2
	T3	3	8	2.67	8	2.67
	T4	3	8	2.67	8	2.67
	T5	2	5	2.50	5	2.50
	T6	3	8	2.67	8	2.67
HB	T1	3	8	2.67	11	3.67
	T2	4	6	1.50	6	1.50
	T3	5	10	2	13	2.60
	T4	3	7	2.33	10	3.33
	T5	4	17	4.25	34	8.50
	T6	5	19	3.80	36	7.20
KH	T1	0	0	0	0	0
	T2	1	1	1	1	1
	T3	2	2	1	2	1
	T4	2	5	2.50	6	3
	T5	2	2	1	2	1
	T6	0	0	0	0	0
GH	T1	3	3	1	3	1
	T2	5	7	1.40	7	1.40
	T3	5	15	3	21	4.20
	T4	4	8	2	9	2.25
	T5	1	4	4	4	4
	T6	5	18	3.60	45	9

Researchers (continued)

SUBJECT	TIME	BPD/YES	SUMSEV	MEAN	W/SUM	MEAN
MV	T1	1	2	2	2	2
	T2	0	0	0	0	0
	T3	1	1	1	1	1
	T4	1	1	1	1	1
	T5	0	0	0	0	0
	T6	0	0	0	0	0

GROUP MEANS:		SEV	W/SUM
	T1	1.31	1.52
	T2	1.32	1.48
	T3	1.69	1.95
	T4	1.83	2.13
	T5	1.59	1.94
	T6	1.72	2.37

APPENDIX 5. DISCOMFORT BY BODY AREA

PERCENTAGE OF BPD/YES RESPONSES FOR BODY AREAS

DATA-TYPISTS

SUBJECT	NECK	L/BK	U/BK	R/SH	L/SH	F/HD	R/TH	L/TH
LB	11	7	1	1	1	7	0	0
AC	0	25	1	0	0	3	0	0
MC	6	1	0	7	0	0	0	0
KF	0	0	17	2	1	0	16	17
CN	12	0	1	43	26	0	0	0
AD	2	1	0	0	0	0	0	0
AP	8	37	0	2	2	0	1	11
TOTALS	39	71	20	55	30	10	17	28
OCCASIONS	428	428	428	428	428	428	428	428
T/O (%)	9	17	5	13	7	1	4	7

TYPISTS

SUBJECT	NECK	L/BK	U/BK	R/SH	L/SH	F/HD	R/TH	L/TH
AK	76	1	1	4	53	0	0	0
BO	0	5	0	0	1	6	0	0
VM	19	6	0	5	5	0	0	0
EL	15	0	0	0	0	11	0	0
MN	1	0	0	0	0	0	0	0
TOTALS	111	12	1	9	59	17	0	0
OCCASIONS	355	355	355	355	355	355	355	355
T/O (%)	31	3	0	3	17	5	0	0

EX AK:

TOTALS	34	11	0	5	6	17	0	0
OCCASIONS	226	226	226	226	226	226	226	226
T/O (%)	15	5	0	2	3	8	0	0

PROGRAMMERS

SUBJECT	NECK	L/BK	U/BK	R/SH	L/SH	F/HD	L/LEG
ID	0	6	0	0	0	0	0
SO	0	0	0	0	0	0	0
TG	12	0	0	7	6	0	0
EF	22	0	0	0	0	0	0
HF	4	0	17	0	0	6	0
CC	0	6	0	0	0	0	0
JH	1	0	0	0	0	0	2
JR	10	0	0	0	0	0	0
TOTALS	49	12	17	7	6	6	2
OCCASIONS	452	452	452	452	452	452	452
T/O (%)	11	3	4	2	1	1	0

RESEARCHERS

SUBJECT	NECK	L/BK	U/BK	R/SH	L/SH	F/HD	R/TH	L/TH
GS	1	11	0	0	0	2	0	0
GP	3	0	0	0	0	0	0	0
RR	0	0	0	0	0	0	0	0
IP	0	0	0	0	0	0	0	0
JGS	1	4	2	0	0	11	0	0
DM	36	25	9	0	0	0	1	1
DZ	1	26	11	0	0	0	0	0
HO	15	18	0	0	0	0	0	0
JL	8	6	0	3	0	8	4	4
EL	3	1	9	0	0	0	0	0
JB	0	2	0	0	0	0	0	0
NC	0	27	0	0	0	2	0	0
SC	0	16	0	0	0	0	0	0
HB	0	13	0	4	10	2	0	0
KH	1	3	1	0	0	0	1	2
GH	17	2	1	3	3	2	1	1
MV	0	3	0	0	0	0	0	0
TOTALS	86	157	33	10	13	27	7	8
OCCASIONS	935	935	935	935	935	935	935	935
T/O (%)	9	17	4	1	1	3	1	1

APPENDIX 6. SUMMARY OF DATA FROM THE PHYSICAL EXAMINATION

Explanation: In these tables '0' is used instead of a tick or cross to refer to the presence of a condition. The subjects are treated individually with their presenting symptoms. 'Time' refers to the period the subject has experienced the pain. 'Clinical' is symptoms which were reported by the subject and verified on objective examination. 'Static' or 'Active' is whether the pain occurs in static or active situations.

'Sub(jective) severity' is the rating on a 1–10 scale allotted to the pain at its severist extreme, whereas 'Obj(ective) severity is the rating allotted the problem on a 1–5 basis by the physiotherapists (1 being 'slight' and 5 being 'severe'). The pain was reported to be either 'constant' or 'intermittent'. Among a series of questions inquiring what activities aggravated the pain 'Occupation' was included as one of the activities. Subjects reported the pain as a 'daily', 'weekly' or 'episodic' occurrence. Four kinds of 'P(ostural) Anomalies' were noted by the physiotherapists. Seven kinds of 'Trauma' were inquired after and eight kinds of 'Pathology', which included Osteoarthritis (O–A) and Rheumatoidarthritis (R–A). Disc lesions were included under the heading 'Bony' pathology. 'R(ange) of movement' was noted by the physiotherapists.

SUBJECT	LB				AC				MC		
AREA	N/sh	LBK	FHD	TH	LBK	N	TH	WR	RSH	RARM	N
TIME (YRS)	3				5	–1			1	1	1
CLINICAL	0	0			0	0					0
C/O STATIC/	0	0	0	0	0	0	0		0	0	0
ACTIVE					0			0			
REFERRED/	0		0		0	0			0	0	0
LOCAL	0	0	0	0	0	0	0	0	0	0	
SUB SEVERITY	5	2	5	1	8	8	4	5	5	5	5
OBJ SEVERITY	3	2	2	1	3	3	1	0	2	2	3
CONSTANT/	0				0						
INTERMITTENT		0	0	0		0	0	0	0	0	0
OCCUPATIONAL	0	0	0	0	0	0	0	0	0	0	0
DAILY	0				0						
WEEKLY		0	0			0	0		0	0	0
EPISODIC				0				0			
P/ANOMALIES:											
Scoliosis											
Kyphosis											
Lordosis		0									
Sh/Depression					R				R		
TRAUMA:											
Whiplash											
School injury											
Later injury					20						
Fractures											
Tendonitis								0		?	
Torn Muscles											
Dislocation											
PATHOLOGY:											
Neurological						0			0		
Bony											
Muscle spasm					0	0					
Medical:											
O–A						?					
R–A											
osteoporosis											
disease											
gout											
R/MOVEMENT											
EMPLOYMENT:	3				20				8		
HSRC	3										
AGE	20				42				28		

SUBJECT	KF				CN				AD	AP	
AREA	UBK	WS	LBK	BUTT	TH	N	RSH	LSH	NONE	LBK	N
TIME (YRS)	11					12	12	12		2	10
CLINICAL						0				0	0
C/O STATIC/	0		0	0	0	0	0	0		0	0
ACTIVE		0									
REFERRED/				0			0	0			0
LOCAL	0	0	0		0	0	0	0		0	0
SUB SEVERITY	6	6	7	4	5	7	7	3		5	4
OBJ SEVERITY	1	2	2	1	1	3	3	2		3	4
CONSTANT/										0	
INTERMITTENT	0	0	0	0	0	0	0	0			0
OCCUPATIONAL	0	0	0	0	0	0	0	0		0	0
DAILY	0				0						
WEEKLY		0				0	0	0			0
EPISODIC			0	0							
P/ANOMALIES:											
Scoliosis										R	
Kyphosis									0		
Lordosis									0		
Sh/Depression										R	
TRAUMA:											
Whiplash						0					15
School injury											
Later injury										2	
Fractures											
Tendonitis		0									
Torn Muscles											
Dislocation											
PATHOLOGY:											
Neurological			0							0	
Bony											
Muscle spasm	0		0				0	0		0	0
Medical:											
O–A											
R–A											
osteoporosis											
disease											
gout											
R/MOVEMENT											
EMPLOYMENT:	11				12				12	10	
HSRC											
AGE	34				30				29	31	

SUBJECT	AK				BO	VM			EL			MN
AREA	N/Ls	N/Rs	LARM	LHP	LBK	N	LBK	TH	N	BHD	LBK	N
TIME (YRS)	–1	–1	–1		–1	16	16	16	5	5		2
CLINICAL	0	0			0	0	0		0		0	
C/O STATIC/	0	0		0	0	0	0		0	0	0	0
ACTIVE			0	0		0	0	0		0		
REFERRED/	0		0					0			0	
LOCAL	0	0		0	0	0	0		0		0	0
SUB SEVERITY	7	4	2	3	2	4	2	2	8	10	10	4
OBJ SEVERITY	3	3	2		2	2	2	2	3	4	3	2
CONSTANT/												
INTERMITTENT	0	0	0	0	0	0	0	0	0	0	0	0
OCCUPATIONAL	0	0	0	0	0	0			0	0	0	0
DAILY	0								0			
WEEKLY		0	0			0		0			0	0
EPISODIC				0	0		0			0		
P/ANOMALIES:												
Scoliosis												
Kyphosis						0						
Lordosis		0			0	0						
Sh/Depression		R			L							
TRAUMA:												
Whiplash	0											
School injury											0	
Later injury												
Fractures												
Tendonitis												
Torn Muscles	S								S			
Dislocation												
PATHOLOGY:												
Neurological	0		0									
Bony												
Muscle spasm	0	0			0	0	0		0	0	0	0
Medical:												
O–A	?					0						
R–A												
osteoporosis						0						
disease								?	?		?	
gout												
R/MOVEMENT	1	1										
EMPLOYMENT:	22				3	16			13			9
HSRC	2				3	–1			3			5
AGE	42				21	38			34			33

SUBJECT	ID	SO	TG	EF	HF			
AREA	LBK	N/shs	N/shs	N	UBK	N/shs	BHD	FHD
TIME (YRS)	–1	–1	–1	7	–1	–1		
CLINICAL		0	0			0		
C/O STATIC/	0	0	0	0	0	0	0	0
ACTIVE								
REFERRED/		0	0	0	0	0	0	
LOCAL	0	0	0	0			0	0
SUB SEVERITY	1	1	2	5	4	4	7	7
OBJ SEVERITY	1	3	3	2	2	3	4	4
CONSTANT/								
INTERMITTENT	0	0	0	0	0	0	0	0
OCCUPATIONAL	0	0	0	0	0	0	0	0
DAILY								
WEEKLY	0	0	0	0	0	0		
EPISODIC							0	0
P/ANOMALIES:								
Scoliosis	R							
Kyphosis								
Lordosis								
Sh/Depression	R	R		R				
TRAUMA:								
Whiplash					3			
School injury			0					
Later injury		2						
Fractures								
Tendonitis								
Torn Muscles								
Dislocation								
PATHOLOGY:								
Neurological					?	0	0	
Bony		0		0				
Muscle spasm	0	0	0	0		0		
Medical:								
O–A								
R–A								
osteoporosis								
disease			D					
gout								
R/MOVEMENT								
EMPLOYMENT:	2	1.5	–1		6			
HSRC	–1	1.5	–1	2	–1			
AGE	22	19	19	21	26			

SUBJECT	CC			JH	JR		
AREA	N	L/HIP	L/WST	N/shs	N/shs	FHD	LBK
TIME (YRS)	10			10	5	5	
CLINICAL	0				0		0
C/O STATIC/	0			0	0	0	0
ACTIVE		0	0				
REFERRED/					0		
LOCAL	0	0	0		0	0	0
SUB SEVERITY	4	4	6	3	7	10	5
OBJ SEVERITY	3		1	1	2	3	2
CONSTANT/							
INTERMITTENT	0	0	0	0	0	0	0
OCCUPATIONAL				0	0		0
DAILY					0		
WEEKLY	0			0		0	0
EPISODIC		0	0				
P/ANOMALIES:							
Scoliosis					0		
Kyphosis							
Lordosis	0						
Sh/Depression	R				R		
TRAUMA:							
Whiplash							
School injury							0
Later injury							
Fractures							
Tendonitis							
Torn Muscles							
Dislocation							
PATHOLOGY:							
Neurological							
Bony						0	
Muscle spasm	0			0	0		0
Medical:							
O–A	0	0	0				
R–A							
osteoporosis							
disease							
gout							
R/MOVEMENT							
EMPLOYMENT:	30			6	3.5		
HSRC	9			5	3.5		
AGE	51			27	22		

SUBJECT	LBP			GS			GP	RR	IP		
AREA	N	LBK	UBK	LBK	N	TH	N	LBK	TH	N	LBK
TIME (YRS)	9	9	9	2	2						
CLINICAL	0	0			0					0	
C/O STATIC/	0		0		0	0	0		0	0	0
ACTIVE	0	0	0	0				0	CIRC		
REFERRED/			0			0					
LOCAL	0	0		0	0		0	0	0	0	0
SUB SEVERITY	8	8	8	8	3	4	5	10	3	3	9
OBJ SEVERITY	4	3		2	2	1	1	1		3	NoEx
CONSTANT/	0										
INTERMITTENT		0	0	0	0	0	0	0	0	0	0
OCCUPATIONAL	0		0	0	0	0	0	0	0	0	
DAILY	0		0								
WEEKLY		0			0		0		0	0	0
EPISODIC						0		0			0
P/ANOMALIES:											
Scoliosis	0										0
Kyphosis							0				
Lordosis	0			0			0				
Sh/Depression	R			R							
TRAUMA:											
Whiplash	9										
School injury											0
Later injury				2		2					
Fractures				0							
Tendonitis											
Torn Muscles			S								
Dislocation											
PATHOLOGY:											
Neurological		0				0					
Bony	0										
Muscle spasm			0	0	0		0	?		0	
Medical:											
O–A	0	0	0		0						0
R–A											
osteoporosis				0	0						
disease											
gout											
R/MOVEMENT											
EMPLOYMENT:				30			13	10	5		
HSRC				15			3	3	5		
AGE	27			56			35	32	27		

SUBJECT	JGS				DM		DZ	HO		JL		
AREA	FHD	N/sh	UBK	LBK	N/sh	LBK	N/shs	LBK	N	N	LBK	TH
TIME (YRS)	L				15	1	2.5	10	L	7		
CLINICAL		0		0	0	0		0		0	0	0
C/O STATIC/	0	0		0	0	0	0	0	0	0		0
ACTIVE			0		0	0					0	
REFERRED/		0	0		0		0		0			CIRC
LOCAL	0	0		0	?	0	0	0	0	0	0	0
SUB SEVERITY	9	5	9	5	5	5	7	4	3	8	9	5
OBJ SEVERITY		2	2	3	4	4	3	2	2	3	?	
CONSTANT/												
INTERMITTENT	0	0	0	0	0	0	0	0	0	0	0	0
OCCUPATIONAL	0	0	0	0	0		0	0	0	0		0
DAILY								0				
WEEKLY	0				0	0	0		0	0	0	0
EPISODIC		0	0	0								
P/ANOMALIES:												
Scoliosis			0									
Kyphosis					0							
Lordosis										0		
Sh/Depression		R			R			R				
TRAUMA:												
Whiplash							0	6	3	3		
School injury					0							
Later injury												
Fractures												
Tendonitis												
Torn Muscles						?	0					
Dislocation												
PATHOLOGY:												
Neurological									?			
Bony										0		
Muscle spasm		0		0	0	0	0	0	0	0	0	
Medical:												
O–A					?				0	0		
R–A												
osteoporosis												
disease												
gout												
R/MOVEMENT												
EMPLOYMENT:	3				1		11	4	27			
HSRC	3				1		2.5	4	8			
AGE	25				29		34	26	55			

SUBJECT	EL		JB	NC	SC		HB
AREA	LBK	TH	None	LBK	LBK	LSH	LBK
TIME (YRS)		now		2	1	L	1
CLINICAL	0	absent		0	0		?
C/O STATIC/	0	0		0			0
ACTIVE				0	0	0	
REFERRED/		CIRC					0
LOCAL	0	0		0	0	0	0
SUB SEVERITY	8	3		4	9	2	4
OBJ SEVERITY	3			2	2	1	?
CONSTANT/				0			
INTERMITTENT	0	0			0	0	0
OCCUPATIONAL	0	0		0			0
DAILY				0			
WEEKLY	0	0				0	0
EPISODIC					0		
P/ANOMALIES:							
Scoliosis	0				0		
Kyphosis			0				
Lordosis			0	0			0
Sh/Depression	R						0
TRAUMA:							
Whiplash							
School injury						0	
Later injury				0			
Fractures							
Tendonitis							
Torn Muscles							
Dislocation							
PATHOLOGY:							
Neurological							
Bony				0			
Muscle spasm	0				0		0
Medical:							
O–A							
R–A							
osteoporosis							
disease							
gout							
R/MOVEMENT							
EMPLOYMENT:	7		8	20			7
HSRC	3		2	9			
AGE	27		30	42	30		29

SUBJECT	KH			GH		MV	
AREA	N/shs	LBK	TH	N	LBK	N	LBK
TIME (YRS)		10		5			
CLINICAL	0	0		0		0	0
C/O STATIC/	0	0	0	0	0	0	0
ACTIVE				0	0		0
REFERRED/			CIRC	0	0	0	
LOCAL	0	0	0	0	0		0
SUB SEVERITY	8	6	3	10	10	8	6
OBJ SEVERITY	1	0		4	0	3	2
CONSTANT/							
INTERMITTENT	0	0	0	0	0	0	0
OCCUPATIONAL	0	0	0	0	0	0	
DAILY							
WEEKLY	0	0	0	0		0	0
EPISODIC					0		
P/ANOMALIES:							
Scoliosis	0			0			
Kyphosis						0	
Lordosis	0						
Sh/Depression				R			
TRAUMA:							
Whiplash							
School injury				45			
Later injury							0
Fractures							0
Tendonitis							
Torn Muscles							
Dislocation							
PATHOLOGY:							
Neurological	?						
Bony		0				0	
Muscle spasm				0		0	0
Medical:							
O–A				0			
R–A							
osteoporosis							
disease							
gout							
R/MOVEMENT		0					
EMPLOYMENT:	21			25		4	
HSRC	9			4		4	
AGE	41			50		28	

APPENDIX 7. ANTHROPOMETRIC AND WORKSTATION MEASUREMENTS

DATA–TYPISTS

MEASUREMENT	LB	AC	MC	KF	CN	AD	AP
ANTHROPOMETRIC:							
age	20	42	28	34	30	29	31
sex	F	F	F	F	F	F	F
weight	60	70	69	63	63	55	63
height (w/o shoes)	1580	1740	1540	1553	1680	1620	1660
elbow height	647	659	680	658	617	606	678
knee height	542	618	558	540	549	559	561
popliteal height	422	491	408	411	423	442	426
buttock–knee length	570	659	578	579	610	594	614
buttock–popliteal length	451	532	447	480	489	456	472
hip breadth	400	420	436	424	411	417	406
WORKSTATION:							
upper arm abduction	12	17	27	18	12	31	18
forearm angle	17	11	4	15	14	16	22
elbow angle	83	95	85	90	92	90	90
hip angle	95	96	98	93	97	97	105
head inclination	10	25	30	25	22	13	22
neck–head angle	35	29	42	40	33	45	42
thigh clearance	0	30	20	65	15	90	55
seated eye height	1140	1235	1090	1100	1170	1090	1113
eye–screen distance	460	770		640	750	750	780
eye–screen inclination	2	30		29	30	26	29
eye–document distance	570	595	550	530	630	560	570
eye–document inclination	45	55	46	41	42	37	40
eye–document deviation	40	8	45	30	20	10	10
screen tilt	5	0	0	0	0	0	
backrest angle	15	5	15	15	5	15	15
seat tilt	5	4	10	10	4	6	10
screen height	1120	835	756	835	790	790	790
keyboard height	795	716	720	716	716	716	716
desktop height	765	695	691	695	695	695	695
backrest height	920	892	880	880	840	820	860
armrest height							
seat height	495	510	475	475	510	440	460
seat depth	430	400	420	420	400	430	420
desktop thickness	140	83	83	83	83	83	83
keyboard thickness	30	21	25	21	21	21	21
desk–edge to keyboard	120	70	31	70	70	70	70

note: all the measurements are in millimetres or degrees except for age, sex and weight.

DATA–TYPISTS	MEAN	SD	MAX	MIN	RANGE
ANTHROPOMETRIC:					
age	32.33	5.16	42	28	14
sex					
weight	64.05	5.56	70	55	15
height (w/o shoes)	1632.17	76.94	1740	1540	200
eye height	1174.33	36.46	1235	1145	90
elbow height	649.67	31.16	680	606	74
knee height	564.17	27.52	618	540	78
popliteal height	433.50	30.66	491	408	83
elbow–fingertip	440.00	27.83	483	411	72
buttock–knee	605.67	30.15	659	578	81
buttock–popliteal	479.33	30.04	532	447	85
hip breadth	419.00	10.51	436	406	30
WORKSTATION:					
upper arm abduction	20.50	7.06	31	12	19
forearm angle	13.67	5.96	22	4	18
elbow angle	90.33	3.27	95	85	10
hip angle	97.67	3.98	105	93	12
head inclination	22.83	5.64	30	13	17
neck–head angle	38.50	6.16	45	29	16
thigh clearance	45.83	29.23	90	15	75
seated eye height	1133.00	58.24	1235	1090	145
eye–screen distance	738.00	56.30	780	640	140
eye–screen inclination	28.80	1.64	30	26	4
eye–document distance	572.50	35.46	630	530	100
eye–document inclination	43.50	6.35	55	37	18
eye–document deviation	20.50	14.61	45	8	37
screen tilt	0	0	0	0	0
backrest angle	11.67	5.16	15	5	10
seat tilt	7.33	3.01	10	4	6
screen height	799.33	30.61	835	756	79
keyboard height	716.67	1.63	720	716	4
desktop height	694.33	1.63	695	691	4
backrest height	862.00	27.57	892	820	72
armrest height					
seat height	478.33	27.69	510	440	70
seat depth	415.00	12.25	430	400	30
seat width	455.00	17.32	470	430	40
backrest width	400.00	15.49	430	390	40
desktop thickness	83.00	0	83	83	0
keyboard thickness	21.67	1.63	25	21	4
desk–edge to keybd.	63.50	15.92	70	31	39

TYPISTS

MEASUREMENT	MN	AK	BO	VM	EL
ANTHROPOMETRIC:					
age	33	42	21	38	34
sex	F	F	F	F	F
weight	58	59	50	64	63
height (w/o shoes)	1590	1710	1520	1640	1630
eye height	1162	1189	1126	1147	1124
elbow height	680	640	647	633	596
knee height	559	568	533	561	570
popliteal height	427	455	412	418	434
elbow–fingertip	405	456	400	423	440
buttock–knee length	583	637	555	639	591
buttock–popliteal	455	485	441	505	467
hip breadth	393	414	380	419	434
WORKSTATION:					
upper arm abduction	13	12	19	20	12
forearm angle	8	10	7	10	19
elbow angle	93	80	95	90	82
hip angle	96	91	95	88	90
head inclination	18	13	18	16	13
neck–head angle	35	35	40	55	25
thigh clearance	65	90	30	20	40
seated eye height	1150	1217	1150	1170	1140
eye–screen distance	720	660	720	490	780
eye–screen inclination	14	20	12	18	13
eye–document distance	600	590	640	570	610
eye–document inclination	49	53	42	60	40
eye–document deviation	55	30	44	32	48
screen tilt	22	23	22	20	21
backrest angle	5	4	10	8	5
seat tilt	3	6	4	6	4
screen height	1020	1020	1020	1033	1020
keyboard height	775	775	775	785	775
desktop height	745	745	745	745	745
backrest height	870	840	950	960	830
armrest height					
seat height	497	550	570	550	510
seat depth	400	430	430	400	400
seat width	440	410	460	430	430
backrest width	400	380	450	380	380
desktop thickness	80	22	80	80	80
keyboard thickness	30	30	30	40	30
desk–edge to keyboard	25	38	40	82	0

TYPISTS	MEAN	SD	MAX	MIN	RANGE
ANTHROPOMETRIC:					
age	33.60	7.89	42	21	21
sex					
weight	59.06	5.76	64.50	50	14.50
height (w/o shoes)	1618.00	69.79	1710	1520	190
eye height	1149.60	27.04	1189	1124	65
elbow height	639.20	30.13	680	596	84
knee height	558.20	14.82	570	533	37
popliteal height	429.20	16.69	455	412	43
elbow–fingertip	424.80	23.53	456	400	56
buttock–knee	601.00	36.33	639	555	84
buttock–popliteal	470.60	25.12	505	441	64
hip breadth	408.00	21.46	434	380	54
WORKSTATION:					
upper arm abduction	15.20	3.96	20	12	8
forearm angle	10.80	4.76	19	7	12
elbow angle	88.00	6.67	95	80	15
hip angle	92.00	3.39	96	88	8
head inclination	15.60	2.51	18	13	5
neck–head angle	38.00	10.95	55	2	30
thigh clearance	49.00	28.37	90	0	70
seated eye height	1165.40	30.84	1217	1140	77
eye–screen distance	674.00	111.27	780	490	290
eye–screen inclination	15.40	3.44	20	12	8
eye–document distance	602.00	25.88	640	570	7
eye–document inclination	48.80	8.17	60	40	0
eye–document deviation	41.80	10.64	55	30	25
screen tilt	21.60	1.14	23	20	3
backrest angle	6.40	2.51	10	4	6
seat tilt	4.60	1.34	6	3	3
screen height	1022.60	5.81	1033	1020	13
keyboard height	777.00	4.47	785	775	10
desktop height	745.00	0	745	745	0
backrest height	890.00	61.24	960	830	130
armrest height					
seat height	535.40	30.59	570	497	73
seat depth	412.00	16.43	430	400	30
seat width	434.00	18.17	460	410	50
backrest width	398.00	30.33	450	380	70
desktop thickness	68.40	25.94	80	22	58
keyboard thickness	32.00	4.47	40	30	10
desk–edge to keyboard	37.00	29.78	82	0	82

PROGRAMMERS MEASUREMENT	ID	SO	TG	EF	HF	CC	JH	JR
ANTHROPOMETRIC:								
age	22	19	19	21	26	51	27	22
sex	F	F	F	F	F	F	F	F
weight	47	51	53	70	73	63	57	54
height (w/o shoes)	1590	1575	1620	1660	1690	1650	1605	1600
elbow height	650	654	641	679	640	604	670	607
knee height	511	527	550	548	596	568	542	533
popliteal height	427	421	437	415	440	432	430	417
buttock-knee	553	565	586	598	597	615	566	580
buttock-popliteal	434	446	476	452	480	500	444	447
hip breadth	383	366	382	445	470	392	430	409
WORKSTATION:								
upper arm abduction	32	30	30	27	18	24	24	24
forearm angle	2	2	2	0	0	15	0	29
elbow angle	120	133	140	152	130	93	158	94
hip angle	90	98	100	93	87	110	92	113
head inclination	15	20	18	20	10	9	12	15
neck-head angle	40	35	35	35	40	44	34	30
thigh clearance	110	150	110	125	150	40	35	25
seated eye height	1115	1100	1095	1140	1160	1160	1140	1120
eye-screen dist.	825	770	780	690	740	690	690	650
eye-screen incln.	7	5	10	10	8	11	18	8
eye-document dist.	550	400	470	550	420	430	450	580
eye-document incln.	50	55	50	46	60	73	62	35
eye-document devn.	55	0	14	35	40	90	25	65
screen tilt	5	1	0	3	5	11	5	1
backrest angle	15	17	9	30	12	12	11	18
seat tilt	5	6	1	6	2	3	5	5
screen height	1065	1025	1025	1025	1050	1060	940	1025
keyboard height	735	805	805	790	805	788	780	787
desktop height	700	760	760	745	765	748	742	752
backrest height	780	873	890	860	870	997	880	890
armrest height		644	645	685	720	725	650	660
seat height	430	483	470	485	480	500	470	500
seat depth	440	470	470	470	450	460	470	475
desktop thickness	23	22	22	22	22	114	22	140
keyboard thickness	40	45	45	45	40	40	30	35
desk-edge to keybd	150	140	230	300	155	40	290	75

PROGRAMMERS	MEAN	SD	MAX	MIN	RANGE
ANTHROPOMETRIC:					
age	26.43	11.28	51	19	32
sex					
weight	60.23	8.80	73	51	22
height (w/o shoes)	1628.57	39.87	1690	1575	115
elbow height	642.14	28.78	679	604	75
knee height	552.00	23.44	596	527	69
popliteal height	427.43	9.85	440	415	25
buttock–knee	586.71	18.16	615	565	50
buttock–popliteal	463.57	21.80	500	444	56
hip breadth	413.43	36.94	470	366	104
WORKSTATION:					
upper arm abduction	25.29	4.19	30	18	12
forearm angle	6.86	11.14	29	0	29
elbow angle	128.57	25.91	158	93	65
hip angle	99.00	9.56	113	87	26
head inclination	14.86	4.63	20	9	11
neck–head angle	36.14	4.53	44	30	14
thigh clearance	90.71	55.63	150	25	125
seated eye height	1130.71	26.52	1160	1095	65
eye–screen distance	715.71	48.26	780	650	130
eye–screen inclination	10.00	4.04	18	5	13
eye–document distance	471.43	68.17	580	400	180
eye–document inclination	54.43	12.26	73	35	38
eye–document deviation	38.43	30.64	90	0	90
screen tilt	3.71	3.77	11	0	11
backrest angle	15.57	7.14	30	9	21
seat tilt	4.00	2.00	6	1	5
screen height	1021.43	38.70	1060	940	120
keyboard height 2nd row	794.29	10.48	805	780	25
desktop height	753.14	8.69	765	742	23
backrest height	894.29	46.56	997	860	137
armrest height	675.57	34.96	725	644	81
seat height	484.00	12.40	500	470	30
seat depth	466.43	8.52	475	450	25
desktop thickness	52.00	51.78	140	22	118
keyboard thickness	40.00	5.77	45	30	15
desk–edge to keyboard	175.71	101.42	300	40	260

RESEARCHERS (TERMINALS)

MEASUREMENT	GS	GP	HO	JB	NC	HB	KH	GH
ANTHROPOMETRIC:								
age	56	35	26	30	42	29	41	50
sex	F	F	M	M	M	F	M	F
weight	83	55	66	76	80	73	88	71
height (w/o shoes)	1680	1640	1720	1760	1850	1650	1845	1660
elbow height	634	623	625	661	706	674	666	660
knee height	575	561	579	574	588	552	604	564
popliteal height	431	444	452	451	461	408	459	431
buttock–knee	640	595	620	600	628	612	637	606
buttock–popliteal	505	461	465	477	505	429	489	478
hip breadth	448	421	398	399	386	499	431	433
WORKSTATION:								
upper arm abduction	18	19	15	20	10	22	11	18
forearm angle	14	27	30	12	10	20	(+)7	10
elbow angle	87	75	75	105	100	93	94	95
hip angle	90	99	100	90	96	90	99	135
head inclination	11	25	20	15	15	14	10	17
neck–head angle	40	36	34	50	50	30	34	30
thigh clearance	30	63	22	75	30	20	0	70
seated eye height	1204	1125	1140	1120	1220	1130	1360	1227
eye–screen distance	500	40	670	880	720	640	700	660
eye–screen inclination	14	9	16	15	11	9	20	24
eye–document distance	480	50	650	430	730	460	690	670
eye–document inclination	50	43	40	60	36	57	55	40
eye–document deviation	0	74	0	0	43	40	0	30
screen tilt	7	7	15	10	0	0	0	3
backrest angle	11	11	12	15	20	0	4	6
seat tilt	5	3	6	5	6	4	1	5
screen height	1080	180	975	1010	1070	1070	1120	990
keyboard height	780	80	785	775	830	802	845	790
desktop height	750	50	745	745	750	765	760	750
backrest height	870	20	845	870	920	805	940	890
armrest height	680	740						
seat height	510	55	530	450	540	460	570	485
seat depth	470	00	400	430	470	430	400	370
desktop thickness	115	115	115	80	120	120	123	115
keyboard thickness	30	30	40	30	80	37	85	40
desk–edge to keyboard	–5	–30	45	240	–40	100	0	25

RESEARCHERS (VDT)	MEAN	SD	MAX	MIN	RANGE
ANTHROPOMETRIC:					
age	38.63	10.61	56	26	30
sex					
weight	74.09	10.42	88	55	33
height (w/o shoes)	1725.63	84.83	1850	1640	210
elbow height	656.13	28.03	706	623	83
knee height	574.63	16.35	604	552	52
popliteal height	442.13	17.86	461	408	53
buttock–knee	617.25	16.81	640	595	45
buttock–popliteal	476.13	25.10	505	429	76
hip breadth	426.88	35.89	499	386	113
WORKSTATION:					
upper arm abduction	16.63	4.27	22	10	12
forearm angle	–14.50	11.56	7	–30	37
elbow angle	90.50	10.90	105	75	30
hip angle	99.88	14.85	135	90	45
head inclination	15.88	4.85	25	10	15
neck–head angle	38.00	8.07	50	30	20
thigh clearance	38.75	27.16	75	0	75
seated eye height	1190.75	81.58	1360	1120	240
eye–screen distance	663.75	115.87	880	500	380
eye–screen inclination	14.75	5.28	24	9	15
eye–document distance	582.50	116.71	730	430	300
eye–document inclination	47.63	9.05	60	36	24
eye–document deviation	23.38	27.91	74	0	74
screen tilt	5.25	5.50	15	0	15
backrest angle	9.88	6.36	20	0	20
seat tilt	4.38	1.69	6	1	5
screen height	1049.38	51.16	1120	975	145
keyboard height	798.38	25.80	845	775	70
desktop height	751.88	7.04	765	745	20
backrest height	870.00	46.52	940	805	135
armrest height	710.00	42.43	740	680	60
seat height	500.00	44.48	570	450	120
seat depth	421.25	35.63	470	370	100
desktop thickness	112.88	13.64	123	80	43
keyboard thickness	46.50	22.67	85	30	55
desk–edge to keyboard	41.88	91.61	240	–40	280

RESEARCHERS (DESK)

MEASUREMENT	GS	GP	HO	JB	NC	HB	KH
ANTHROPOMETRIC:							
age	56	35	26	30	42	29	41
sex	F	F	M	M	M	F	M
weight	83.50	55	66	76	80	73	88
height (w/o shoes)	1680	1640	1720	1760	1850	1650	1845
elbow height	634	623	625	661	706	674	666
knee height	575	561	579	574	588	552	604•
popliteal height	431	444	452	451	461	408	459
buttock–knee	640	595	620	600	628	612	637
buttock–popliteal	505	461	465	477	505	429	489
hip breadth	448	421	398	399	386	499	431
WORKSTATION:							
upper arm abduction	35	34	60	30	20	50	30
forearm angle	–8	–14	–40	0	0	0	0
elbow angle	130	68	90	100	90	90	90
hip angle	90	88	100	90	92	83	85
head inclination	14	55	31	50	69	33	50
neck–head angle	34	52	38	70	94	37	72
thigh clearance	130	114	160	137	13	140	115
seated eye height	1180	1145	1184	1120	1160	1100	1210
eye–screen distance							
eye–screen inclination							
eye–document distance	590	380	430	430	390	430	420
eye–document inclination	64	62	60	80	70	53	65
eye–document deviation							
screen tilt							
backrest angle	9	14	20	19	11	15	21
seat tilt	5	5	10	6	3	6	8
screen height							
keyboard height							
desktop height	740	745	760	745	765	765	745
backrest height	910	890	850	870	900	870	890
armrest height	680	670	635	660	730	675	700
seat height	500	500	470	500	530	505	528
seat depth	470	460	460	480	460	470	480
desktop thickness	22	22	22	20	22	20	22
keyboard thickness							
desk–edge to keyboard							

RESEARCHERS (DESK) continued

MEASUREMENT	RR	IP	JGS	DM	DZ	JL	EL	SC
ANTHROPOMETRIC:								
age	32	27	25	29	34	55	27	30
sex	F	M	F	M	F	F	F	M
weight	59	78	60.50	79	66	66	64.50	101
height (w/o shoes)	1730	1780	1720	1820	1780	1730	1720	1960
elbow height	655	674	687	694	629	648	638	734
knee height	595	593	556	591	586	593	581	621
popliteal height	470	471	441	473	465	468	442	485
buttock–knee	497	629	617	618	646	651	647	701
buttock–popliteal	494	508	488	484	515	527	485	547
hip breadth	413	390	411	393	413	437	439	441
WORKSTATION:								
upper arm abduction	7	65	36	20	30	14	30	27
forearm angle	–11	0	10	–14	–20	0	0	–16
elbow angle	80	79	89	104	90	80	107	90
hip angle	75	80	82	87	80	85	102	120
head inclination	50	48	30	37	33	60	39	30
neck–head angle	80	74	41	71	65	80	43	42
thigh clearance	110	100	130	130	130	30	105	120
seated eye height	1142	1190	1100	1148	1157	1210	1120	1135
eye–screen distance								
eye–screen incln.								
eye–document distance	450	460	335	450	440	420	480	440
eye–document inclination	80	65	70	55	75	65	51	65
eye–document deviation	0							
screen tilt								
backrest angle	12	10	10	20	16	5	15	10
seat tilt	5	5	5	10	4	9	4	5
screen height								
keyboard height								
desktop height	745	765	745	760	745	740	745	745
backrest height	1070	890	880	850	870	940	890	870
armrest height	675	660	670	660	640	710	655	
seat height	510	500	500	500	460	550	500	480
seat depth	430	460	480	490	470	390	440	460
desktop thickness	22	22	20	20	22	22	22	22
keyboard thickness								
desk–edge to keyboard								

RESEARCHERS (DESK)	MEAN	SD	MAX	MIN	RANGE
ANTHROPOMETRIC:					
age	34.53	9.87	56	25	31
sex					
weight	73.03	12.35	101	55	46
height (w/o shoes)	1759.00	84.18	1960	1640	320
elbow height	663.20	32.33	734	623	111
knee height	583.27	18.25	621	552	69
popliteal height	454.73	19.50	485	408	77
buttock–knee	622.53	43.01	701	497	204
buttock–popliteal	491.93	28.53	547	429	118
hip breadth	421.27	29.40	499	386	113
WORKSTATION:					
upper arm abduct	32.53	15.81	65	7	58
forearm angle	–7.53	12.19	10	–40	50
elbow angle	91.80	14.50	130	68	62
hip angle	89.27	11.15	120	75	45
head inclination	41.93	14.24	69	14	55
neck–head angle	59.53	19.39	94	34	60
thigh clearance	110.93	39.45	160	13	147
seated eye height	1153.40	35.81	1210	1100	110
eye–screen distance					
eye–screen inclination					
eye–document distance	436.33	55.24	590	335	255
eye–document inclination	65.33	8.76	80	51	29
eye–document deviation					
screen tilt					
backrest angle	13.80	4.77	21	5	16
seat tilt	6.00	2.20	10	3	7
screen height					
keyboard height					
desktop height	750.33	9.54	765	740	25
backrest height	896.00	53.29	1070	850	220
armrest height	672.86	26.00	730	635	95
seat height	502.20	22.58	550	460	90
seat depth	460.00	24.78	490	390	100
desktop thickness	21.47	0.92	22	20	2
keyboard thickness					
desk–edge to keyboard					

APPENDIX 8. ANTHROPOMETRIC MEASUREMENT PROTOCOL

PROTOCOL FOR TAKING MEASUREMENTS

It is probably best if one person takes the measurements whilst the other writes down the results.

Fill in date and time. While obtaining height and weight of subject, ask for age.

The seated anthropometric measurements should be taken with the subject wearing shoes. Three instruments are employed:

A long rule on a high stand (A)
a short rule on a low stand (B)
and calipers (C),
which have been cunningly disguised as a couple of T–squares.

The long rule starts from 700mm so all figures read on this must have 700mm added to them.

The stool should be adjusted so that the seat height corresponds roughly to a position just below the popliteal crease. Eye height should be measured with 'A' placed to the righthand side. The T–square can be brought infront of the subject's nose and the top edge adjusted until it bisects the eyes. The figure can be read off directly but a check can be made by adding the figure to 700mm, which is the height at which the long rule starts.

Elbow height should be measured with 'B' placed to the left of the subject. Again the top edge of the horizontal rule is used to determine the figure.

Knee height measurement requires the stand to be brought forward to an appropriate position where the <u>lower</u> edge of the rule is used.

'B' is again used for measuring popliteal height with the <u>top</u> edge of the rule.

'C' is not a very satisfactory device and requires a lot of care to be used accurately. This is compounded by the fact that, although the inside edge of the adjustable rule is always being used for measurement, the actual reading must be taken from a mark on the rule slightly inside the edge because thee T of the T–square does not begin at zero but some 5mm before zero. Care must be taken to remember this when taking readings (it might be an idea for each person to remind each other of this anomaly in the initial stages).

Elbow–fingertip length is taken from the elbow to the longest finger.

The buttock–knee and buttock–popliteal lengths can be read from the font edge of the backrest, making sure that the buttocks are touching that edge.

Hip breadth can be read from behind the stool.

SUMMARY:	eye height	(A)	
	elbow height	(B)	
	knee height	(B)	
	popliteal height	(B)	
	elbow–fingertip	(C)	
	buttock–knee	(C)	
	buttock–popliteal	(C)	or Tape Measure
	hip breadth	(C)	

PROTOCOL FOR MEASURING WORKSTATION DIMENSIONS

Several subjects will work at more than one workstation. The dimensions of such other workstations should also be measured, together with a note on the proportion of time normally spent at each.

Several instruments are used: the long rule (A), the short rule (B), calipers (C), an angle–measuring device (D), a protractor with string attached (E) and a tape measure (TM).

Measures are first taken with the subject in situ:

Upper arm abduction is the angle (using E) between the vertical line starting from the cronium (shoulder joint) reaching down the side of the body and from the acronium reaching to the epicondylus (elbow joint).

Forearm angle (using E) is the angle between the elbow–lower arm and the horizontal, taken from the elbow joint.

Elbow angle (using D or E) is the angle between the upper and lower arm, taken from the elbow joint.

Hip angle (using D) takes as its three reference points the knee, the hip joint and the shoulder joint.

Head inclination (using E or D) compares the line from the ear to the middle of the nose with the horizontal plane.

Neck–head angle (using E) compares the line from the seventh cervical vertebra at the top of the neck and the ear with the vertical plane.

Thigh clearance (using a TM) measures the vertical distance between the thigh and the underside of the desk.

At this stage, the long rule and stand are placed beside the subject so that the horizontal rule can be adjusted to eye height. The subject can then withdraw before further measurements are taken:

Eye–screen distance (using TM) is taken from the stand to the middle of the screen.

Eye–screen inclination (using E) is the angle from the horizontal to the middle of the screen taken from the stand.

Eye–document distance (using TM) is taken from the stand to the middle of the document.

Eye–document inclination (using E) is the angle from the horizontal to the middle of the document taken from the stand.

Screen–document deviation (using E) is the angle between the line taken from the stand to the middle of the screen and the line to the middle of the document.

Screen tilt (using D) is the angle of the screen from the vertical.

Backrest angle (using D) is similar to the above).

Seat tilt (using D upside down) compares the seat line to the horizontal plane.

Screen height (using A) simply requires the stand to be moved forward so the horizontal rule can be used to measure the height of the middle of the screen.

Keyboard height (of the home row) is measured similarly but using the bottom edge of the rule.

Desktop height again uses A.

Backrest height uses A.

Stand A is now replaced by stand B to measure armrest height with the lower edge of the horizontal rule.

Seat height is measured similarly.

Seat depth (using TM) must be measured taking into consideration the position of the backrest and how this determines the 'effective' depth.

Seat width (using TM) is taken from the extreme points.

Desktop thickness (using TM) is taken from the desk surface downwards to include all support under the desktop.

Keyboard thickness (using TM) from desk surface to home (second) row.

Desk–edge to keyboard (using TM).

SUMMARY:

upper arm abduction	(E)	forearm angle	(E)
elbow angle	(D or E)	hip angle	(D or E)
head inclination	(D or E)	neck–head angle	(E)
thigh clearance	(TM)	eye–screen distance	(TM)
eye–screen inclination	(E)	eye–document distance	(TM)
eye–document inclination	(E)	screen–document deviation	(E)
screen tilt	(D)	backrest angle	(E)
seat tilt	(D upside down)	seat height	(A)
keyboard height	(A)	desktop height	(A)
backrest height	(A)	armrest height	(B)
seat height	(B)	seat depth	(TM)
seat width	(TM)	backrest width	(TM)
desktop thickness	(TM)	keyboard thickness	(TM)
desk–edge to keyboard	(TM)		

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Other addresses

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Hoofkantoor

Privaatsak X41, Pretoria 0001
Republiek van Suid-Afrika
Telegramme RAGEN
Telefoon (012) 202 9111
Teleks 3 20893 SA
Faks (012) 265362

Ander adresse

Nasionale Instituut vir Personeelnavorsing (NIPN)

Posbus 32410, Braamfontein 2017
Republiek van Suid-Afrika
Telegramme NAVORSPERS
Telefoon (011) 339 4451
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Faks (011) 403 2353

Wes-Kaaplandse Streekkantoor

Privaatsak X5, Roggebaai 8012
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Posbus 17302, Congella 4013
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