HSE
Health & Safety
Executive

Ergonomics of using a mouse or other non-keyboard input device

Prepared by the **University of Surrey & Loughborough University**
for the Health and Safety Executive 2002

RESEARCH REPORT 045

HSE
Health & Safety
Executive

Ergonomics of using a mouse or other non-keyboard input device

Valerie Woods,[1] Sarah Hastings,[2]
Professor Peter Buckle[1] &
Dr Roger Haslam[2]

[1]Robens Centre for Health Ergonomics
European Institute for Health & Medical Sciences
University of Surrey
Guildford
GU2 7TE

[2]Health & Safety Ergonomics Unit
Department of Human Sciences
Loughborough University
Loughborough
Leicestershire
LE11 3TU

Findings from a two-year study investigating health problems associated with use of non-keyboard input devices (NKID) are presented. The research used a combination of methods to determine the extent to which different NKID are currently in use, how they are used and problems that result. Evidence was collected through a literature review; questionnaire survey of 128 IT and health and safety managers; workplace assessments involving interviews and observation with 45 users across 9 different companies; a questionnaire survey of 848 users (3500 questionnaires issued, 24% response rate); and laboratory work including an expert assessment of different devices, a laboratory trial comparing traditional and L-shaped desks with three different arm support conditions, and a case study investigating touch screen use.

This report and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.

HSE BOOKS

First published 2002

ISBN 0 7176 2162 6

SUMMARY

What were the aims of the study?

The aims of the study were to:

1. Determine the extent to which different non-keyboard input devices (NKID) are used

2. Document patterns of NKID use i.e. tasks and proportion of time for which they are used

3. Describe the range of workstation configurations occurring in practice

4. Identify the extent of individual variation among NKID users in their manner of device operation

5. Measure prevalence of musculoskeletal and other complaints associated with NKID use

6. Examine differences in user behaviour when operating NKID that may have resulted from prior musculoskeletal problems

7. Identify desirable and undesirable aspects of NKID in respect of user comfort and health

8. Collate and validate best practice advice concerning use of NKID

9. Provide guidance, where feasible, on the suitability of different NKID for generic tasks (e.g. word processing, CAD)

How was the study carried out?

- Through a review of the literature relevant to the health of NKID users
(*Stage 1: Literature review*)

- Through a questionnaire survey of over 100 health and safety and information technology (IT) managers
(*Stage 2: Manager questionnaire survey)*

- By undertaking ergonomics work system assessments at nine locations, with 45 NKID users
(*Stage 3: Workplace assessments*)

- Through a questionnaire survey of 850 NKID users
(*Stage 4: User questionnaire survey*)

- By conducting a laboratory study comprising an expert assessment of a variety of NKID devices, a user trial of mouse use and workstation configuration, and a case study investigating touch screen use
(*Stage 5: Laboratory assessment)*

- Through discussion with experts
  (*Stage 6: Expert meeting on current NKID issues*)

- By comparing the results of each part of the study and identifying areas of common agreement

Extent of NKID use (aim 1)

- The mouse is by far the most common device used with computers at a desk. The mouse was used with desktop computers at 97% of organisations responding to the manager survey (stage 2) and with laptops at 64%. It was evident from the workplace assessment interviews (stage 3) and user questionnaire responses (stage 4) that the majority (90%) use a mouse on a daily basis, operating the device with their right hand

- Other devices are used to a small extent. Trackballs were used with desktop computers at 20% of organisations participating in the manager survey. Touchpads and trackballs were used with laptops at 31% and 28% of organisations respectively. 13% of the workplace assessment interviewees used trackballs or a joystick mouse, 7% used touchscreens and touchpads. Small percentages of user questionnaire respondents use devices other than the mouse, e.g. trackball (4%) and touchscreen (3%)

- The main devices in use were Microsoft, IBM, Compaq and Logitech mice with 2 buttons (67% of workplace assessment interviewees and 85% of user questionnaire respondents) although 3-button mice were also quite common (20% of workplace assessment interviewees and 10% of user questionnaire respondents)

Patterns of NKID use (aim 2)

- Information collected by the manager survey, workplace assessment interviews and user questionnaire survey (stages 2-4) indicated that most NKID use occurs in conjunction with word processing, reading or sending email, working with spreadsheets, accessing databases, data entry and information searching (e.g. Internet search)

- The workplace assessments and user questionnaire indicated that a large percentage of daily work time was spent on the computer, 6 hours on average. The mean percentage of total work time that workplace assessment interviewees perceived they spent using an input device was 64%

- The majority of workplace assessment interviewees and user questionnaire respondents considered themselves to be regular users of the mouse and touchscreen. Regularly was defined as moving between the keyboard and input device when carrying out a task, such as the movements required when word processing. The majority of joystick mouse, trackball and CAD tablet users indicated 'continual' as their intensity of use. Continual was defined as very intense usage, where the hand was on the device the majority of time during the computer task (e.g. searching websites). Some computer pen and touchpad users considered themselves intensive users, while others thought their use was regular

NKID workstation configuration (aim 3)

- Many (67%) workplace assessment interviewees (stage 3) and user questionnaire respondents (stage 4) had L-shaped desks. The majority of user questionnaire respondents (55%) had L-shaped desks with the computer positioned in the deep curve of the desk and the NKID located to the right hand side of the keyboard. This configuration means the forearm has more available support from the desk when using the NKID than at a traditional rectangular desk

- Some 20% of workplace assessment interviewees and 12% of user questionnaire respondents had L-shaped desks but with their computer located on the narrow part of the desk

- 33% of workplace assessment interviewees and 27% of user questionnaire respondents had a traditional rectangular straight edged desk

- The laboratory user trial (stage 5) examined two desk shapes with different arm support conditions. It was found that:

    - subjects rated the L-shaped desk as most comfortable and preferred to have their forearm fully supported on the desk while using NKID
    - least effort was reported by subjects when they worked at the L-shaped desk with the forearm fully supported
    - muscle activity was less when the user had the arm fully supported on the desk

- The majority of workplace and user questionnaire respondents, including left handed users, had their input device positioned to the right of the keyboard

- Over 30% of people worked at more than one workstation (44% workplace assessment interviewees and 32% user questionnaire respondents)

- A significant number of users (44% workplace assessment interviewees; 24% user questionnaire respondents) worked with a wrist rest when using the computer and over 10% used support when using NKID e.g. gel pad built into mouse mat (11% of workplace assessment interviewees and 13% of user questionnaire respondents)

Individual variation in NKID operation (aim 4)

- Variation in how NKID are used to conduct standard tasks was noted during the workplace assessments (stage 3) and followed up in the user questionnaire (stage 4). Respondents were asked to report how they carried out common tasks e.g. closing and opening files, cutting, pasting and highlighting text

- Relatively few respondents use keyboard shortcuts to carry out these tasks (e.g. using 'Ctrl+X' to cut). The shortcut keys are used most extensively for common tasks such as cutting and pasting

- Pull down menus at the top of the screen and icons at the top of the screen on the menu bar are used more extensively. Device buttons (used to activate menus without the mouse travelling to the top of the screen) are used by around one third of respondents

- These findings illustrate a reliance on NKID to perform tasks that are frequent elements of computer work. They also indicate that the hand is often moving the NKID (e.g. moving the cursor to the top of the screen to press an icon) as opposed to operating the device in a stationary position to activate menus

What are the problems (aim 5)?

Musculoskeletal pain or discomfort from all causes

- 85% of workplace assessment interviewees (stage 3) and 65% of user questionnaire respondents (stage 4) reported muscular aches, pain or discomfort in the 12 months prior to the interview. Approximately 40% of both samples reported problems in the last 7 days

- Information collected by survey stages of the research indicated that the main body locations of concern were:

  - lower back
  - neck
  - right shoulder
  - right wrist and hand

- The prevalence of musculoskeletal pain or discomfort in the user questionnaire survey was generally less than for a Nordic reference sample with the exception of the upper back

- A large number of users (67% of workplace assessment interviewees and 37% of user questionnaire respondents) thought their aches and pains were related to things they do, or equipment used, at work (e.g. using the mouse for long periods, long duration and intensive typing, sitting in same position most of day, poor chairs, workstation set-up)

- 24% of workplace assessment interviewees and 25% of user questionnaire respondents thought their aches and pains were related to things they do away from work (e.g. sport, driving, gardening, carrying heavy loads)

- 19% of those manager survey respondents able to provide sickness absence information (stage 2) reported absence as a result of neck, shoulder and arm pain in the last 12 months. 24% of workplace assessment interviewees had been absent from work as a result of pain or discomfort. 9% of user questionnaire respondents had been absent from work in the last year as a result of aches and pains

Musculoskeletal pain or discomfort attributed to NKID

- 20% of organisations in the managers survey (stage 2) indicated having received reports of neck, shoulder and arm pain associated with use of NKID

- 42% of mouse users in the workplace assessment sample (stage 3) reported pain or discomfort associated with use of their device

- 17% of user questionnaire respondents (stage 4) had pain or discomfort that they thought was related to mouse use; a further 2% reported pain or discomfort due to other NKID

- An increase in the prevalence of self-reported symptoms for certain body locations was noted among user questionnaire respondents as the duration of daily time spent on the computer increased. This relationship was among the most apparent for the right wrist/hand and coincides with 90% of survey participants using their device on this side

Visual symptoms

Information was collected from user questionnaire respondents (stage 4) concerning visual symptoms:

- Many (59%) had experienced tired eyes in the last 12 months, 38% had tired eyes in the last 7 days

- 27% reported impaired visual performance in the last 12 months, 14% had impaired visual performance in the last 7 days

- 31% had red or sore eyes in the last 12 months, 17% had red or sore eyes in the last 7 days

- Almost half the sample (46%) had headaches in the last 12 months, 23% had headaches in the last 7 days

- Half the sample (52%) thought their visual symptoms were work related (e.g. looking at a computer screen most of the day, glare on screen, poor lighting, poor air conditioning). 12% said this affected how they arranged their workstation

- 20% attributed their visual symptoms to things they did away from work (e.g. socialising, sports, driving, playing computer games)

Postural concerns

The following postures were identified as areas of concern by the literature review (stage 1), workplace assessment observations (stage 3) and during the laboratory trial (stage 5). The poor postures observed coincide with the pain or discomfort reported by workplace assessment interviewees (stage 3) and user questionnaire respondents (stage 4):

- Neck flexion when looking at the screen, keyboard and documents

- Insufficient back support

- Static postures

- Deviated and extended wrist when using a device - the laboratory study indicated that mouse operation frequently required an extended wrist posture

- Poor shoulder posture

Work organisation

Work organisation problems were identified in the workplace assessments (stage 3) and user questionnaire survey (stage 4) with respect to:

- Many users reporting that they work at their computer for long periods of time (exceeding 2 hours) without taking regular breaks
- A frequent requirement for fast and intensive work
- Inadequate support from supervisors

Workstation

The main areas of concern highlighted during the workplace assessments (stage 3) and in the user questionnaire (stage 4) were:

- Insufficient back support from chairs (13% workplace assessment interviewees, 22% user questionnaire respondents)
- Lack of desk space (31% workplace assessment interviewees, 25% user questionnaire respondents)
- Screen reflections and glare (49% workplace assessment interviewees, 39% user questionnaire respondents)
- Poor distribution of health and safety advice (29% workplace assessment interviewees, 28% user questionnaire respondents)
- Lack of cleaning of equipment (42% workplace assessment interviewees, 46% user questionnaire respondents)
- Poor maintenance of equipment (42% workplace assessment interviewees, 23% user questionnaire respondents)

Influence of prior musculoskeletal problems (aim 6)

- The manager questionnaire (stage 2) and the workplace assessments (stage 3) results indicated that provision of an alternative NKID was a common response by health and safety personnel when a musculoskeletal problem had been reported
- Information collected by the workplace assessment interviews and user questionnaire (stage 4) indicated that back and upper limb pain is of sufficient severity to affect individuals' lives, both at work and during leisure
- Among workplace assessment interviewees, 35% said the pain or discomfort had some or considerable effect on their work performance in general in the last year, 15% said it had some or considerable effect on their keyboard use and 31% said it affected their device use:
    - 18% had changed their work tasks

- 24% had altered their work pace
- 42% had changed their work posture
- 16% had changed their equipment
- 9% had changed their device

- Of user questionnaire respondents, 24% said the pain or discomfort had some or considerable effect on their work performance in general in the last year, 22% said it had some or considerable effect on their keyboard use and 19% said it affected their device use:

  - 4% had changed their work tasks
  - 7% had altered their work pace
  - 17% had changed their work posture
  - 8% had changed their equipment
  - 3% had changed their device

NKID design (aim 7)

Undesirable aspects of NKID were identified during all stages of the study. The main problems are: unsuitable device size, awkward shape, uncomfortable to grip and to operate, jittery device movement, poor precision and complex devices with too many controls.

Desirable device features include:

- Appropriate size and shape of device to ensure comfortable hand and finger positions for individual users

- Smooth device movement

- Easy to operate

- Good control and precision

- Adequate responsiveness and speed

- Easy to configure and adjust operational settings for the device

Best practice for NKID use (aims 8 and 9)

Given the complex nature of NKID risk, arising from interacting factors, an ergonomics approach to risk management is desirable. This should consider all aspects of the human-computer interaction.

Based on evidence from the literature (stage 1) and the findings of this research (stages 2-6), recommendations for best practice are:

- NKID should be selected to provide precision and accuracy appropriate to the task, with operation that is consistent and predictable e.g. finger operated touchscreens at present often offer lower precision than mice or trackballs

- Users should ensure they are seated comfortably (e.g. feet on floor, back fully supported by backrest, unrestricted chair movement) and that they have adequate support for their arm when using NKID. This study has indicated that having the arm fully supported is beneficial in terms of comfort, effort and low muscle activity

- Provision of L-shaped (curved) desks should be considered. L-shaped desks provide beneficial arm support when arranged appropriately (e.g. with computing equipment located in the curved region of the desk). However, the size and shape of L-shaped desks may make it more difficult to position them so that screen glare and reflections are avoided

- Users should position their device close to their body to avoid reaching or stretching when operating the NKID

- Ensure there is enough space to position and operate NKID effectively. Many desks seen during the study were crowded with other items and NKID were often located poorly as a result e.g. the user has to reach too far to operate the device

- Some operators find it helpful to learn to use NKID with either hand

- Prolonged NKID use was evident during the study. Work scheduling should aim to integrate computer and non-computer based tasks during the course of the working day. Users should be encouraged to take frequent breaks from computing work (e.g. 5 minutes every hour)

- Endeavour to introduce variety into the way computing tasks are conducted e.g. cutting and pasting text. Instead of reliance on devices, users should be prompted to try keyboard alternatives

- Address psychosocial issues. Musculoskeletal conditions are known to be influenced by job satisfaction and morale

- Ensure procedures are in place for users to report pain or discomfort or other problems with devices

What else should be done?

Designers and Manufacturers

Designers and manufacturers of NKID need to:

- Address poor relationships between hardware and software (e.g. the placement and size of screen icons, which lead to unnecessary cursor/NKID movement)

- Use existing ergonomics guidance (e.g. anthropometric data, device shape and button layout) to ensure their designs are appropriate

- Seek feedback and views from users of equipment to improve devices

- Evaluate alternative device designs with respect to user comfort and health

- Note that touch screen implementations that mimic mouse driven user interfaces may cause problems with respect to shoulder posture and load

- Provide ergonomics advice with devices (e.g. how to set-up and operate)

Health and Safety Managers/Purchasers

Those responsible for health and safety or the purchase of NKID should:

- Extend advice on workstation set-up to include NKID, taking account of recent developments in desk shapes (e.g. position of device on L-shaped desks) and ensure that NKID are included in workstation assessments (see Device Assessment Checklist, Appendix 4)

- Provide alternative devices to allow for different workstation set-ups, hand size and individual preference (See Device Purchasing Checklist, Appendix 5)

- Consider NKID use when purchasing other equipment (e.g. specifying keyboards without numeric keypads)

- Give users the option of using NKID accessories (e.g. adequate size mouse mats or wrist supports)

- Encourage good work organisation practices (e.g. alternating NKID work with non-computer work)

- Develop monitoring policies for the maintenance of equipment (e.g. checking a mouse ball is clean and moves easily, ensuring that buttons operate correctly)

- Establish reporting systems for musculoskeletal health problems

Trainers

It must be emphasised that training, however effective, cannot overcome inherent risks in equipment design or a system of work. Training should be complementary rather than a substitute for the other measures that have been recommended. The following issues should be covered by training:

- Provision of general health and safety advice

- Awareness of posture, with particular reference to NKID (e.g. position on the desk)

- Use of device buttons and facilities, including alternative methods of performing tasks

- Training delivery, with induction and refresher courses provided to an appropriate schedule

Policy and guidance makers

Policy and guidance makers need to:

- Adopt an ergonomics approach to NKID risk assessment (already advocated by HSE)

- Persuade organisations to increase variety in their allocation of work types to individuals throughout the day, to reduce extended periods of time working in static postures

- Provide guidance on arranging workstations where NKID will be used, including mention of the benefit of support provision for the arm

- Provide information on how to assess workstations where NKID are in use (see Device Assessment Checklist, Appendix 4)

- Emphasise the need for information and training regarding use of NKID

Researchers

There is a need for the research community to:

- Investigate further the effects of workstation configuration and arm support on user comfort and health

- Examine the benefits of different forms of wrist and other support appliances

- Work more closely with designers to improve the ergonomics aspects of hardware and software design

- Explore optimal strategies for work organisation where intensive computer use is unavoidable

- Conduct longer-term studies on the effects of NKID use on the health of users, especially younger and older workers

CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Ten years ago, when the Health and Safety (Display Screen Equipment) Regulations (HSE, 1992) were drafted, the majority of computer interaction occurred with text driven interfaces, using a keyboard. It is not surprising then that the guidance accompanying the DSE Regulations included virtually no mention of the computer mouse or other non-keyboard input devices (NKID).

In the intervening period, graphical user interfaces, incorporating 'windows, icons and pull down menus' (WIMPS), with a heavy reliance on pointing devices such as the mouse, have transformed user computer interaction. Accompanying this, however, have been increasing anecdotal reports of musculoskeletal health problems affecting NKID users.

While the performance aspects of NKID (e.g. accuracy and speed) have been the subject of detailed research, the possible implications for user health have received comparatively little attention. The research presented in this report was commissioned by the Health and Safety Executive to improve understanding of the nature and extent of NKID health problems. This investigation, together with another project examining mobile computing (Heasman *et. al.*, 2000), was intended to contribute to a planned review and updating of the DSE Regulations and accompanying guidance.

RESEARCH AIMS

The aims of this research were to:

1. Determine the extent to which different NKID are used

2. Document patterns of NKID use i.e. tasks, periods and proportion of time for which they are used

3. Describe the range of workstation configurations occurring in practice, especially with regard to NKID placement and use of aids such as mouse mats and arm rests

4. Identify the extent of individual variation among NKID users in their manner of device operation

5. Measure prevalence of musculoskeletal and other complaints associated with NKID use

6. Examine differences in user behaviour when operating NKID that may have resulted from prior musculoskeletal problems

7. Identify desirable and undesirable aspects of NKID in respect of user comfort and health

8. Collate and validate best practice advice concerning use of NKID

9. Provide guidance, where feasible, on the suitability of different NKID for generic tasks

REPORT FORMAT

In order to achieve these objectives, the study comprised:

- A review of the literature relevant to the health of NKID users
  (Stage 1: Literature review)

- A questionnaire survey of health and safety and information technology (IT) managers
  (Stage 2: Manager questionnaire survey)

- Ergonomics work system assessments at nine workplace locations
  (Stage 3: Workplace assessments)

- A questionnaire survey of NKID users
  (Stage 4: User questionnaire survey)

- Laboratory assessments: an expert assessment of a variety of NKID devices, a user trial of mouse use and workstation configuration, and a case study investigating touch screen use
  (Stage 5: Laboratory assessment)

- Discussion with experts
  (Stage 6: Expert meeting on current NKID issues)

The findings of the six stages of the study are reported in the following sections.

The various survey and laboratory studies undertaken for this research were approved by the University of Surrey and Loughborough University ethical advisory committees.

STAGE 1

LITERATURE REVIEW

The following review collates previous research relevant to the health of NKID users. No attempt has been made to consider the literature dealing with user performance aspects of NKID, other than where this has a bearing on user health.

MUSCULOSKELETAL ILL HEALTH

The risk of musculoskeletal disorders (MSDs) is the primary health concern in connection with use of NKID. MSDs most commonly affect the upper limbs (neck, shoulders, arms, hands/wrists), back and lower limbs (knees, hips) and may result in debilitating pain, discomfort or numbness. MSDs arise in many forms and the symptoms are frequently non-specific. Some disorders classified as MSDs exhibit well defined signs and symptoms (e.g. carpal tunnel syndrome, tenosynovitis, tennis elbow), others are less well defined such as myalgic conditions involving pain and discomfort, numbness and tingling sensations throughout the neck, shoulders, upper limbs and lower back and lower limbs.

Many studies have been conducted examining the factors associated with MSDs but despite the widespread recognition of the multi-factorial nature of these conditions, few investigations have considered comprehensively and simultaneously all the main factors associated with these problems (Hagberg *et. al.*, 1995).

Previous studies have identified the following risk factors (Hagberg 1988, Hagberg *et. al.*, 1992; Bongers *et. al.*, 1993; Smith and Carayon, 1996):

Physical: heavy, static or monotonous work, extreme or constrained postures, repetitive movements, unsuitable workplaces and equipment, forces, exposure to vibration or cold environment

Psychosocial: work organisation, interpersonal relationships, short cycle tasks, poor work control, piece rate payment system, poor management, unsatisfactory training, lack of breaks

Personal: gender, age, seniority, exercise habits, lifestyle, psychological characteristics and capacities

Musculoskeletal symptoms may result from non-occupational (e.g. hobbies, sports activities) as well as occupational activities.

A key issue with NKID are the prolonged static and constrained postures which accompany typical use. Postures arise from a combination of device design and workstation configuration. Duration and intensity of use depend upon the nature of tasks being undertaken and the manner in which work is organised. Other issues, psychosocial and personal, then have a bearing on users' experience and reporting of health problems.

The effects of poor posture and static load on the muscles of the neck and shoulders during upper extremity work had been well documented prior to the advent of the mouse and other NKID. For example, Maeda (1977) and Westgaard *et. al.* (1985) reported on the relationship between low level prolonged static muscle load on the neck and shoulders and musculoskeletal injuries. Work requiring shoulder flexion and abduction had been identified as contributing to symptoms in the neck and trapezius region (Hagberg, 1981; Kilbom and Persson, 1987; Schuldt *et. al.*, 1987; Kilbom, 1988).

PATTERNS OF NKID USE

It is apparent from general observation that the computer mouse is the most commonly used input device, other than the keyboard, and use of the mouse has been increasing. However, only a small number of studies have actually tried to quantify the extent to which the mouse is used; no studies have been found which deal with the extent of other NKID use. Computer mouse usage has been demonstrated to account for up to two-thirds of computer operation time, depending on the software used and the task performed (Johnson *et. al.*, 1993; Karlqvist *et. al.*, 1994).

Among the main actions NKID are used to perform are selection, dragging, cutting, pasting and scrolling. The extent to which these are required depends on the purpose and design of the software and the manner in which it is used. An editing task may require more by way of selection, cutting and pasting whereas an information search on the internet may involve more scrolling. Some users perform operations using the keyboard, reducing NKID interaction.

Although more research is required on the extent to which all NKID are used and the tasks they are used for, caution needs to be exercised interpreting the accuracy of self-reported work hours, as these have been found to overestimate use (Faucett and Rempel, 1996) or are otherwise unreliable (Gerr *et. al.*, 1996).

Individual differences

Taylor and Hinson (1988) investigated individual differences in the ability to use a mouse to point to words in a piece of displayed text. They found that performance of a user depended on the nature of the task, the inherent characteristics of the input device, the implementation of the device and its driving software, users' previous experiences of the task and device and other individual user characteristics. This list illustrates the range of factors affecting performance with NKID.

User handedness is a particular issue that needs to be considered. Hoffman *et. al.* (1997) surveyed student users and found all had their mouse installed on the right hand side of the keyboard. An experiment was performed to see if left-handed users were disadvantaged by this arrangement. The hand used had no statistically significant effect for left-handers but a very large effect for right-handers. Possibly as a result of being forced to use their non-preferred hand in many situations, left-handers seem more adept at using their non-preferred hand, so that manual performance is as good as that of the preferred hand.

Peters and Ivanoff (1999) again reported that most computer mouse users have exclusive experience with the right hand as even left-handers use a right-handed mouse. Peters and Ivanoff compared precision of right and left-handers having right-handed mouse experience with left-handers having left-handed mouse experience. While subjects may have perceived their non-preferred hand to be clumsier, in absolute terms the difference was small. As a consequence, it was suggested that alternating use of the preferred and non-preferred hand might be advocated for mouse users in those situations in which the preferred hand may be subject to pain or discomfort.

NKID AND HEALTH PROBLEMS

Almost all research attention regarding NKID and health problems has been directed at the mouse, although there has been some limited consideration given to trackballs. Little is known about health and comfort advantages and disadvantages of other devices, such as joysticks, touchpads and touchscreens.

Anecdotal reports of shoulder and arm discomfort relating to mouse use are common but the prevalence of musculoskeletal disorders or symptoms has not been well documented. Few systematic ergonomics studies of mouse use or its relationship to musculoskeletal symptoms have been reported (Karlqvist *et. al.*, 1994; Fogelman and Brogmus, 1995; Hamilton, 1996; Cooper and Straker, 1998), meaning that objective data regarding any causative link between mouse use and injury is lacking.

Fogelman and Brogmus (1995) reviewed United States workers compensation claims for 1987-1993 to determine the prevalence of musculoskeletal disorders related to mouse use. The authors reported that although the prevalence of claims related to mouse use was low, there were indications of an increasing problem. They reported that mouse users had a greater prevalence of symptoms in the upper or lower (wrist) arm than other workers.

Karlqvist *et. al.* (1996) recorded present musculoskeletal symptoms (as opposed to symptom history over the past week or year) among a group of 542 computer assisted design (CAD) users. Karlqvist *et. al.* found a high prevalence of symptoms (e.g. 25% neck; 18% right shoulder, 6% right wrist, 7% right hand and fingers), with females reporting more than males. Location of the mouse on the table when working and duration of mouse use seemed to be risk factors for upper limb problems.

Hanson *et. al.* (1997, 1999) considered the major factors associated with musculoskeletal disorders through a large questionnaire survey of keyboard users. In a follow on case-control study, no relationship was found between using a mouse and musculoskeletal disorders. However, only a small number of subjects had a mouse and many reported using it rarely. This last point was presumably at least in part due to the research being undertaken in the mid 1990's, when mouse use was less common.

RISK FACTORS

Carter and Bannister (1994) identified possible causes of musculoskeletal injuries to computer workers as: seated work, awkward positions, static work, inactivity, overuse, stress on bone and connective tissue and pressure on blood vessels and nerves. Working with NKID requires static, repetitive and often intensive movement of the upper limbs.

Posture

The postures adopted to use NKID depend on the size of the device, workstation configuration, user anthropometry and individual operating technique.

Mackinnon and Novak (1997) identified three potential mechanisms through which postures during NKID use might contribute to the development of musculoskeletal disorders: increased pressure on nerves at entrapment points, increased neural tension and use of muscles while contracted.

NKID, particularly the computer mouse, may lead to musculoskeletal discomfort and injury as a consequence of exposure to postures involving wrist extension, ulnar deviation and other non-neutral joint positions (de Krom *et. al.*, 1992; Karlqvist *et. al.*,1994; Bergqvist *et. al.*, 1995; Matias *et. al.*, 1998, Cook *et. al.*, 2000). An important wrist injury mechanism arises from the narrowing of the carpal tunnel during extension and deviation, causing increased pressure on the median nerve and other structures (Weiss *et. al.*, 1995; Mackinnon and Novak, 1997; Werner *et. al.*, 1997). Computer mouse usage can also generate prolonged unilateral shoulder flexion, abduction and external rotation (Karlqvist *et. al.*, 1994), leading to upper arm pain or discomfort.

Force Exertion

In addition to wrist posture, it appears that the posture and force exertion of the fingers also affect carpal canal pressure (Rempel *et. al.*, 1997). Rempel *et. al.* found that the effects of finger tip force on carpal tunnel pressure were independent of and greater than those due to wrist posture during a finger-pressing task. Keir *et. al.* (1998) established that for the same finger tip force magnitude, a pinch grip created twice the carpal tunnel pressure than a simple finger press. The suggestion from these studies is that MSDs may originate from both button clicking and use of the fingers to grip and manoeuvre a device.

Intensity of Use

Several studies have documented a relationship between upper extremity pain and the period of time an operator uses a keyboard or mouse (Punnett & Bergqvist, 1997).

Hagberg (1995) examined self-reported musculoskeletal symptoms within a group of computer operators, with intense mouse users reporting higher levels of discomfort in the shoulder-scapular, wrist and hand-finger regions than a comparison group of low frequency users. These findings are commensurate with other studies that have found mouse use to be associated with raised levels of muscle activity in the shoulder region, abducted arms, and ulnar deviation of the wrist (Karlqvist *et. al.*, 1994; Harvey and Peper, 1997). It seems likely that finger symptoms relate to the frequency and forces involved in device button operation, as discussed above.

Karlqvist *et. al.* (1996) reported an association with neck and upper extremity symptoms and extent of mouse use. They found that more than 5.6 hours of mouse time per week had increased risk of shoulder symptoms.

More recently, Cook *et. al.* (2000) found no relationship between self-reported duration of mouse use and musculoskeletal symptoms in a cross-sectional survey of 270 users. Cook *et. al.* were unable to explain the discrepancy between this finding and those of earlier studies, other than to highlight the problem with relying on usage self-reporting.

Workstation Configuration

The dimensions and arrangement of a workstation have an important influence on device placement and user posture.

With regard to mouse position, there is evidence that placement allowing a near neutral posture is preferable (Karlqvist *et. al.*, 1996; Karlqvist, 1997). The position of the mouse away from the midline of the body results in users working with the arm unsupported, the shoulder abducted and externally rotated and the arm in forward flexion (Franzblau *et. al.*, 1993; Karlqvist *et. al.*, 1994, 1996; Cooper and Straker, 1998; Aarås *et. al.*, 1997; Fernström and Ericson, 1997; Harvey and Peper, 1997; Cook and Kothiyal, 1998). Karlqvist *et. al.* (1994) reported a higher prevalence of symptoms when the mouse was used in a less optimal position (away from the midline of the body).

However, keyboards incorporating a numeric keypad may impede right-sided mouse users, increasing the distance of the mouse from the user (Cook and Kothiyal, 1996; Cook *et. al.*, 2000). In an early study, Card *et. al.* (1978) explored the relationship between three mouse positions and muscular activity in the neck and shoulder region in standard, extreme and modified (with a compact keyboard) positions. Operating the mouse in an extreme position of shoulder abduction and flexion significantly increased electromyographic (EMG) activity in anterior and middle deltoid muscles but not for the middle trapezius. Activity in the anterior and middle deltoid muscles was significantly lower when using the mouse adjacent to a keyboard without a numeric keypad. This positions the mouse closer to the midline of the body thereby minimising abduction and flexion of the right shoulder.

Arm Support

The importance of upper limb support when working with NKID has been explored to some extent, with wrist/arm support found to be beneficial (Damann and Kroemer, 1995; Paul *et. al.*, 1996; Karlqvist, 1997).

Aarås *et. al.* (1997) performed a lab study measuring EMG from the upper part of the musculus trapezius and from the lumbar part of musculus erector spinae using the mouse as an input device. The muscle load was significantly less when sitting with supported forearms compared to sitting without forearm support.

Wahlström *et. al.* (2000) found that with a wrist only supported working technique, subjects had greater wrist extension, higher muscle activity in the left and right trapezius (i.e. shoulder muscles) and highest ratings of perceived exertion in the neck and shoulder, than for other greater arm support conditions.

Task Influences

Keir *et. al.* (1999) examined carpal tunnel pressures in subjects performing different tasks, using three different computer mice. Similar carpal tunnel pressures and wrist postures were found for all devices. Repeated dragging tasks, however, increased carpal tunnel pressure more than pointing actions. These pressure levels suggested a need to reduce sustained button down activities, to work with NKID for shorter durations and to interrupt prolonged NKID use with other tasks for the device hand.

Andre and English (1999) identified concerns associated with web browsing and mouse use. These included constant finger clicking while scrolling through pages, 'mouse freeze' (keeping the hands on the mouse when not in use), and leaning away from the mouse when not using it, thereby placing stress on the wrists and elbows.

Device Comparisons

It is apparent from a small number of studies that different devices result in different operating postures, both within and between device categories. The mouse appears to require greater ulnar deviation of the wrist, the trackball increased wrist extension, for example, although the extent of this depends on the design of the particular device and the fit to the user.

Karlqvist *et. al.* (1994) investigating mouse and trackball use, found only minor differences in postures for the two input devices, with a greater effect arising from device location. Different mouse positions resulted in large differences in shoulder postures while wrist extension was more pronounced with the trackball. Elbow flexion was influenced by NKID position but not by type of input device. Work with the mouse and trackball caused different levels of muscular load in the neck/shoulder and hand/forearm muscles. Joint positions differed depending on size and design of the input device and the operator's anthropometric dimensions. Broad shouldered subjects did not rotate the shoulder outwards as much as small-shouldered subjects.

Subsequent work by Harvey and Peper (1997) and Karlqvist (1997) suggested that trackballs reduce the loading on shoulder muscles, while increasing the extent of undesirable wrist postures. Although, in both these studies, and Haward (1998), the subjects did not seem able to detect this at a subjective level.

Burgess-Limerick *et. al.* (1999) and Burgess-Limerick and Green (2000) described the postures adopted by twelve subjects using a mouse and trackball to perform standardised tasks. Mouse use was accompanied by extreme ulnar deviation and wrist extension. In comparison, trackball use resulted in less ulnar deviation but greater wrist extension, perhaps offsetting any benefit. This study also found individual differences in postures adopted to manipulate trackballs.

Looking at a device found most often with lap-top computers, Fernström & Ericson (1997) found decreased shoulder activity with a track-point mouse (small joystick placed in centre of keyboard) when compared with standard mouse use.

Aarås *et. al.* (1997) examined a joystick mouse designed to give a more neutral forearm position, comparing this with a traditional mouse requiring more pronation of the forearm. The muscle load of the forearm was significantly less when using the new mouse compared with a traditional design. A prospective epidemiological field study was carried out to evaluate these results. With respect to pain intensity and frequency for the intervention group, there were significant improvements for the wrist/hand, forearm, shoulder and neck after intervention, whereas in the control group only small changes were observed. This suggests the joystick mouse may offer an improvement over the traditional mouse in terms of musculoskeletal comfort and health. A joystick mouse requires, however, a 'power' rather than 'precision' grip, which may have user performance implications.

Ichikawa *et. al.* (1999) studied pen-tablet devices with regard to pointing time, accuracy, mental workload and subjective ease of operation. Two types of tablet (indirect by moving stylus on pad on desk and direct using pen on liquid display) were compared with the mouse. The direct tablet had a shorter pointing time, while the mouse had an increased error rate, especially for small targets. Subjectively, the mouse was evaluated highly for ease of pointing and load to the wrist, elbow, arm and shoulder. In view of the mouse error rate, Ichikawa *et. al.* concluded the mouse to be a less suitable pointing device for operations requiring high accuracy. However, this finding contradicts other researchers (e.g. Douglas and Mithal, 1997), that have found the mouse to be one of the more accurate pointing devices. It seems likely Ichikawa *et. al.*'s conclusion was formed on the basis of the limited device comparison undertaken for their experiment, and should be interpreted as such.

GUIDANCE ON NKID SELECTION AND USE

At present there is very little information available to guide Display Screen Equipment (DSE) users or their managers concerning NKID selection and use. Sources such as Armstrong *et. al.* (1995) and ISO 9241-9 (2000) provide guidance on NKID design and application, but with information more relevant to designers and manufacturers of devices than purchasers or users. In the case of Armstrong *et. al.*, the recommendations are based on a theoretical analysis of mouse use. ISO 9241-9 (2000) collates the views of relevant experts. Both references provide broad recommendations regarding posture, but are more specific with respect to features such as button operating forces and grip characteristics. Limited information on mouse use is included in 'Working with VDUs' (HSE, 1998). Interestingly, few of the increasing number of manufacturers making claims regarding the 'ergonomic' design of their equipment provide much by way of guidance on their use.

CONCLUSIONS

This review indicates that concerns exist over the effects of NKID use on musculoskeletal ill health in terms of the postures required to operate devices, how devices are positioned and their intensity of use. Many aspects of NKID design and use, especially with respect to user comfort and health, require further research. Some of the more serious gaps in knowledge concern the extent to which NKID are used, the demands of various task types and the use and benefit of alternative NKID.

SUMMARY

- concern has been expressed in the literature regarding possible health consequences of NKID use
- while a small number of epidemiological studies have found an association between intensity and duration of mouse use and reported musculoskeletal symptoms, others have found no relationship
- surveys have found that almost all mouse users appear to use the device with their right hand, even users who are left handed
- laboratory studies looking at the mouse and trackball have found that poor postures occur when using these devices, affecting fingers, wrist, arm and shoulder
- there has been little investigation with respect to other NKID
- device design has been shown to have an effect on posture (particularly wrist extension and ulnar deviation) and other factors known to affect musculoskeletal risk
- the design of other computing equipment affects device positioning on users desks, e.g. the inclusion of a numeric keypad in keyboards
- there is some evidence that alternative NKID designs, e.g. joystick mouse, may be beneficial regarding user comfort, but manufacturers' claims regarding the benefits of other devices are often unsubstantiated
- there is almost no guidance currently available to users or their managers regarding use of NKID

STAGE TWO

MANAGER QUESTIONNAIRE SURVEY

A questionnaire survey of IT and health and safety managers was conducted to collect data on the types of non-keyboard input devices (NKID) currently in use in organisations and to identify the various applications for which these devices are used. The questionnaire survey was also designed to investigate problems with the use of NKID and to collect information on health problems and sickness absence associated with computer and NKID usage. This stage of the project gathered preliminary data to inform subsequent phases of the research.

METHODS

The survey comprised two questionnaires. A questionnaire for IT managers (Appendix 1) was designed to ascertain the numbers of desktop and laptop computer users in their organisations, the NKID used, and to explore the type of work performed with these devices. Problems relating to use of NKID were also investigated as was anticipated future use of NKID.

The second questionnaire (Appendix 2) for health and safety managers also comprised these questions and in addition collected information on the number of reports of neck, shoulder or arm pain in the organisation in the previous 12 months and the extent of sickness absence in relation to the occurrence of this pain and discomfort.

QUESTIONNAIRE DISTRIBUTION

The questionnaires were distributed by post in Spring 1998 to IT and health and safety managers at organisations throughout the UK that were known to Surrey and Loughborough Universities. In total, 256 questionnaires were sent out; however, 41 organisations chose not to participate and returned their questionnaires immediately.

Information about the questionnaire was also distributed via an electronic mailing list for the Universities Safety Association (i.e. HASNET). This list had a membership of 150 safety officers, covering universities and colleges of further education. Details were provided about the study and instruction was given on how to download the questionnaire from the study web site. This may have introduced some bias (e.g. the membership was limited to universities and colleges, attracting organisations who had internet access and were active in web groups and forums) into the study sample. This was considered acceptable given the priority was to gather as much background information as possible prior to proceeding with the following stages of the study. There was no overlap of questionnaire returns from those distributed electronically and those mailed out by post.

It is acknowledged that there is likely to be selection bias among all those that responded from either route, as the respondents are likely to be those who are interested, concerned and active in the area.

RESPONSE RATE

The response rate to the postal questionnaire was 46% (n = 99). An additional 29 replies were received via the Internet. In total, 128 IT/health and safety managers (22% IT and 78% health and safety managers) representing 102 different organisations responded to the questionnaire survey.

ORGANISATION PROFILE

Table 1 presents an analysis of questionnaire distribution and responses, broken down by categories used in the Labour Force Survey (LFS), as reported in the Health and Safety Statistics 1997/98 (HSC, 1997).

The 128 organisations that responded to the questionnaire survey gave good coverage across industrial sectors. The possible over-representation of educational institutions was due to the response from the questionnaire distributed via the HASNET electronic mailing list. Table 1 also shows the numbers of questionnaires returned from each LFS category. This includes the responses received from both postal and Internet groups.

Table 1
Number of companies in LFS categories that were surveyed (1st column) and responded (2nd column) to the questionnaire survey

Category	Surveyed	Responded
Manufacturing	33	11
Distribution & repair	3	0
Education	8	32
Public administration and defence	35	14
Extraction & utility supply	7	2
Construction	58	24
Health & social work	41	20
Transport, storage & communication	8	1
Hotels & restaurants	0	0
Agriculture	1	1
Consumer/leisure services	15	4
Finance & business	36	12
Other: publishing (7), Tourism (1), Misc (3)	11	7
Total	**256**	**128**
Internet replies		29
Postal questionnaire		99

Organisation size

The size of the organisations that responded to the questionnaire ranged from those with 2 employees to those having 10,000 employees. The mean number of employees in each organisation was 1011 (sd=1774.2). The median number of employees in organisations was 210, the mode was 50. The total number of employees represented by the questionnaire survey was 124,350.

Computer user profile

95% (n=118,077) of the total number of people represented by the questionnaire were computer users. It was not possible to determine accurate data for the number of computer users who used desktop, laptop computers or both in the organisations as a whole, since many questionnaire respondents were unable to provide this breakdown. However, questionnaire data representing 79,628 employees indicated that 80% used desktop computers (n=63,319), 9% used laptops (n=7846) and 11% used both desktop computers and laptops (n=8463).

DEVICES USED WITH DESKTOP & LAPTOP COMPUTERS

In order to investigate the types of NKID used, the managers were asked to report the NKID currently used with both desktop and laptop computers in their organisations.

Desktop

- The mouse was used with desktop computers at 97% of organisations surveyed. At 73% of these organisations, all desktop users used the mouse

- Trackballs were used by 20% of organisations to operate desktop computers

- Touchpads were reported to be used with desktop computers at 9% of organisations surveyed

- 8% of organisations used a touchscreen to operate desktop computers

- Joysticks were used to operate desktop computers at 2% of organisations

- Examination of the data for desktop computers indicated that the mouse was used at the majority of organisations of any size (see Table 2) and that touchscreens, touchpads and trackballs were used to a greater extent at organisations with more than 500 employees. There was little use of joysticks at organisations of any size. Overall there appeared to be more device types used in organisations of a larger size

Table 2
Size of organisation (indicated by number of employees) and use of different devices with desktops

	Up to 100 employees	**101-500 employees**	**501-1000 employees**	**1001+ employees**
Number of organisations	43	34	9	31
Mouse desktop	100% (n=43)	97% (n=33)	100% (n=9)	94% (n=29)
Touchscreen desktop	0% (n=0)	6% (n=2)	33% (n=3)	13% (n=4)
Touchpad desktop	2% (n=1)	6% (n=2)	22% (n=2)	23% (n=7)
Trackball desktop	14% (n=6)	12% (n=4)	33% (n=3)	29% (n=9)
Joystick desktop	0% (n=0)	3% (n=1)	0% (n=0)	6% (n=2)

- In order to see if device use differed in different types of organisations, the percentage breakdown of device use with desktop computers was examined for organisations in six LFS categories (numbers of organisations in the other categories was considered too small for analysis)

- Table 3 indicates that some variation existed in device use with desktop computers although the mouse was used at the majority of organisations. The mouse was used less in the public administration category, where touchscreen use was higher than in other organisations. Touchpads were used in approximately half of the manufacturing organisations and to some extent in other organisation categories with the exception of health and social work. There was little use of joysticks at organisations of any kind

Table 3
Type of organisation and use of different devices with desktops

	Manufacturing	Education	Public Admin	Construction	Health & social work	Finance & business
Number of organisations	11	32	14	24	20	12
Mouse	100% (n=11)	94% (n=30)	79% (n=11)	100% (n=24)	90% (n=18)	83% (n=10)
Touchscreen	18% (n=2)	0%	29% (n=4)	0%	10% (n=2)	0%
Touchpad	27% (n=3)	9% (n=3)	14% (n=2)	4% (n=1)	5% (n=1)	8% (n=1)
Trackball	46% (n=5)	22% (n=7)	21% (n=3)	17% (n=4)	5% (n=1)	17% (n=2)
Joystick	9% (n=1)	0%	7% (n=1)	0%	0%	0%

Laptop

- The mouse was used with laptop computers at 64% of organisations surveyed. At 31% of organisations, all laptop users used a mouse
- 31% of organisations used touchpads with their laptop computers
- Trackballs were used to operate laptops at 28% of organisations
- 6% of organisations surveyed used a touchscreen to operate laptops
- Joysticks (mini-joysticks or trackpoint mouse) were used to operate laptop computers at 6% of organisations
- Examination of the data indicated that the mouse was used with laptops at the majority of organisations of any size (see Table 4)
- In order to see if device use differed in different types of organisations, the percentage breakdown of device use with laptops was examined for organisations in six LFS categories
- Half the health and social work and one third of the education organisations used the mouse with laptops; mouse use was higher in other organisation categories (table 5). Touchscreens were used to some extent at construction and finance and business organisations. Touchpads were used at a substantial number of manufacturing and health and social work organisations. They were also used to some extent in the other categories with the exception of education where use was low. One fifth of public administration organisations used joysticks with laptops but there was little use of joysticks at other organisations

Table 4
Size of organisation (indicated by number of employees) and use of different devices with laptops

	Up to 100 employees	101-500 employees	501-1000 employees	1001+ employees
Number of organisations	43	34	9	31
Mouse laptop	49% (n=21)	71% (n=24)	100% (n=9)	68% (n=21)
Touchscreen laptop	9% (n=4)	6% (n=2)	11% (n=1)	0% (n=0)
Touchpad laptop	19% (n=8)	32% (n=11)	67% (n=6)	39% (n=12)
Trackball laptop	19% (n=8)	24% (n=8)	33% (n=3)	48% (n=15)
Joystick laptop	5% (n=2)	3% (n=1)	0% (n=0)	16% (n=5)

Table 5
Type of organisation and use of different devices with laptops

	Manufacturing	Education	Public Admin	Construction	Health & social work	Finance & business
Number of organisations	11	32	14	24	20	12
Mouse	73% (n=8)	31% (n=10)	86% (n=12)	92% (n=22)	55% (n=11)	75% (n=9)
Touchscreen	0%	3% (n=1)	7% (n=1)	13% (n=3)	0%	17% (n=2)
Touchpad	46% (n=5)	9% (n=3)	21% (n=3)	33% (n=8)	45% (n=9)	25% (n=3)
Trackball	36% (n=4)	16% (n=5)	36% (n=5)	21% (n=5)	45% (n=9)	25% (n=3)
Joystick	0%	6% (n=2)	21% (n=3)	4% (n=1)	5% (n=1)	8% (n=1)

Other NKID used

35% of organisations reported that other NKID were also in use. The following NKID were mentioned: bar code wands (11%), voice recognition software (8%), tablet/puck and digitisers for CAD (8%), scanners (7%), writing recognition software (3%), air mouse, mouse trapper and pen pads (1%).

NKID APPLICATIONS

Respondents were asked about the applications NKID were used for in their organisations (percentages outlined in the following sections refer to the percentages of organisations responding and not individual users, and include both desktop and laptop computer work).

Mouse

The mouse appeared to be used most commonly at the majority of organisations for word processing (at 95% of organisations), spreadsheets (94%), accessing database information (89%) and using accounting or specialised software (86%). The mouse was also used for programming (at 60% of organisations), CAD (51%) and control operations (25%). A number of other applications were also listed: games development and graphics (2% of organisations).

Touchscreens

Touchscreens were used in the organisations surveyed for accessing databases (6% of organisations), control operation (4%) and word processing (4%). They were also used for accounting, programming, spreadsheets, telephone call handling (2%) and CAD (1%).

Touchpads

Touchpads were used to conduct word processing (25% of organisations), spreadsheets (22%), accessing databases (16%), accounting software (12%), programming (7%), CAD (6%) and control operations (4%).

Trackball

Trackballs were used for word processing (at 27% of organisations), spreadsheets (20%), accessing databases (18%), accounting software (14%), CAD (13%), programming (5%) and control operations (2%).

Laptop mini-joystick/trackpoint mouse

Laptop mini-joysticks were used for word processing (at 9% of organisations), spreadsheets (8%), accounting (6%), databases (4%), programming (2%) and CAD (1%).

PROBLEMS WITH NKID

Information was collected from organisations on problems experienced with the use of various NKID. The percentages of problems outlined in the following section are those experienced by the organisations and not by individuals.

The problems experienced with various NKID are presented in Table 6. The second column indicates the percentage of organisations using a device, the third column the percentage of organisations reporting problems with that device. Over 1/3 of organisations who used the mouse and 2/3 of organisations using touchscreens reported problems; 1/3 using trackballs reported problems; all organisations that used touchpads and joysticks reported problems. Problems with device design, maintenance, workstation set-up and use are outlined in the fourth column.

FUTURE NKID USE

20% of organisations that responded to the questionnaire foresaw using new NKID in the future. The NKID mentioned for future use were: voice activated software (7%), scanners, touchscreens, barcode readers, alternative types of mouse, i.e. foot operated, joystick (2%), trackballs and CAD tablets (1%).

Table 6
Problems with NKID reported by organisations

	Organisations using device	Organisations with problems	Reported problems (% include multiple responses)
Mouse	97%	38%	- pain/discomfort in fingers/hands/wrists after prolonged use (17% of all organisations) - maintenance (e.g. ball gathers dust and sticks) (11%) - poor workstation set-up (6%) - size and shape (6%)
Trackballs	20%	7%	- difficulty in use (4%) - high level of maintenance required (e.g. to remedy sticking) (2%) - pain/discomfort in fingers (1%)
Touchpads	9%	9%	- difficulties with their use (i.e. lack of precision) (4%) - length of time required to get used to using them (2%) - wrist/hand discomfort (2%) - skin infections (1%)
Touchscreens	8%	5%	- become very dirty with use (1%) - difficult to control and use (2%) - skin infections (1%) - problems relating to static (1%) - inappropriate lighting, reflections, poor workstation set-up (2%)
Joysticks	8%	8%	- difficult to control and use due to size (6%) - skin infections (2%)

PAIN AND DISCOMFORT

Questions relating to employee health were only asked on the questionnaire for health and safety managers.

In the last 12 months:

- Half of organisations surveyed (48%) had received reports from individuals of neck, shoulder or arm pain (arising from all activities)

- 2 in 5 organisations (40%) had experienced neck, shoulder or arm pain or discomfort associated with the use of computers

- Approximately 1 in 5 organisations (17%) had received reports of neck, shoulder or arm pain or discomfort associated with use of NKID

It might reasonably be assumed that organisations mentioning reports of pain or discomfort associated with NKID are for the most part a subset of those mentioning reports of problems arising from all activities and from use of computers. On this basis, it appears from the data that NKID use may account for a third of all neck, shoulder and arm pain in these organisations and half of that which was computer related.

SICKNESS ABSENCE DATA

In general, the reporting of sickness absence data on the questionnaires was poor and incomplete. 41% did not or could not report sickness absence data. Some companies provided thorough information but others mentioned that this information was not available in the format requested. A number said this information was confidential.

Further reasons for poor reporting of this information by respondents may include poor recording systems within organisations, records not kept in enough detail or data recorded with no attempt to identify the causes of problems.

11% of all organisations surveyed (or 19% of organisations that could provide information) reported sickness absence for neck, shoulder or arm pain in the last 12 months.

48% of all organisations (or 81% of organisations able to provide information) said there had been no sickness absence as a result of these problems.

SUMMARY

- Results have been reported from a questionnaire survey of IT and health and safety mangers, examining use of NKID in organisations
- Almost all organisations covered by the survey had desktop computer users, with a majority using these with a mouse (97%)
- Other devices used with desktops included trackballs (20% of organisations), touchpads (9%), touchscreens (8%) and joysticks (2%)
- The mouse was also the most common device used with laptops (64% of organisations), followed by touchpads (31%), then trackballs (28%)
- It appears that many organisations are issuing mice to be carried around with laptops. This may indicate users are dissatisfied with devices built in to laptops. It may also be a reflection of how laptops are used at the workplace i.e. as desktop computers, sometimes with docking stations. The use of mice with laptops may be difficult in some situations i.e. when travelling by train
- Most use of NKID was with common office software such as word processing, email, spreadsheet and database applications
- A range of problems were reported with all devices, although musculoskeletal pain/discomfort was mainly reported in connection with mouse, touchpad and trackball use
- 1 in 5 organisations reported neck, shoulder or arm pain or discomfort associated with NKID use
- NKID use may have been a factor in approximately 30% of all organisations in this study that reported neck, shoulder or arm pain or discomfort

STAGE THREE

WORKPLACE INTERVIEWS & ASSESSMENTS

All organisations (n=128) that completed the manager questionnaire (stage 2) were asked if they would participate in further parts of the study (i.e. workplace assessments and/or user questionnaire survey). 9 organisations agreed to participate in the workplace assessment stage; all of these were visited. In-depth interviews and observations were undertaken with 45 intensive and non-intensive non-keyboard input device (NKID) users at the 9 organisations to gain detailed insight into how users arrange their workstations and use NKID for different tasks.

As the workplace study was dependent on the goodwill of participating organisations, the subject recruitment procedure had to be pragmatic. Selection of subjects involved a contact person at each organisation identifying 5 subjects representative of the devices and workstations, work tasks and roles found within the organisation. Contacts were given guidelines on how to select subjects to reduce bias with regard to, for example, workstation layout or MSD history, although it was not possible to check their adherence to these. Some selection bias may, therefore, still have occurred.

Interviews at users' workstations included questions exploring how respondents use their NKID, applications used, duration and frequency of use, ease of use and musculoskeletal problems. Observations were also made of posture and workstation set-up at all sites. Diaries were completed by 29 users to record the time spent using NKID during a typical working day, the type of work carried out (e.g. word processing), breaks taken, software programs used and the intensity of their NKID use.

ORGANISATION PROFILE

The LFS categories (see stage one, Table 1) of organisations participating in the workplace assessments are shown in table 7.

Table 7
Number of companies in LFS categories visited during the workplace assessments

Category	Number
Manufacturing	1
Education	1
Public administration and defence	1
Construction	1
Health & social work	1
Agriculture	1
Finance & business	2
Transport, storage and communication	1

The size of organisations varied from 181 to 4065 employees with 45–4000 NKID users.

BIOGRAPHICAL DATA

The sample comprised 31% male and 69% female NKID users. The mean age of users was 37 years (range 19-67 years). The mean height of users was 1610 mm (range 1570-1830 mm). 98% were right handed. 98% of participants participated in hobbies and activities outside of work (e.g. sports, reading, gardening). 22% smoked.

WORK BACKGROUND

The roles in which the subjects were employed were wide ranging (e.g. Fire Control Officers, Legal Secretaries, Administrative Assistants and Computer Analysts). The average number of years subjects had been employed within their present job was 6 years (range 3 months–22 years). The number of days worked ranged from 3 to 5 with 89% of participants working a five-day week. The average number of hours worked in a week was 38 (range 5-50 hours). 53% said their working hours were flexible, with the remainder reporting that their work hours were fixed.

WORKSTATION SET-UP & EQUIPMENT

Chair

A variety of chairs were used in the workplace, with heights ranging 370–600mm from the ground (mean=522mm). This was the height the chair had been adjusted to by the user.

Desk

67% of subjects worked at L-shaped workstations (n=33). 47% (n=23) had their computer screen positioned in the deep curve of the desk. 20% (n=10) had L-shaped desks but placed the computer on a narrow part of the desk. 33% (n=16) had a traditional rectangular desk. 44% worked at more than one workstation.

The length of desks varied from 630-3640mm (mean=1909mm, mode=1800mm). The depth of desks varied between 700-1200mm (mean=864mm, mode=800mm). The height of desks varied from 690-810mm (mean=724mm, mode=720mm). Desk thickness varied from 20-120mm (mean=40mm, mode=30mm). Height of legroom available ranged 600-745mm (mean=683mm, mode=690mm). Width of legroom varied between 490-1500mm (mean=452mm, mode=504mm). Depth of legroom ranged 310-1000mm (mean=700mm, mode=750mm). All desks observed at the 9 workplaces met the requirements of the DSE Regulations (HSE, 1992).

Screen

The majority of computer screens were Compaq (31%) and Dell (18%). Other manufacturers included Sun, Viglen, RM and Phillips. The distance of the screen from the desk edge ranged from 300-750mm (mean=469mm, mode=400mm). 11% had more than one computer on the desk.

NKID

The most frequent manufacturers of all NKID were: Microsoft (40%), Compaq (29%) and Logitech (7%). The most common number of buttons on a device was two (67%)

but ranged from 1-5. 20% of devices had 3 buttons. 95% of interviewees used a mat with their device.

The height of devices varied from 25-115mm (mean=36mm, mode=30mm). The width of devices ranged from 55-80mm (mean=63mm, mode=60mm). The distance devices were found positioned from the front of users' desks ranged from 100-1020mm (mean=623mm, mode=180mm).

Accessories

20% of interviewees had a screen filter. 10% worked with a document holder. 44% used a wristrest at the keyboard. 11% used a support (e.g. gel pad built into the mouse mat) with their device.

USE OF COMPUTERS & NKID

The mean number of years using computers was 12 (range 1-27 years). The mean length of time using computers in the current job was 5 years (range 2 months-16 years). Experience of using NKID ranged from 1 to 17 years (mean=8 years).

The mean number of hours per day spent using a desktop computer was reported to be 6 hours (range=4-12 hours). 67% of participants also used a desktop computer at home for an average of 1 hour per day (range=10 minutes-5 hours). Questions were also asked in relation to laptop computer use. 46% used a laptop at work, 23% used a laptop at home and 23% used a laptop at both work and home.

From the diaries it was apparent that the mean percentage of total work time (minus breaks) spent using an input device was 64%. The use of an input device varied from 2-100% of the working day. 20% expected their device use to increase in future.

The majority of interviewees (n=44) used a desktop computer, with only one person using a laptop as their main computer at their workstation. A range of NKID were seen during the interviews and these are listed in table 8. The majority of interviewees (89%) used a mouse. Devices used with laptop computers included a mouse (n=2), trackball (n=3), touchpad (n=3) and mini-joystick (n=3). Almost all users operated their NKID with their right hand.

Interviewees were asked about the intensity of their NKID use (see table 8). Continual was defined as very intense usage, where the hand is on the device the majority of time during the computer task (e.g. searching websites). Regularly was defined as moving between the keyboard and input device frequently when carrying out a task, such as the movements required when word processing. Occasional is where most work is done with the keyboard and the device was operated infrequently. The majority of respondents considered themselves to be regular users of the mouse and touchscreen. The majority of joystick mouse, trackball and CAD tablet users indicated 'continual' as their intensity of use. Some computer pen and touch pad users considered themselves intensive users, while others thought their use was regular.

Intensity of use could be related to the type of device, with some requiring more intense use than others. This might be due to the location and number of buttons on the device or the way in which users operate the devices. Alternatively this may be influenced by the nature of users' work or their workload. However, with the exception of one trackball user, who estimated that 100% of her daily computer work time involved using the trackball, there appears to be little evidence that these non-mouse users are spending more of their daily computer work time using their device than mouse users.

Table 8
Devices used with desktop computers by interviewees

Devices	% using device now*	Number using device now*	Range of daily computing time using device	Intensity of use
Mouse	91 (89% on a daily basis)	41	15-100%	10% continual 85% regular 5% occasional
Trackball	7	3	2-100%	67% continual 33% occasional
Touchscreen	7	3	20-50%	100% regular
CAD tablet	2	1	15%	100% continual
Computer pen	4	2	5-70%	50% regular 50% continual
Touchpad	7	3	2-70%	33% continual 33% regular 33% missing
Joystick	13	6	2-60%	33% continual 67% missing

* refers to all devices currently used (for some users this is daily use, for others this is once or twice a week). In addition, some interviewees used more than one device

TASKS & NKID USE

Exploration of the tasks completed with NKID indicated that the majority of work tasks (e.g. wordprocessing, database work, email) were conducted with the mouse. Table 9 shows the range of time spent on tasks each day.

METHODS OF NKID USE

To identify the purposes for which NKID are used, interviewees were asked to report how they carry out common tasks (table 10). Tasks included closing and opening files, cutting, pasting and highlighting.

Relatively few interviewees use keyboard shortcuts (e.g. 'Ctrl+X' to cut) to carry out tasks. Shortcut keys were reported to be used most extensively when pasting. The pull down menus at the top of the screen, icons on the menu bar and device buttons (used to activate menus without the mouse travelling to the top of the screen) are used more often. It appears that pull down menus at the top of the screen and icons on the menu bar are used frequently for opening and closing files and that device buttons activating menus are used more for highlighting and saving. This illustrates a reliance on NKID to perform tasks which are common features of computer work. It is also noticeable from the data that subjects used a variety of methods to perform these standard tasks.

Table 9
Tasks and NKID use

Work tasks (number who conducted tasks)	Range of time spent on task each day (minutes)	Device used for task (percentage of users)
Email (n=43)	4-300	88% mouse; 5% trackball; 5% joystick; 2% missing
Wordprocessing (n=39)	3-420	87% mouse; 3% trackball; 5% joystick; 5% missing
Spreadsheets (n=31)	10-300	81% mouse; 6% trackball; 3% joystick; 10% missing
Accessing database (N=27)	10-300	85% mouse; 4% trackball; 4%/joystick; 7% missing
Data Entry (n=30)	3-360	80% mouse; 6% trackball; 4% joystick; 10% missing
Statistics (n=18)	15-180	72% mouse; 11% trackball; 6% joystick; 11% missing
Graphics (n=22)	2-180	77% mouse; 9% trackball; 5% CAD tablet; 9% missing
CAD (n=7)	30-420	86% mouse; 14% CAD tablet
Programming (n=9)	30-315	67% mouse; 11% touchpad; 22% joystick
Accounting (n=8)	15-240	100% mouse
Control operation (n=4)	120	100% mouse
Information search (n=35)	10-240	91% mouse; 3% trackball; 3% joystick; 3% mouse and touchpad

Table 10
Main methods used by respondents to conduct standard computing tasks (respondents using other methods or combinations of methods not included)

Task	Keyboard shortcuts (%)	Pull down menus at top of screen (%)	Icons on menu bar (%)	Device button to activate menus (%)
Open	4	29	36	7
Close	4	16	36	7
Cut	2	12	18	22
Paste	36	4	13	27
Highlight	2	11	9	60
Save	0	2	7	89
Print	2	82	2	11

EXTENT OF PROBLEMS

Workstation

Workstation configurations varied considerably across and within organisations. Organisational issues also influenced the workstation set-up of some interviewees. Within some organisations, purchasing policies limited the desk configurations available to users. In most instances, users had little or no influence on the size, shape or orientation of the desk they worked at, as these were standard across the organisation.

Chair
22% of interviewees said their chair was uncomfortable. 13% said it did not offer sufficient back support. 67% did not adjust the chair during the day. 20% said their feet were not supported while sitting, with postural observations finding that 16% of users did not have adequate foot support.

Desk
Workstations were often cluttered, lacking in space, with desks set-up in such a way that made it difficult for the user to organise their equipment to suit their requirements. Monitor size may have had an impact on the lack of space on the desk, mean screen size (as measured diagonally) was 415 mm (range 310-530). 9% said their equipment was not within easy reach. 31% reported not having sufficient desk space. 9% did not have enough legroom. 22% had poor cable management.

Keyboard
11% of interviewees said they did not have enough space to rest their hands/wrists when working at the keyboard. 7% of keyboards did not have a matt surface. 13% of keyboards were not clean.

Display screen
25% of interviewees were not happy with the set-up of their screen. Observation indicated that 49% of screens were too low and 7% were too high. 8% of screens were not tilt adjustable. 7% of interviewees said the screen characters were not of adequate size. 49% had screen reflections and glare. 24% of users reported that they could not take actions to reduce these problems.

NKID position
It was observed that users were often required to place the input device at some distance away from the keyboard. The distance from the user to the NKID ranged 300-1100mm (mean=493mm). Measures of elbow angle were also taken while users were working, ranging from 95 to 165°, with a mean of 121°, suggesting that users hold their arm in an extended posture when operating their device.

All interviewees had a keyboard incorporating a numeric keypad. In addition to the keyboard, other factors observed to be affecting the placement of NKID included the arrangement of workstation furniture, equipment, desk, central processing unit and display screen. These affected the location of the keyboard, which in turn affected the placement of the pointing device.

General
42% of interviewees said their equipment was not maintained or cleaned. 29% had not received advice on health and safety. 47% had not had their workstation assessed (or did not know whether an assessment had taken place).

Mouse

89% (n=40) of the sample used a mouse. Pain or discomfort associated with use of the mouse was reported by 42% (n=19). Problems included feelings of weakness, stiffness and general discomfort in the wrist and hand when using the mouse for long periods. Strategies adopted by users to alleviate pain or discomfort were explored, however, often little had been done by the users themselves. Changing the hand operating the device was reported as one such measure.

20% of mouse users reported problems using their device. 7% of interviewees did not find the shape and button activation of the mouse comfortable or easy to operate. 13%

said they were unable to reach the device easily without stretching or leaning. 51% did not clean or have their device cleaned regularly. 82% had not received any training in the use of the mouse.

Another problem was mouse size. The mouse was reported to be too large by one interviewee and too small by another, so that it was difficult for them to operate the buttons and rest their hand comfortably.

Some users (7%) reported that their mouse mat slipped away over a period of time, causing the device to move away from their body, resulting in reaching and stretching when operating it.

Responsiveness and speed of the mouse were also identified as causing annoyance to some users, specifically, the mouse sticking, i.e. ball ‘sticking’ and ‘freezing’. A further problem for some users was being unable to access software facilities to change the speed at which the mouse operates.

Other Devices

64% of users used some other device besides the mouse (n=29). Pain or discomfort were reported by 16% of this group. 75% of other device users reported problems with non-mouse devices.

Touchscreens
Problems reported by touchscreen users included: unresponsiveness of the system, difficulty in scrolling through menus and the small size of print and buttons making it difficult to navigate through information. The screens also became very dirty, with multi-user workstations exacerbating this problem.

Pen/tablet
Difficulties associated with pen and tablet devices included the pen ‘freezing’ during use and the necessity for regular replacement. 11% were unhappy with the shape and button activation of the device, 13% had received no training in the use of the device, 2% experienced numbness in the right wrist and hand as a result of using the device and this interfered with their ability to grip the pen.

Trackball
Being unable to change operational settings was a problem for users of trackballs, i.e. the settings for buttons. While other devices, including the mouse, offer features allowing users to customise buttons, trackballs often allow further customisation to streamline tasks and address issues such as handedness. This problem arose due to organisational policy, with users not allowed access to the appropriate software control panels once the device had been installed on their computer.

Work Organisation

Interviewees were asked a range of questions exploring issues associated with work organisation e.g. breaks taken during the day, support offered by colleagues and supervisors. The definition of a break was left to the discretion of interviewees, with interpretation of this likely to have varied.

22% of interviewees said that the longest period of time worked at a VDU without a break was 2 hours, 18% reported 3 hours and 4% said 6 hours. A small number of users (2%) reported working at their VDU for up to 8 hours without a break.

Frequent rest breaks were not taken by 38% of interviewees and 9% of these did not take a lunch break. 56% had worked overtime in the last month. The total number of overtime hours worked ranged from 1 to 49 hours.

Results from further work organisation questions are presented in table 11. The majority of interviewees reported being required to work fast and intensively, with 24% of the sample never having enough time to do all the work required of them. Help and support is available to over 75% of interviewees. The majority said they have a choice in how they do their work but only 29% of the sample often have discretion over what they do at work. The majority (73%) are often able to decide when to take breaks.

Table 11
Work organisation factors (% respondents)

Work organisation factors	Often (%)	Sometimes (%)	Never (%)
Have to work very fast	36	62	2
Have to work intensively	53	47	0
Have enough time to do everything	22	53	24
Others help if not enough time	27	49	24
Have a choice in deciding HOW you do your work	69	24	7
Have a choice in deciding WHAT you do	29	47	24
Can you decide when to take your breaks	73	22	4

Pain or discomfort

Interviewees were asked about their recent history of pain or discomfort.

- 85% of interviewees reported muscular aches, pains and discomfort in the last 12 months
- 49% reported muscular discomfort in the last 7 days
- 60% reporting pain or discomfort experienced a change in their symptoms over the day, with symptoms getting worse as the day progressed
- 24% had been absent from work as a result of the pain or discomfort
- 40% had sought medical advice (e.g. seen their doctor) due to the pain or discomfort
- 40% had their aches and pains diagnosed medically. Diagnosed conditions included tennis elbow, 'RSI' and work related muscular stiffness, tenosynovitis, brachial neuralgia, a disc problem and arthritis
- 36% had taken medicine for these aches and pains. Medicines taken for aches and pains included a range of painkillers, aspirin and ibuprofen

Location of pain or discomfort

The occurrence of muscular aches, pains and discomfort among interviewees over the last 12 months is shown in table 12. The main body areas of concern were: the neck, lower back, right wrist and hand, the shoulders, upper back and knees.

Table 12
Pain or discomfort experienced by workplace interviewees over last 12 months (n=45)

Body area	Workplace users (%)
Neck	49
Lower back	47
Right wrist & hand	42
Right shoulder	31
Left shoulder	31
Upper back	31
Knees	22
Hips and thighs	18
Left wrist & hand	16
Right elbow	13
Ankles/feet	13
Left elbow	0

The occurrence of muscular aches, pains and discomfort among interviewees during the last 7 days is shown in table 13. The main body areas of concern were: the neck, lower back and right wrist and hand.

Table 13
Pain or discomfort experienced by workplace interviewees in last 7 days (n=45)

Body area	Workplace users (%)
Neck	22
Lower back	22
Right wrist & hand	20
Hips and thighs	13
Right shoulder	13
Knees	13
Upper back	11
Left wrist & hand	9
Ankles/feet	9
Left shoulder	7
Left elbow	2
Right elbow	0

Effects of pain or discomfort
35% said that the pain or discomfort had some or considerable effect on their work performance in general in the last 12 months. 15% said it had some or considerable effect on their keyboard use and 31% said it affected their device use.

18% had changed work tasks and 24% had altered their work pace because of back pain. 42% had changed their work posture, 16% had changed equipment, 9% had changed device.

Away from work, pain or discomfort had some or considerable effect on leisure activities (43%), sleep (29%), conducting housework (22%) and socialising (9%).

Causes of problems
67% of respondents thought their aches and pains were related to things they did or equipment they used at work including using the mouse for long periods, long duration and intensive typing, sitting in a poor position and an inadequate chair. 24% thought the aches and pains were related to things done away from work including sport, carrying heavy loads, stress outside of work, using their PC at home and driving.

Posture

Postural information was obtained through observation of participants working, table 14 (it was only possible to observe 44 of the 45 interviewees working).

Table 14
Postural risk assessment (n=44)

	Yes (%)	No (%)	Missing (%)
Sufficient space under desk	84	16	
Chair at suitable height	86	14	
'Good' back support	46	54	
'Good' foot support	80	16	4
Screen height/angle allows comfortable head/neck position	68	30	2
Shoulders held in good posture	34	64	2
Upper arms hang vertically	75	25	
Forearms approximately horizontal	93	7	
Minimal wrist extension/flexion	71	29	
Minimal radial/ulnar deviation	52	48	
Space in front of the keyboard to support hands/wrists	82	18	

In general, the main postures of concern were:

- Insufficient back support
- Flexed neck posture when looking at the screen, keyboard and documents
- Poor shoulder posture
- Poor forearm and wrist posture: wrists were frequently observed in extension during use of keyboards and NKID

Device risk assessment

Subjective ratings by the researchers, using predetermined scales, were made of several aspects of device use, through observing participants at work:

- 96% of those observed used their right hand to operate their device
- 89% had a ‘normal’ grip on the device, 4% had a ‘tight’ grip’
- In general the size of movements made with a device was ‘average’ (63% of users) as opposed to ‘small’ (29% of users) or ‘large’ (4% of users) (small= <5cm; average= 5-10 cm; large= >10 cm)
- The speed of device movement was ‘slow’ (9% of users), ‘normal’ (60% of users) and ‘fast’ (22% of users)
- 85% of interviewees moved the device ‘smoothly’

Arm support
The method of arm support adopted by subjects when using their NKID is shown in table 15.

Table 15
Subjects' NKID arm posture while working at their desk (n=45)

Supported on desk	**%**
Hand	2
Wrist	26
Lower arm	33
Wrist and lower arm	28
Hand and Wrist	7
Missing data	5

Some overlap is apparent as users changed their posture when operating the device. It was apparent that the posture adopted by subjects with regard to arm support was affected by desk size, shape and free space on the desk surface.

SUMMARY

- 45 NKID users, working for 9 different organisations, were interviewed and observed at their workstations
- Two thirds of interviewees worked at L-shaped desks, the majority of these having their computer positioned in the deep apex of the desk
- One fifth of L-shaped desk users had their VDU positioned on a narrow part of the desk
- In many instances organisational purchasing policies restricted the choice of workstation available to users
- Almost one third of users had insufficient desk space
- Almost half of interviewees worked at more than one workstation
- Almost all users had a desktop computer, with the majority using a 2 button mouse (Microsoft mouse most common, followed by Compaq)
- A small number of interviewees used a support appliance with their input device
- Some users had their NKID positioned at some distance away from their keyboard, requiring an extended arm posture when used
- Interviewees reported working at their computer for a significant proportion of the working day, 6 hours on average, with two thirds also using computers at home
- Many users reported working for prolonged periods without a break
- A majority of interviewees rated their intensity of mouse operation as regular use, as compared with continual and occasional use
- Most users used a combination of input device with pull down menus, icons and device button to activate menus, for performing computing tasks
- Few users used keyboard shortcuts for these tasks
- Two fifths of interviewees reported that their equipment is not maintained or cleaned
- Almost one third did not recall receiving advice on health and safety
- In some instances users are prevented from configuring their device (i.e. software settings) by organisational policy
- Two fifths of mouse users reported pain or discomfort attributed to mouse use
- Poor wrist and shoulder postures were observed among individuals working at their computer

STAGE FOUR

USER QUESTIONNAIRE SURVEY

Stage 4 of the research involved a questionnaire survey of a large number of users (target n=5000), supplementing the in-depth information obtained by the workplace interviews and assessments (stage 3). The questionnaire addressed the extent to which NKID are used for various tasks, how they are used, workstation configurations and the prevalence of musculoskeletal problems.

Self-report questionnaires do have limitations. The method relies on the memory of respondents and their ability to report accurately and reliably. Selection-bias is possible with, for example, persons having a particular interest in the topic (e.g. those who have experienced problems with NKID) more likely to respond than others. These limitations need to be considered when interpreting results. To reduce the effects of such influences in this study, the conclusions and recommendations at the end of this report are based on the findings of all of the study stages (i.e. literature review, workplace interviews and assessments, laboratory trials and expert consultation, in addition to the data from this questionnaire).

METHODS

A ten page questionnaire (Appendix 3) was used to gather information on respondent biographical details, extent and intensity of NKID usage, type of work activities conducted with NKID, workstation configurations, methods of NKID operation, views on device design, work organisation details and self-reported prevalence of musculoskeletal and visual symptoms. Respondents were not required to give their name.

The presence of pain or discomfort was investigated using the Nordic Musculoskeletal Questionnaire (Kourinka et al, 1987). This has been used in studies of Nordic workers and many British occupational groups, and therefore allows comparison of this study group with other working populations.

The questionnaire was developed and piloted among interested parties, including the HSE, ergonomics experts, DSE and NKID users.

As stated on the questionnaire, a donation was made to the UK registered charity (no. 1061934) Express Link-Up for every questionnaire returned. This charity provides computers in hospitals for children.

QUESTIONNAIRE DISTRIBUTION

Contacts in 45 organisations agreed to distribute questionnaires to NKID users. Initially 4719 questionnaires were sent out for distribution in this way during June/July 1999. However, 12 organisations then decided they could no longer assist with the study, leaving 3890 questionnaires with organisations. Follow up with the contacts indicated that in some cases it had not been possible for them to distribute all their questionnaires and that only 3550 had been handed out to users for completion.

The questionnaires were returned by individual respondents directly to the Robens Centre for Health Ergonomics. A return of 848 completed questionnaires represented a response rate of 24%.

As part of the distribution described above, a sustained effort was made with one company, willing to distribute a large number of questionnaires to their personnel (approximately 1000 employees), with the aim of achieving an increased response rate for comparison purposes. However the response rate for this organisation was similar to the overall sample (25%).

The implications of this response rate and any potential bias towards over representation of cases has been explored with reference to responses from the workplace interviewees (stage 3), later in the report.

BIOGRAPHICAL DATA

The sample comprised 42% male and 57% female respondents, having a mean age of 39 years (mode=27, range 17-64 years). 86% of the sample were right handed. The mean height of respondents was 171cm (mode=173cm, range 135-198cm). 19% of the sample smoked. These biographical details were similar to those of subjects participating in the workplace interviews (stage 3), although the workplace sample included a greater percentage of right handers (95%).

WORK BACKGROUND

The average number of years in the job was 11 (sd=19.8), ranging from less than 1 to 41 years (mode=1, median=4 years). 86% of the sample were full time workers, with 9% working part-time. The average (and modal) number of days worked per week was 5 (sd=0.9) but this varied from 1-7 days. The average number of hours worked per week was 38 (sd=9.2) (mode=35, range 7-78 hours). 55% of the sample said their working hours were flexible, 41% reported they were fixed.

Job Title

The job categories of respondents were wide ranging and the main job titles (n=656) are shown in table 16.

Other respondents (n=202) were grouped under 44 different job titles including personnel, design, site agents, estimators, buyers, researchers, scientists and facilities managers.

Business Sector

The questionnaire was distributed to users in a wide range of industrial sectors (table 17), working in organisations varying in size and number of NKID users. All LFS categories used in stages 2 and 3 of the research were surveyed.

WORKSTATION SET-UP

The majority of respondents (55%) had L-shaped desks with their computer screen positioned in the deep curve of the desk and their NKID to the right side of the keyboard. As observed for the workplace assessments (stage 3), this arrangement often means the arm receives more support from the desk when using NKID than at a traditional rectangular desk. A further 12% had L-shaped desks but placed the computer on the narrow part of the desk. 27% had a traditional rectangular desk and 3% had a separate VDU table in addition to their work desk. 32% worked at more than one workstation. 8% had more than one screen on their desk.

Table 16
Job titles of questionnaire respondents (n=656)

Job title	Number
Administration	100
PA/secretary	93
Finance	55
Office	51
Analyst	48
Manager	43
Nurse/senior nurse/adviser	39
IT	37
Student	34
Engineer	25
Health and safety	24
Customer services	23
Surveyor	16
Emergency response	16
Accountant	15
Social worker	13
Training	12
Fire officers	12

Table 17
Business sectors of questionnaire respondents

Business sector	% all respondents (n=848)
Insurance	25
Construction/civil engineering	16
Healthcare and social work	12
Education	8
Public administration and defence	6
Education and research	6
Ambulance service	5
Health and safety	5
Local government	5
Finance	4
Extraction and utility supply	3
Agriculture	3
Manufacturing	2

USE OF COMPUTERS

All questionnaire respondents used a desktop computer and 13% also used a laptop. The mean number of years using a computer in their current job was 4.8 (sd=4.7) (mode=1; range 1-25 years). The mean (and modal) number of hours worked on a desktop computer per day at work was 6 (sd=2.3). The mean number of hours using a desktop computer per day at home was 2 (sd=1.7) (mode=1 hour). The mean (and modal) number of hours worked on a laptop per day at work was 4 (sd=2.7). The mean number of hours using a laptop per day at home was 2 (sd=9) (mode=1).

USE OF NKID

The average number of years using NKID was 7.5 (sd=3.9) (mode=10, range 1-24 years). 19% thought their NKID use was likely to increase in future. It is evident from table 18 that the majority of respondents were daily mouse users who operate the device with their right hand.

Table 18
Devices used by questionnaire respondents

Device	% using device daily	% others using device at some point during week	Total % using device	Total % using device right handed
Mouse	90	4	95	89
Trackball	4	4	8	8
Touchscreen	3	4	7	7
Touchpad	2	5	7	7
Computer pen	1	2	3	3
Joystick	1	4	5	5
Puck and digitiser	<1	1	2	2
Optical/remote mouse	<1	2	2	2
Spaceball mouse	<1	<1	2	2
Voice software	<1	2	3	N/A

Other devices were used to a small extent by respondents. All other devices were used with the right hand. Trackball use was lower than at the workplaces visited in stage 3. A very small percentage of the sample were very occasional or non-users of NKID. The design of the questionnaire made it impossible to provide an accurate figure for this but it is unlikely these respondents amounted to more than 1-2% of the sample.

Mouse

A variety of mouse device models were employed. The main devices used (by 64% of users) are shown in table 19. Others included: Mitsumi (2%), Dell (1%) and Toshiba (1%). The number of buttons on different device models varied between 1 and 5. Two was the most common number of buttons on the device (82%); 10% had 3 buttons. 23% had a scroll wheel on the mouse.

Table 19
Questionnaire respondents using various mouse types

Mouse type	%
Microsoft	26
IBM	20
Compaq	11
Logitech	7

24% of questionnaire respondents used a wrist rest while working at the keyboard. 13% said they used support when using a mouse. 10% had support built into their mouse mat (e.g. a gel filled raised area to support the wrist).

Other NKID

11% of respondents used NKID other than the mouse on a daily basis. These included trackballs (4%), touchscreens (3%), touchpads (2%), joysticks (1%), computer pen (1%) and CAD tablets (1%). The main manufacturers of these devices were IBM, Compaq, Logitech, Sumagraphics, Toshiba and Philips (each accounting for 1% of all devices). 6% of these devices had 1 button, 2% had 2 buttons and 1% had 3 buttons. 1% of users had some form of support when using the device (e.g. built in support on trackball).

TASKS & NKID USE

Exploration of the tasks completed with NKID indicated that the majority of work tasks are conducted with the mouse. Respondents were asked to indicate the intensity of their NKID use (see table 20). Continual was defined as very intense usage, where the hand is on the device the majority of time during the computing task (e.g. searching websites). Regularly was defined as moving between the keyboard and input device when carrying out a task, such as the movements required when wordprocessing. Occasional is where most work is done with the keyboard and the device is operated infrequently. The majority of respondents considered themselves to be regular device users.

METHODS OF NKID USE

Variation in how NKID are used to conduct standard computing tasks was noted during the workplace assessments (stage 3) and followed up in the user questionnaire survey. To identify the purposes for which NKID are used, respondents were asked to report how they carry out common tasks (e.g. closing and opening files, cutting, pasting and highlighting), table 21.

Although keyboard shortcuts are used to carry out some tasks, the majority of respondents conducted tasks using pull down menus at the top of the screen, and screen icons at the top of the screen on the menu bar, particularly for opening, closing, saving and printing. Use of buttons on the device to activate menus are also used in some instances (e.g. for highlighting).

This illustrates a reliance on NKID to perform these common computing tasks. It indicates that the hand is frequently moving the mouse around the screen (e.g. moving the cursor to top of screen to press an icon) as opposed to operating the device in a stationary position to activate menus. It is also apparent that some people employ more than one method to perform these operations.

Table 20
Time, device and intensity in work tasks

Task (number of respondents who conducted task)	Minutes spent daily on task	Device used for each task (% respondents conducting task)*	Intensity of device use during task
Wordprocessing (n=663)	mean=113 mode=60 range=5-480	50% mouse 17% mouse/keyboard 15% keyboard	13% continual 71% regular 16% occasional
Email (n=549)	mean=54 mode=30 range=4-300	46% mouse 18% mouse/keyboard 10% keyboard	12% continual 74% regular 14% occasional
Spreadsheets (n=509)	mean=80 mode=30 range=5-420	51% mouse 21% mouse/keyboard 8% keyboard	13% continual 70% regular 17% occasional
Accessing database (n=465)	mean=84 mode=30 range=5-600	52% mouse 16% mouse/keyboard 10% keyboard	17% continual 67% regular 16% occasional
Data entry (n=391)	mean=94 mode=30 range=5-650	37% mouse 18% mouse/keyboard 17% keyboard	17% continual 60% regular 23% occasional
Information search (n=381)	mean=46 mode=30 range=1-360	60% mouse 11% mouse/keyboard 4% keyboard 1% trackball	26% continual 56% regular 18% occasional
Statistics (n=188)	mean=59 mode=60 range =3-420	35% mouse 16% mouse/keyboard 8% keyboard 1% trackball	11% continual 58% regular 31% occasional
Graphics (n=136)	mean=57 mode=30 range=5-435	43% mouse 11% mouse/keyboard	18% continual 40% regular 42% occasional
Accounting (n=123)	mean=88 mode=30 range=5-450	36% mouse 18% mouse/keyboard 2% trackball	10% continual 63% regular 27% occasional
Programming (n=105)	mean=159 mode=30 range=5-420	26% mouse 15% keyboard 13% mouse/keyboard	21% continual 40% regular 39% occasional
CAD (n=69)	mean=166 mode=30 range=2-480	34% mouse 12% mouse/keyboard 3% trackball 3% CAD tablet 2% pen	22% continual 30% regular 48% occasional
Games development (n=32)	mean=22 mode=30 range=5-50	23% mouse 3% joystick 3% mouse and keyboard	3% continual 25% regular 72% occasional
Control operations (n=32)	mean=45 mode=30 range=30-120	6% mouse 3% joystick 3% mouse and keyboard	31% regular 69% occasional

* results not listed for devices used by less than 1% of respondents and for respondents who did not indicate device used

EXTENT OF PROBLEMS

Workstation

Chair

13% of respondents found their chair uncomfortable and 22% said it did not offer sufficient back support. 15% could not adjust the chair to suit them during the day. 62% of the sample had armrests and 12% said the armrests were uncomfortable. 13% did not have their feet comfortably supported.

Table 21
Method used by questionnaire respondents to conduct standard computing tasks (including multiple responses)

Task	Keyboard shortcuts (%)	Pull down menus at top of screen (%)	Icons on menu bar (%)	Device button to activate menus (%)
Open	24	63	64	29
Close	21	52	59	26
Cut	27	29	49	36
Paste	28	28	49	37
Highlight	22	20	40	39
Save	25	48	60	18
Print	26	51	68	21

Desk

11% said the equipment they used regularly was not within easy reach on the desk. 7% had insufficient legroom. 25% did not have enough space on the desk. 34% had no say in how their workstation had been arranged.

Keyboard

14% of respondents did not have space in front of the keyboard to rest their hands occasionally. 11% said the keyboard was not in a comfortable position for typing.

Screen

7% said the height of the screen was not satisfactory. 10% were dissatisfied with the screen position. 3% said the screen image was not stable and 5% found the screen characters difficult to read. 39% had reflections and glare from their screens. 17% could not take action to reduce these reflections and glare problems.

General

23% of respondents believed their desk equipment was not maintained or did not know whether it was maintained adequately. 46% said their equipment was not cleaned adequately. 11% said there was no reporting system or that they did not know how to report equipment faults. 28% said they had received no advice on health and safety with regard to using a display screen.

Mouse

7% of respondents were unhappy with the size of their mouse while 8% were dissatisfied with the device shape. 2% indicated they found the buttons difficult to operate. 21% found the mouse movement jittery. 8% indicated their mouse was difficult to control. 6% had to stretch to reach their device. 10% were unhappy with how the workstation had been set-up with respect to using their mouse.

63% of respondents said their mouse was not cleaned regularly. 68% had not received training regarding how to use their mouse. 16% had experienced problems using their mouse. 17% had pain or discomfort that they thought was mouse related. 6% did not use a mouse mat. 20% said their mouse mat was not large enough.

Other NKID
Other NKID were used by 11% of the sample. The following percentages are based on the whole sample: 2% were unhappy with the size of the device, while 1% were dissatisfied with the shape. 2% indicated the buttons were difficult to operate. 1% found the device movement jittery. 2% indicated they experienced problems controlling the device. 1% had to stretch to reach the device. 1% were unhappy with how the workstation had been set-up with respect to using the device. 4% said the device was not cleaned regularly. 7% had not received training regarding how to use the device. 2% had experienced problems using devices other than the mouse. 2% had pain or discomfort that they thought was related to use of devices other than the mouse.

Work Satisfaction

A question focussing on job dissatisfaction indicated that 70% were occasionally dissatisfied with their job, 16% frequently dissatisfied and 2% always. 37% of respondents reported that the help and support received from supervisors was not satisfactory and 21% were dissatisfied with the help and support received from colleagues. 31% were not satisfied with their work as a whole.

Work Organisation

Respondents were asked how long they worked at the computer without taking a break. As in the workplace interviews (stage 3), the term ‘break’ was not defined and left to the respondent to interpret. The mean time reported was 146 minutes (sd=100.9). The modal (and median) amount of time spent working without taking a break was 120 minutes.

25% spent more than 1 hour but less than 2 hours continuously working at the computer. 23% of the sample said they worked at the computer for 120 minutes without taking a break. 41% said they worked for more than 2 hours at the computer without taking a break. 58% worked for these periods of time on a daily basis. 59% said they sometimes did not take breaks from their computer work, 6% said they never did. 35% said they sometimes did not take a lunch break, 4% said they never did.

Responses to questions concerning workload, pace, support, control and decision making at work are presented in table 22.

Table 22
Occurrence of work organisation factors

Work organisation factors	Often (%)	Sometimes (%)	Never (%)
Have to work very fast?	37	58	4
Have to work intensively?	48	48	2
Have enough time to do everything?	25	51	23
Others help if not enough time?	16	65	16
Have a choice in deciding HOW you work?	65	27	6
Have a choice in deciding WHAT you do?	36	43	19
Decide when to take your breaks?	65	27	2

The respondents often had to work fast and intensively and generally had a lot of work to do. This was also reflected in the interviews during the workplace assessments (stage 3). The questionnaire responses indicated that help was generally available if under pressure. Most respondents appeared to have control over how their work was conducted and when breaks were taken. Less control was apparent over what the users did at work, this being understandable as few people can choose the content of their work.

VISUAL SYMPTOMS

Self-reported visual symptoms existed among the questionnaire sample:

- 59% had experienced tired eyes in the last 12 months, 38% in the last 7 days
- 27% had impaired visual performance in the last 12 months, 14% in the last 7 days
- 31% had red or sore eyes in the last 12 months, 17% in the last 7 days
- 46% had headaches in the last 12 months, 23% in the last 7 days

52% thought their visual symptoms were work-related (e.g. looking at a computer screen most of the day, glare on screen, poor lighting, poor air conditioning). 12% said this affected how they set-up the workstation. 20% attributed their visual symptoms to things they do away from work (e.g. socialising, sports, driving, playing computer games).

Comparison with other workers

The visual symptom data for questionnaire respondents in this study have been compared to those of a sample of intensive keyboard users, table 23. The comparison group undertook computer work for 8 hours per day, with a lunch break and short break in the morning and afternoon (Woods and David, 2000).

Table 23
Visual symptoms experienced by questionnaire respondents and a group of intensive keyboard workers

Visual symptoms	This study (n=848) Last year (%)	Other (n=175) Last year (%)	This study (n=848) Last 7 days (%)	Other (n=175) Last 7 days (%)
Tired eyes	59	41	38	26
Headaches	46	30	23	12
Impaired visual performance	27	27	14	15
Red or sore eyes	31	26	17	16

Tired eyes and headaches were more common among respondents in this study, for both the last 12 months and last 7 days, than among the comparison group. Other symptoms were similar for the two groups.

PAIN OR DISCOMFORT

- 65% of respondents had experienced muscular aches, pains and discomfort during the last 12 months
- 43% reported muscular discomfort during the last 7 days
- 22% had sought medical advice (e.g. seen their GP) for these aches and pains
- 9% of respondents had been absent from work as a result of aches and pains within the last 12 months
- 14% reported having their aches and pains diagnosed medically; examples provided by respondents included 'RSI', tenosynovitis
- 17% had pain or discomfort that they thought was related to using a mouse; 2% attributed their pain or discomfort to other input devices (e.g. trackball, touchpad)

Location of Pain

The occurrence of musculoskeletal aches, pains or discomfort among respondents in the last year is shown in table 24. This information is presented in a similar format to musculoskeletal pain or discomfort results from other studies to allow comparison (e.g. Woods et al, 1999). The main body areas of concern were the lower back, neck, right shoulder, right wrist and hand.

Table 24
Pain or discomfort experienced by questionnaire respondents over the last 12 months

Body area	% (n=848)
Lower back	33
Neck	31
Right shoulder	20
Right wrist & hand	16
Upper back	15
Left shoulder	14
Knees	11
Fingers/thumbs	10
Hips/thighs	9
Ankles/feet	9
Right arm	7
Left wrist & hand	6
Right elbow	5
Left arm	2
Left elbow	1

Table 25 gives the occurrence of muscular aches, pains or discomfort over the 7 days prior to questionnaire completion. The lower back and neck were the most prevalent sources of pain or discomfort.

EFFECTS OF PAIN OR DISCOMFORT

Upper Limb Pain

24% of respondents said that upper limb pain has some or considerable effect on their work performance in general. 22% said it has some or considerable effect on keyboard use. 19% said it has affected their device use.

4% had changed their work tasks and 7% had altered their work pace because of the upper limb pain. 17% had changed their work posture, 8% had changed equipment and 3% had changed their device.

Table 25
Pain or discomfort experienced by questionnaire respondents during the last 7 days

Body part	% (n=848)
Lower back	21
Neck	21
Right shoulder	15
Right wrist & hand	10
Upper back	9
Left shoulder	8
Fingers/thumbs	8
Ankles/feet	7
Knees	7
Right elbow	7
Hips/thighs	6
Left wrist & hand	4
Right arm	4
Left arm	1
Left elbow	1

Away from work, upper limb pain was reported as having some or considerable effect on leisure activities (25% of respondents), sleep (25%), conducting housework (22%) and socialising (16%).

Back Pain

24% of respondents said that back pain has some or considerable effect on their work performance in general. 16% said it has some or considerable effect on their keyboard use and 11% said it affected their device use.

5% had changed their work tasks and 8% had altered their work pace because of back pain. 31% had changed their work posture, 11% had changed equipment, 1% had changed their device.

Away from work, back pain was described as having some or considerable effect on leisure activities (35% of respondents), sleep (31%), conducting housework (30%) and socialising (21%).

ATTRIBUTED CAUSES OF PAIN OR DISCOMFORT

Perceived Associations Between Work and Pain

37% of respondents thought their aches and pains were related to things they do or equipment they use at work (e.g. sitting in same position most of day, using the mouse for long periods, workstation set-up, poor chairs, lack of wrist support). 17% had pain or discomfort that they thought was related to the mouse; 2% thought their pain or discomfort was related to other input devices. 25% thought the aches and pains were related to things done away from work (e.g. sport and exercise, driving, gardening).

Analysis of Work Associations

The relationship between duration of computer use (1 hour to more than 8 hours per day) and the prevalence of pain or discomfort (last 7 days) among respondents has been examined in further detail (table 26 and figure 1).

Table 26
Prevalence (%) of pain or discomfort in last 7 days by duration (number of hours) of use

Body part/no. of hours	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**8+**
n	**22**	**46**	**48**	**73**	**118**	**170**	**137**	**94**	**117**
Neck	32	17	21	16	24	24	21	30	27
Right shoulder	14	13	13	15	17	16	11	21	20
Left shoulder	5	2	2	6	12	8	8	11	10
Right elbow	0	2	0	7	2	5	3	5	4
Left elbow	0	0	0	0	2	1	1	2	2
Right forearm	5	2	2	6	1	7	4	9	7
Left forearm	0	2	4	3	0	0	2	2	2
Right wrist & hand	5	4	4	14	8	13	8	18	16
Left wrist & hand	0	0	4	3	8	2	7	5	4
Upper back	9	2	8	14	10	7	9	15	15
Lower back	18	20	13	15	20	24	24	25	24
Fingers/thumbs	5	0	0	11	9	9	8	9	10

In general, an increase in the prevalence of self-reported symptoms is evident as the duration of time spent on the computer increases. This is particularly apparent for the shoulders, forearms, wrists and hands.

There are also differences in the prevalence of pain or discomfort between the left and right sides of the body for the wrists, forearms, shoulders and elbows. The prevalence of problems on the right side appears to be greater. The association between pain or discomfort for the right wrist/hand was significant ($p<0.05$, chi-square=5.6). Associations for other body parts were either not significant or had too few responses in cells to permit meaningful comparison.

It seems reasonable to hypothesise that the difference in pain on the right side of the body is due, primarily, to mouse rather than keyboard use. This is because keyboard interaction is expected to balance the workload fairly equally between both hands, whereas the mouse is generally used by the dominant hand only. Further research is needed to examine this suggestion.

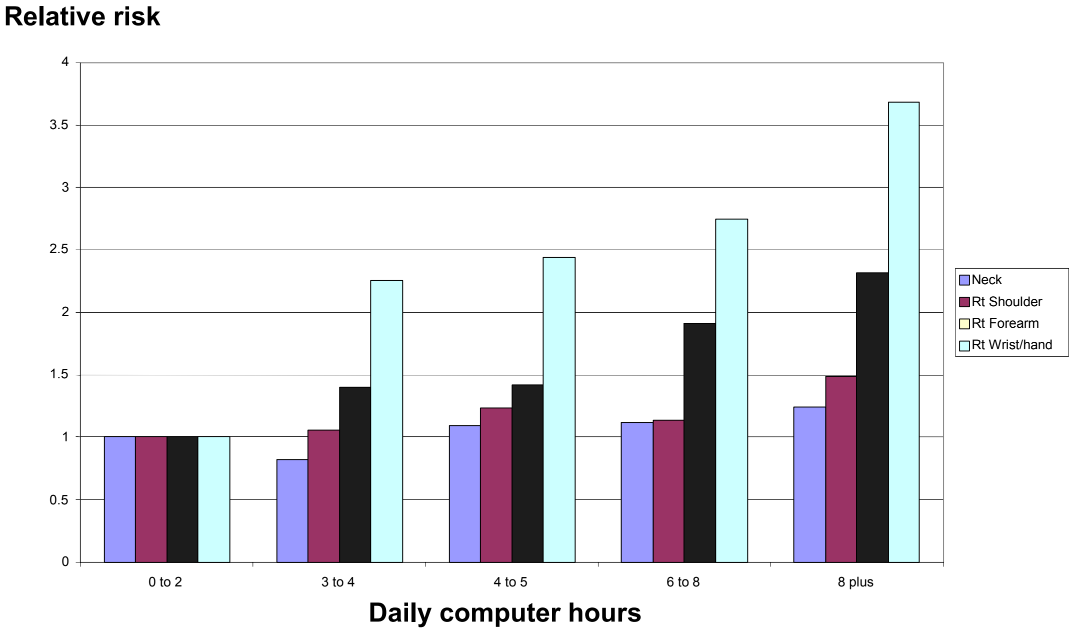


Figure 1
Daily computer hours and musculoskeletal symptoms

COMPARISON WITH OTHER WORK GROUPS

Comparison with Workplace Assessment Results (Stage 3)

Results from the user questionnaire survey (stage 4) have been compared with those from the workplace interviews (stage 3), to examine the likelihood of response bias with respect to case status (i.e. where cases are more likely to respond than non-cases).

In general, a lower annual prevalence of pain or discomfort was found for the user questionnaire respondents when compared with workplace interviewees (see table 27). A similar prevalence of pain or discomfort for the last 7 days was apparent in the two groups for the neck, lower back and shoulders. All other body parts, although similar, were lower in the user questionnaire group.

No evidence is apparent from this comparison of response bias relating to case status in the user questionnaire response group.

Comparison of Musculoskeletal Symptoms with Other Workers

The musculoskeletal literature suggests that levels of reporting of MSDs is greater for females than males. Annual prevalence rates for pain or discomfort among female (n=478) and male subjects (n=352) were compared with workers in other studies that have used the Nordic questionnaire (table 28). The Nordic reference set (Ydreborg & Kraftling, 1987) comprised assistant cooks, cleaners, nursery/outpatient nurses and secretaries.

Table 27
Pain or discomfort experienced by user questionnaire and workplace respondents

Body area	Questionnaire (n=848) Last year (%)	Workplace (n=45) Last year (%)	Questionnaire (n=848) Last 7 days (%)	Workplace (n=45) Last 7 days (%)
Neck	31	49	21	22
Lower back	33	47	21	22
Right wrist & hand	16	42	10	20
Left wrist & hand	6	16	4	9
Right shoulder	20	31	15	13
Left shoulder	14	31	8	7
Upper back	15	31	9	11
Knees	11	22	7	13
Ankles/feet	9	13	7	9
Left elbow	1	0	1	0
Right elbow	5	13	7	2
Hips and thighs	9	18	6	13

Table 28
Annual prevalence of musculoskeletal symptoms compared with male and female Nordic workers

	This study Females (n=478) (%)	Nordic Females (n=2586) (%)	Rel Risk	Conf Interval	This study Males (n=352) (%)	Nordic Males (n=343 4) (%)	Rel Risk	Conf Interval
Neck	33	37	0.89	0.78,1.82	30	25	1.2*	1.02,1.43
Shoulders	36	40	0.9	0.79,1.08	32	25	1.28*	1.10,1.50
Elbows	6	12	0.51**	0.35,0.73	8	11	0.72	0.50,1.04
Forearms	9	----			24	----	N/A	
Wrists/hands	21	23	0.91	0.75,1.10	9	14	0.65**	0.46,0.91
Upper back	15	11	1.37*	1.08,1.74	16	10	1.59*	1.23,2.07
Lower back	31	47	0.66**	0.57,0.76	36	44	0.82**	0.71,0.95
Hips	8	14	0.57**	0.41,0.78	9	12	0.76	0.54,1.07
Knees	10	20	0.5**	0.38,0.66	12	24	0.5**	0.37,0.66
Ankles/feet	8	16	0.5**	0.36,0.68	10	13	0.77	0.55,1.06
Fingers/thumbs	8	----			12	----	N/A	

* Study population had significantly ($p<0.05$) greater prevalence of reported problems than Nordic reference group
** Study population had significantly ($p<0.05$) lower prevalence of reported problems than Nordic reference group

In the present study, pain or discomfort data were collected for both right and left sides of the body. Other studies in the literature present more general data (e.g. shoulders, elbows). In order to compare the sample with other work groups, left and right side data have been combined as has been done in previous HSE studies (Mackay *et. al.*, 1998).

In the present study, 66% of female questionnaire respondents reported pain or discomfort in the last 12 months and 43% in the last 7 days. 65% of male respondents reported pain or discomfort in the last 12 months and 43% in the last 7 days.

The female data show that the prevalence of self-reported pain or discomfort in the elbows, lower back, hips, knees and ankles/feet are significantly lower than in the Nordic population. Pain or discomfort in the wrists and hands is similar to the Nordic group, whilst upper back pain is significantly greater than among the Nordic population.

For males, the prevalence of self-reported pain or discomfort in the wrists/hands, lower back and knees is lower than the Nordic reference group. Pain or discomfort in the neck, shoulders and upper back is significantly higher among this study group than the Nordic population.

This comparison suggests that, for both sexes, the musculoskeletal problems are generally less or comparable to a Nordic reference group. Exceptions relate to the upper back and, for males, the neck and shoulder regions. It should be noted that to some extent, variation between the Nordic reference group and the present sample might be expected due to geographical and occupational differences between the samples.

SUMMARY

- Results have been presented from a questionnaire survey with 848 respondents (24% response rate)
- Despite the low response rate, there is no evidence of selection bias related to presence of musculoskeletal symptoms
- The findings support those from the workplace interviews and assessments (stage 3), and provide additional quantification
- Over half of respondents had an L-shaped desk, typically with their computer positioned in the deep corner apex; a further one in ten L-shaped desk users had their computer positioned on a narrow part of the desk
- Almost all respondents had their input device positioned to the right of the keyboard
- One third of respondents worked at more than one workstation
- Use of the mouse was widespread, with most respondents using this device on a daily basis; other devices used to a much more limited extent were trackballs, touchscreens and touchpads
- 4 out of 5 respondents had a 2 button mouse, with the most common supplier being Microsoft, followed by IBM and Compaq
- 1 in 10 respondents had some form of wrist support for their mouse, most often incorporated into their mouse mat
- NKID were reported to be used most frequently with office application software, usually for word processing, spreadsheet and database work; data entry and email were also common activities requiring significant use of NKID
- Respondents performed computing tasks using a combination of pull down menus, icons and device buttons to activate menus; use of keyboard shortcuts were reported to be used more frequently than found in the workplace interviews, but still somewhat less than performing operations using an input device
- Almost one third of respondents said they had not received advice on health and safety regarding the use of their computer
- Almost two thirds of respondents indicated that their NKID was not cleaned or maintained regularly
- A sizeable minority criticised some aspect of the design or performance of their device

- Approximately two thirds of respondents said they had received no training in using their device
- The majority of respondents (64%) reported working at their computer for prolonged periods (two hours or more) without a break
- The majority of respondents had at least some discretion in deciding what work to do, how to do it and when to take breaks
- Almost one fifth of respondents (19%) had pain or discomfort attributed to using their device
- In general an increase in the prevalence of self-reported symptoms was noted as the duration of time spent on the computer increased, this being particularly evident for the shoulders, forearms, wrists and hands
- There were also differences in the prevalence of pain or discomfort between the left and right sides of the body for the wrists, forearms, shoulders and elbows, with the right side being greater (implicating mouse use as a possible risk factor)
- The prevalence of upper limb pain or discomfort in this survey was generally less than or comparable to those of a Nordic reference group. Exceptions relate to the upper back and, for males only, the neck and shoulder regions

STAGE FIVE

LABORATORY ASSESSMENTS

A three part laboratory assessment investigated device use and design issues. The laboratory work allowed examination of key aspects of NKID and their use under more controlled and standardised conditions than possible with the field investigations (presented in the preceding sections of this report, stages 2-4). The first component of the laboratory work involved an expert assessment of a range of devices (mice, trackballs and joystick mouse). The second element was a user trial, exploring mouse use, desk configuration and upper limb support. The third phase was a case study at a workplace, investigating the use and design of touchscreens.

EXPERT ASSESSMENT

27 experts evaluated a range of NKID. All worked in the field of health and safety (e.g. as ergonomists, physiotherapists, health and safety advisers and researchers/ lecturers).

Method

The experts were asked to provide background information (e.g. age, time spent using computers and devices used), to conduct three tasks, completing an assessment proforma for each device. The experts were asked to assess as many devices (eight in total) as time allowed.

The tasks were designed so that the major features and functions of devices were utilised (e.g. clicking, dragging, cutting, pasting, highlighting, scrolling). Task one involved the experts answering a questionnaire, scrolling through information and clicking answers. Task two was an editing task that required cutting, pasting and highlighting. Task three required the user to pick up a variety of shapes and drag and drop them into a different position on the screen. The same tasks were employed as for the subsequent user trial and took approximately twelve minutes to complete.

The questionnaire was based on previous research in this area and the results of other stages of this study. The questions related to four areas of device usage:

- General operation
- Device performance
- Device design
- Device comfort

Expert Details

The majority (70%, n=19) of the experts were right handed. 68% (n=18) were male, 32% (n=9) female. The mean age was 38.4 years (sd=9.1) (mode=31, range 23-58 years).

Computer and NKID Usage

As 6 subjects did not complete this section of the questionnaire, the percentages below are based on 21 experts.

The mean number of years the experts had used computers was 15.6 (sd=7.6) (mode 12, range 5-33 years). The mean number of years using NKID was 9.9 (sd=3.1) (mode 10, range 5-18 years).

The mean number of hours using a computer in a day was 4.9 (sd=2.2) (mode 3, range 1-10 hours). A small number of the experts (19%, n=4) also used a laptop during the working day, the mean length of time being 3 hours (sd=2.8) (mode 2, range 1-7 hours).

Like the workplace interviewees (stage 3) and the user questionnaire respondents (stage 4) the majority of experts were daily mouse users who operated the device with their right hand. 95% (n=20) reported using a mouse on a daily basis. One used it infrequently. 86% (n=18) operated the mouse with their right hand, 5% (n=1) with their left and 14% (n=3) with both hands. It is acknowledged that familiarity with mouse use may have influenced the expert evaluation, although the data still provide useful insights into general device design issues.

33% (n=7) of experts reported using a trackball infrequently, all with their right hand.

5% (n=1) said they use a touchpad on a daily basis, while 52% (n=11) worked with a touchpad infrequently. 48% (n=10) reported operating their device with their right hand, 10% (n=2) with their left hand.

29% (n=6) of experts reported using a touchscreen, but only infrequently. 14% (n=3) operated the touchscreen with their right hand, 10% (n=2) with their left and 5% (n=1) with both hands.

29% (n=6) indicated they use a joystick mouse infrequently. 5% (n=1) operating the device with their left hand, 24% (n=5) with the right.

One subject reported using a computer pen infrequently, with the right hand. One subject worked with a cordless mouse on a daily basis, two used a cordless mouse infrequently. All used the cordless mouse with the right hand. None of the subjects had used a puck and digitiser or a spaceball.

Devices

The eight devices evaluated by the experts were (table 29): 3 trackballs that differed in terms of size, shape and number of buttons (devices 2, 6, 7), 4 mice that differed in terms of numbers of buttons, shape and grip (devices 1, 4, 5, 8) and a joystick mouse that included support for the wrist (device 3).

RESULTS

The questionnaire responses are presented in 6 sections.

- Overall device ratings
- General operation

- Device performance
- Device design
- Device comfort
- Subjective comments

Table 29
8 non-keyboard input devices assessed by expert subjects

	**Device 1** Logitech mouse Buttons: 3 Material: Smooth plastic Size: 12cm (L) x 6cm (W) x 4cm (H) Shape: oval		**Device 2** Logitech large trackball Buttons: 4 and trackball Material: Smooth plastic Size: 21cm (L) x 9cm (W) x 7cm (H) Shape: curved with built in rest for right hand/wrist
	**Device 3** Joystick mouse Buttons: 2 Material: Smooth plastic Size: 11.5cm (L) x 8cm (W) x 10.5cm (H) Shape: joystick with built in support for wrist		**Device 4** Microsoft mouse Buttons: 2 Material: Smooth plastic Size: 13cm (L) x 6-7cm (W) x 3.5cm (H) Shape: slightly curved to suit right hand
	**Device 5** Kensington mouse Buttons: 4 and scroll wheel Material: smooth plastic Size: 15cm (L) x 8.5 cm (W) x 5cm (H) Shape: curved dome		**Device 6** Microsoft trackball Buttons: 2 for thumb on side, scroll wheel and trackball Material: Smooth plastic Size: 17.5cm (L) x 8.5cm (W) x 5cm (H) Shape: curved with space to rest right hand
	**Device 7** Logitech trackball Buttons: 2 and trackball Material: Smooth plastic Size: 16.5cm (L) x 8.5cm (W) x 5cm (H) Shape: curved to suit both hands		**Device 8** Logitech curved mouse Buttons: 1 thumb, 2 for fingers and scroll wheel Material: smooth plastic, with textured surface on sides Size: 15cm (L) x 6.5cm (W) x 4.5cm (H) Shape: curved, moulded to the right hand

L = length W = width H = height

Overall Device Ratings

Table 30 presents the percentage of subjects who rated the devices highly (either satisfied/very satisfied, very easy/easy or comfortable/very comfortable). From these crude percentages it is apparent that large differences existed in device preference. All experts were either satisfied or very satisfied with device 4, 75% with device 1 and 56% with device 8. These devices were all mice. In terms of overall operation, devices 1 and 4 were rated highly in all cases. Device 8 was thought to be very easy/easy to use by about half the sample. Device 4, followed by device 1 and then 8, were rated highest on the comfort scale. The results for devices 2, 3, 5, 6 and 7 on these scales were poor. Three of these devices are trackballs, one is a mouse and one a joystick mouse.

Table 30
% of experts who rated the devices highly

	1	2	3	4	5	6	7	8
Overall rating (very satisfied/satisfied)	75	0	17	100	9	20	22	56
Overall operation (very easy/easy to use)	100	9	8	100	9	40	30	56
General comfort (very comfortable/comfortable)	73	27	25	100	9	30	30	63

The means for overall satisfaction, general operation and comfort rating scores for each device are shown in table 31. Differences between devices are apparent from the mean and modal scores. As in table 30, mouse devices 1, 4 and 8 appeared to be considered most satisfactory overall although the modal score for device 8 was high. In terms of general operation and comfort devices 1, 4 and 8 were once again considered most satisfactory.

Table 31
Overall mean scores for devices

	Overall mean (& modal) satisfaction score*	Overall mean (& modal) operation score**	Overall mean (& modal) comfort score***
Device 1	2.3 (2)	4.3 (4)	3.5 (4)
Device 2	3.8 (4)	2.3 (2)	2.9 (3)
Device 3	3.6 (4)	2.7 (3)	2.8 (2)
Device 4	1.9 (2)	4.6 (5)	4.3 (4)
Device 5	4.0 (5)	2.4 (2)	2.3 (1)
Device 6	3.2 (4)	3.0 (2)	3.0 (3)
Device 7	3.3 (4)	3.0 (2)	3.1 (3)
Device 8	2.5 (4)	3.4 (2)	3.4 (2)

*Subjects rated devices on a scale of 1-5 from 'very satisfactory' to 'very unsatisfactory'. A lower mean and modal score implied greater satisfaction.
**Subjects rated devices on the general operation scale of 1-5 from 'very difficult to use' to 'very easy to use'. A higher mean and modal score implied easier use.
***Subjects rated each device on the general comfort scale of 1-5 from 'very uncomfortable' to 'very comfortable'. A higher mean and modal score implied greater comfort.

The analysis of overall scores for each device indicated that mice were rated more favourably in terms of overall satisfaction, operation and comfort than trackballs or the joystick mouse. It appears that the most typical 2 button mouse (device 4) was still the most liked device but that the 3 button mouse (device 1) and the curved mouse (device 8) were also favoured. As 95% of the sample used a mouse on a daily basis, it is possible that familiarity may have affected these ratings. 33% of the sample used trackballs but infrequently and 29% used a joystick mouse also infrequently.

In the following sections, analysis of the questionnaire results will explore the design and use issues that made devices 1, 4 and 8 more popular than other devices.

General Operation

The percentage of experts who agreed or agreed strongly with statements concerning the general operation of the devices (e.g. obvious how to use, operation speed) is given for each device in table 32 below.

Table 32
% of experts who agreed or agreed strongly for questions relating to the general operation of devices

General operation	1	2	3	4	5	6	7	8
Obvious how to operate device	93	14	42	100	8	65	100	56
Easy to discover how to operate	86	43	67	100	8	76	100	62
Device design enhances it operation	57	14	25	85	8	17	9	50
Easy to use	86	14	25	100	8	50	50	75
Kept making mistakes	0	57	58	8	65	40	50	19
Operation speed acceptable	79	46	50	100	27	60	50	75
Too complicated to use	0	50	33	0	73	20	20	38
Requires little effort to operate it	78	21	43	92	17	33	47	81
Cables do not interfere	93	93	83	85	92	92	82	93
Interaction between hard & software adequate	86	29	33	100	17	50	73	75
Prefer an alternative device	43	64	75	0	83	70	80	67

These results suggest that:

- Some devices are less intuitive to use: 3 devices scored less than 50% (devices 2, 3 and 5) on how obvious they were to use; ratings improved for some devices on how easy it was to discover how to use the device but ratings for devices 2 and 5 were still poor

- Some devices are not easy to use: devices 1, 4 and 8 were rated highly by many experts (at least 80%) as easy and uncomplicated to use. Over half the sample said they kept making mistakes with devices 2, 3, 5 and 7

- A number of devices were considered too slow to use: only 27% were satisfied with the speed of device 5

- 5 devices required too much effort to use: only devices 1, 4 and 8 were rated as requiring little effort to operate

- Cables were not a problem when using any device

- Interaction of the device with the software was a concern for devices 2, 3 and 5 (e.g. pointer speed, unclear regarding function of some buttons and controls)

- Many said they would prefer to use an alternative device except when they were using device 4

Device Performance

The percentage of experts who agreed or agreed strongly with statements concerning the performance of the devices (e.g. responds as would expect, adequate control) is given for each device in table 33.

Table 33
% of experts who agreed or agreed strongly for questions relating to the performance of devices

Device performance	1	2	3	4	5	6	7	8
Responds as would expect	93	29	25	92	8	33	64	56
Operates in same manner for similar tasks	93	57	83	92	50	67	91	80
Adequate feedback	84	79	50	92	33	68	64	81
Precision adequate	100	21	25	84	16	42	27	87
Responsiveness satisfactory	100	50	33	92	8	33	55	87
Adequate control	100	21	25	100	0	33	46	81
Allows precision task to be conducted	93	36	8	92	8	25	18	75
Feedback for button actuation	93	50	75	85	67	66	64	81
Too sensitive	0	50	33	8	36	40	50	6
Right level of control	96	7	8	92	18	10	20	69
Easy to select information on screen	86	21	25	100	27	30	20	75
Easy to place pointer	86	21	17	92	18	50	10	94
Easy to move pointer around screen	86	21	33	100	46	50	80	93
Force for actuation	71	55	58	91	55	70	90	56
Smoothness	79	64	50	91	55	60	67	81
Effort	64	27	17	91	36	40	50	75
Accuracy	71	18	8	100	20	20	20	60

These results suggest that:

- Some devices (devices 2, 3, 5, 6) did not respond as the experts expected; however the devices were consistent in their response for similar tasks
- Feedback from the devices appeared to be acceptable
- Some devices were not thought to be accurate or precise enough: devices 2, 3, 5, 6 and 7
- Device responsiveness was considered inadequate when using devices 3, 5 and 6
- Some devices were not considered sensitive enough, especially devices 2, 6 and 7
- Selecting information and placing the pointer was difficult with a number of devices (2, 3, 5 and 7)
- All devices were considered by over 50% of the sample to require adequate force for actuation
- Devices 2, 3, 5 and 6 were considered to require too much effort to use (i.e. not necessarily force but perhaps a need to stretch to reach controls)

- All devices were considered by at least 50% to be smooth to use

Device Design

The percentage of experts who agreed or agreed strongly with statements concerning device design (e.g. grip comfort, size of device) is given for each device in table 34.

Table 34
% of experts who agreed or agreed strongly for questions relating to device design

Device design	1	2	3	4	5	6	7	8
Design makes me feel positive towards use	71	7	25	92	17	17	9	50
Grip surface prevents slipping	71	71	50	77	50	58	55	81
Grasped easily	78	21	42	85	17	58	64	63
Can be positioned easily	86	64	25	92	42	58	55	69
Can be positioned quickly	71	57	25	84	17	42	36	88
Held without excessive effort	86	50	83	100	19	58	46	88
Design prevents inadvertent button activation	50	29	17	69	0	33	46	38
Shape of button assists finger positioning	50	21	36	85	25	58	36	62
Shape of button assists button actuation	64	29	50	77	25	50	27	50
The device does not cause unintended pointer movement	79	7	25	85	0	25	18	62
Operable by either hand	79	7	0	15	65	0	82	6
Does not cause pressure points that degrade performance	86	50	58	77	42	58	36	87
Device accommodates hand size	100	50	67	77	42	58	36	75
Device is stable, does not slip/rock	93	79	67	100	83	67	91	81
Device weight does not impair usability	93	86	83	100	75	67	100	87
Device size was satisfactory	86	39	50	100	18	60	30	69
Device shape was satisfactory	57	21	42	100	9	60	30	56
Could reach all buttons	79	29	65	100	27	70	60	75

As only the designs of devices 1, 4 and 8 made the subjects feel positive about using the device, this suggests there are design issues that need to be addressed. The results suggest that:

- The grip of some devices was not satisfactory: devices 2, 3, 5 and 7 were consistently rated low by over half of the experts for a number of aspects of the grip: difficult to grasp (2, 3 and 5), positioning (3 and 5) and holding the device (2, 5 and 7), pressure points from the grip (5, 7), unsatisfactory shape (2, 3, 5 and 7)

- Inadvertent hitting of device buttons/controls was a problem while using devices: only devices 1 and 4 scored well

- Reaching the device buttons was difficult on devices 2 and 5

- Button shape was considered unsatisfactory on devices 2, 3, 5 and 7

- Only devices 1, 5 and 7 were considered suitable for use by either hand

- Dissatisfaction with device size was apparent for some devices: 2, 5 and 7

- All devices were considered stable and a suitable weight by at least 65% of subjects

Device Comfort

The percentage of experts who agreed or agreed strongly with statements concerning device comfort (e.g. does not cause wrist pain or pressure points) is given for each device in table 35.

Table 35
% of experts who agreed or agreed strongly for questions relating to device comfort

Device comfort	1	2	3	4	5	6	7	8
Does not cause pressure points that cause discomfort	71	50	50	77	42	75	55	75
Operated without undue deviations of hand/wrist from neutral	64	54	50	62	25	43	64	69
Operated without undue deviations of fingers from neutral	64	21	58	68	33	33	27	69
Operated without undue deviations of arm from neutral	71	71	25	77	50	83	73	69
Operated without undue deviations of shoulder from neutral	79	79	42	92	67	92	91	69
Operated without undue deviations of head from neutral	93	86	92	100	75	100	100	88
Operated without undue deviations of neck from neutral	86	86	83	85	58	100	91	88
Very high/high finger fatigue	18	36	8	0	55	30	40	13
Very high/high wrist fatigue	0	18	42	0	64	20	40	25
Very high/high arm fatigue	0	9	25	0	27	0	10	25
Very high/high shoulder fatigue	0	0	25	0	9	0	0	6
Very high/high neck fatigue	0	0	0	0	9	0	0	0

It appears from these results that:

- Devices 1, 4, 6 and 8 caused the least problems with regard to pressure points. Over 45% of the sample thought that using devices 2, 3 and 7 resulted in pressure points; nearly 60% thought using device 5 caused pressure points

- At least 50% of the sample thought devices 3, 5 and 6 required the hand/wrist to be deviated from neutral

- More than 65% of the sample thought devices 2, 5, 6, 7 required the fingers to be deviated from neutral

- More than 55% of the sample thought device 3 required the shoulder and arm to be deviated from neutral

- 75% or more said all the devices could be operated without undue deviations of the head

- More than 40% of the sample thought device 5 required the neck to be deviated from neutral

- More than 30% of the sample thought using devices 2, 5, 6 and 7 resulted in very high or high levels of finger fatigue

- At least 40% of the sample thought using devices 3, 5, and 7 resulted in very high or high levels of wrist fatigue

- More than 25% of the sample thought using devices 3, 5 and 8 resulted in very high or high levels of arm fatigue

- 25% thought using device 3 resulted in very high or high levels of shoulder fatigue

- The majority of experts did not report high levels of neck fatigue in relation to using any of the devices

Subjective Comments

The expert comments concerning the mice evaluated are given in table 36. Comments for trackballs are presented in table 37. The comments fall into nine consistent categories and these give an indication of the main aspects of NKID design that are important and should be considered when selecting a device:

- Hand and finger position
- Size of device
- Shape of device
- Control of device
- Device precision
- Device sensitivity
- Ease of use/intuitive
- Ease of movement of device, buttons and trackball
- Suitable accessories e.g. suitability of size and material of mat

SUMMARY

The results of this expert assessment of a selection of mice and trackballs appear to favour the ‘traditional’ 2-button mouse (e.g. device 4). However, it is possible there may have been a bias effect with the expert panel, with the majority being regular mouse users. Nevertheless, the assessment raised important general points for the design and use of devices:

- It is important to ensure the size of a device is suitable for the user. Where a device is too large (e.g. too wide to grip sufficiently or too long), users can find it difficult to reach buttons. This can limit the control the user has over a device and result in unnecessary effort, perhaps with pain and discomfort a consequence

- A number of the trackballs had built-in support, where the user rests the full hand on the device. This may result in wrist deviations due to the height of the device above the work surface (e.g. device 2 was 7cm high)
- Subjective comments concerning trackballs indicated that fingers need to be held or 'float' above the device to avoid inadvertent button or ball activation. Some experts in the assessment indicated that this resulted in finger fatigue
- The shape of a device is also important in terms of user comfort. Awkward postures may result from certain shapes e.g. devices designed for the right hand (i.e. curved to fit the right hand) when used with the left
- The assessment showed that user perception of the accuracy and precision of devices varies. It is important that users feel they have control over a device and can use it to point to and select information easily
- Experts found some devices easier and more intuitive to use than others. Some were thought to be too complex. A number of devices had up to 5 buttons/controls for the user to work with. While this provides alternative options for the fingers and thumbs, clear information needs to be provided to ensure users understand the function of additional controls
- The experts expressed concern regarding the movement of some devices. Rolling of some trackballs was difficult as the ball was too large. Once again this could be related to the size of the device and whether the user can reach controls adequately. Adjustments may be required to the software settings of a device and it is desirable that users can change these easily
- It is important that a device is compatible with all software the user works with. Again, users need to be given information on how to access and change settings of the device e.g. pointer speed, function of the buttons
- The provision of a suitable mouse mat may be beneficial for some users. The mat should be of adequate size for moving the cursor around the screen; long travel distances are sometimes required (e.g. when moving the cursor from the bottom to the top of the screen). Different user techniques for working with devices affects the mat area required (i.e. some people move the mouse around the mat more than others). The material of the mat should provide enough friction for device movement to be predictable and smooth. Mat thickness should be kept to a minimum to avoid increased wrist extension

Obviously how important any of these design issues is depends on the length of time and the intensity with which a device is used. These findings have been incorporated into a Device Assessment Checklist (Appendix 4) and a Device Purchasing Checklist (Appendix 5).

Table 36
Subjective comments from experts on mice

Device 1 	**Negative** • Cramping in ring finger; design too wide in the front • Very awkward, large, difficult to control • Middle button not easy to use and not enough information on function (not self-evident) **Positive** • Precise, easy to move and use • OK • Works fine but only used left button and the double click button did not seem to work • Very easy to use! • Excellent
Device 3 	**Negative** • Higher perceived exertion • Forearm pain, difficult to control • Can't use index finger, I wanted to move pointer by moving joystick, not whole unit, don't like movement for the shoulder, not possible to use left handed; too sensitive to movement; I hate this thing, the height of the platform under the wrist is too high • Horrible • Movement of device feels a little awkward and difficult to be accurate, strain noted in wrist • Lack of familiarity, difficult to use it in the way the device information suggests, full support of forearm seems to inhibit movement, have to bend thumb to reach buttons, a lot of work for thumb and wrist movement, could develop pain and discomfort **Positive** • Higher comfort; when move the mouse, less precision • Ok with learning and experience • Needs larger mat or software adjustment to increase pointer speed; button not working as described, otherwise fairly comfortable • Quite easy to use
Device 4 	**Negative** • Familiar, feels very comfortable but wrist deviation **Positive** • Is this my favourite because it is familiar? • Precise, easy to use & move, higher perceived comfort for hand • OK • Easy to use • Excellent

Device 5 	**Negative** • Too large; complex, fingers have to float when not used which leads to discomfort in wrist; awkward wrist extension • No rest for the hand and fingers; could not figure out how to use button and scroll • Awkward, imprecise and uncomfortable • Difficult to control scroll function, kept over shooting • Extremely frustrating, too sensitive, too many buttons, poor shape: does not match hand shape • Not easy to use at all • Got used to it for clicking and editing, pain building up across back of hand; difficult to drag and drop, starts to hurt, too big for hand; less accuracy and precision **Positive** • Very nice aesthetics, works well too, buttons easily operable, not much effort needed
Device 8 	**Negative** • Like a traditional mouse; did not care much for the shape • Device is too tall, too much angle on my wrist, no left handed possibility, mouse mat on this desk was very low friction so impedes performance • Not easy to use • Highlighting difficult, sometimes just goes mad down page, have to get used to scroll **Positive** • Easy and comfortable to use; most comfortable with neutral wrist posture; scroll easy to use which reduced movement of wrist and hand • Brilliant: smooth, fitted well in hand, easy to operate and still very much like good old 2 button mouse • Really like shape

Table 37
Subjective comments from experts on trackballs

Device 2 	**Negative** • Ball rolled very poorly due to the bearings inside • Very difficult to use • Difficult hand position, cramp in wrist; difficult to roll ball to where I want it; click direction weird • Ache in forearm • Difficult to control, easy to miss button for double click as there are two buttons close together • Very fatiguing for fingers • Sometimes scroll runs away with you • Too big • Less accurate and a bit awkward for cut and paste: select whole word very quickly not individual letters • Requires hyperextension of the wrist and finger movement to roll the ball **Positive** • Initially not that easy to use but after a while it got better • Nice to use in some ways, fast but not too accurate • OK • Like light level of pressure needed for two upper buttons; lots of options for both fingers, rarely use thumb but this encouraged it
Device 6 	**Negative** • Better than device 5 but fingers still required to float to avoid inadvertent activation of ball • Difficult button placement; sensitive ball; only positive item is scroll wheel • Too awkward and imprecise • Difficult to control pointer with finger • Overshoot with trackball; good for drag and point tasks • Very fatiguing for fingers • Better than device 2 in some ways but easy to accidentally operate the ball, still necessary to extend index finger • Poor **Positive** • 2nd favourite trackball • Easy to use
Device 7 	**Negative** • Better than devices 5 and 6 but fingers still floating over ball; right hand button difficult to use • Did not like the friction of the ball; too loose • Strange to double click with pinkie; ball moves ok • Wrist pain, difficult to control pointer • Difficult to point precisely; tend to move trackball with tips of fingers so fingers are extended • Very poor **Positive** • Easy to use

USER TRIAL

An important observation from the workplace assessments (stage 3) was the variety of workstation furniture now in use, with a trend towards L-shaped or corner desks. The prevalence of L-shaped desks was confirmed by the user survey (stage 4), with 67% of respondents reporting having a workstation of this type. Differences in the way users support their arm during mouse use were also noted, affecting hand, arm and shoulder posture. Upper limb posture is a risk factor for musculoskeletal pain or discomfort, especially when constrained or held for long periods.

The user trial reported in the following sections investigated the merits of different desk and arm support configurations with respect to user comfort and health. The experimental conditions replicated situations observed during the workplace assessments.

Aims

The user trial aimed to investigate the effects of working with three arm support postures while using a mouse. Support methods were examined while subjects worked at two workstation configurations, a straight desk and an L-shaped desk. Dependent variables were muscle activity, wrist and finger posture and self-reports of comfort and effort.

EXPERIMENTAL PROCEDURES

Subjects

Twenty subjects were recruited to participate in the experiment according to the following criteria:

- More than 5 years experience of using NKID
- Right handed
- Aged between 18-50 years
- Male and female
- No previous history of upper limb disorders

Experimental Conditions

All subjects completed six experimental conditions: three arm support methods and two desk shapes, as illustrated in table 38.

Table 38
Experimental conditions

Desk 1 Standard straight			**Desk 2** L-shaped		
Forearm supported	Wrist supported	No support	Forearm supported	Wrist supported	No support

The methods of arm support were:

- 'Arm supported' - subject had forearm supported fully on the desk with the hand on the mouse
- 'wrist supported' - subject had only the wrist touching the desk with the hand on the mouse
- 'no support' - subject had only the hand on the mouse with no area of the forearm touching the desk.

Workstation Configuration

Two workstation configurations were used, a straight (rectangle) desk and a corner (L-shaped) unit, figure 2. Subjects were provided with an adjustable chair, without arm rests, and asked to adjust it so that their legs were well supported with their feet resting flat on the floor. A footrest was provided for use if required.

The mouse and keyboard were placed on a non-adjustable surface, at approximately elbow level. The monitor was positioned at a fixed height above the work-surface (300 mm to the mid point of the screen), at a distance of 550 mm from the desk edge. This distance was appropriate for both workstation configurations. The height of the desk was fixed at 720 mm. The angle of the monitor was set to be within the subject's 'normal line of sight'.

The monitor, keyboard and mouse were arranged in a 'typical' workstation arrangement with the keyboard placed directly in front of the monitor and the mouse and mouse mat located to the right of the keyboard. All users were familiar with this workstation arrangement. Subjects were instructed to place the device in a comfortable position for them while working but the position was very much determined by the condition, i.e. with the forearm fully supported the mouse would be located the forearm length away from the subject.

Figure 2
Workstation configurations showing straight and L-shaped desks
(front edge of straight desk is partially obscured by chair in this photograph)

Task

Subjects completed three tasks, these being shortened versions of the tasks described previously for the expert assessment (see Expert Assessment, Method Section). All three tasks were completed within a two-minute duration.

Measurement of Wrist and Finger Movement Using Electrogoniometry

Wrist and finger postures were measured using a Penny and Giles twin axis goniometer, (Penny & Giles, Model M180, Gwent, UK), and two finger single axis goniometers (G35). Penny & Giles electrogoniometers have been used widely in ergonomics and clinical studies and their validation accuracy has been assessed by Smutz *et. al.* (1994), with the conclusion that the system is capable of measuring wrist motion in three planes to an accuracy of 2-3º.

The electrogoniometers were used to record wrist flexion/extension (F/E) and wrist ulnar/radial deviation (U/R) on the right side. Additionally, electrogoniometers were used to record the movement of the thumb and index finger when operating the device.

The electrogoniometer was attached with double-sided (medical) adhesive tape and secured with adhesive medical tape. Goniometry recordings were analysed using the Penny and Giles DL1001 software analysis package.

Following goniometer mounting, calibration readings were recorded for maximum readings, with the subject's wrist (1) flexed, (2) extended, (3) radially deviated, and (4) ulnar deviated. Subjects were asked to hold their right arm and wrist as straight as possible for 5 seconds and then to flex their right wrist as far as possible, and hold the position for five seconds. They were then asked to re-straighten their wrist, and hold for 5 seconds, and then to extend it as far as possible and hold for 5 seconds before re-straightening. This was repeated for ulnar and radial deviation.

The values presented in the results section are mean values of degree of extension, flexion, ulnar and radial deviation.

Muscular Load

Muscle activity was measured throughout the trials from four separate muscles using a commercial EMG system (Model ME3000P; Mega Electronics Ltd; Koupio, Finland). Electromyography (EMG) is the detection and recording of electrical signals produced by muscle tissue as it contracts. The signal is detected by electrodes placed on the surface of the skin.

The muscles examined were the:

- Right first interossei (FDI) (hand)
- Right extensor digitorum (ED) (forearm)
- Pars descendent of the right (RTRAP) and left (LTRAP) trapezius muscles. (shoulders)

These muscles have been used in trials by other researchers (e.g. Wahlström, 2000) and were thought to be most indicative of muscular demands during mouse use.

Procedure for electrode placement
Self-adhesive surface electrodes were placed in pairs with a 35 mm inter-electrode distance. For the FDI muscle, the electrodes were modified (cut) resulting in an inter-electrode distance of 25 mm. Prior to attaching the electrodes, the skin was dry shaved as necessary and cleaned with alcohol.

Explanation of MVC's and RVE's
It is not possible to compare directly muscles or subjects because the output voltage of an EMG signal is not an absolute measure of muscle activity. A common procedure is to normalise the detected myoelectric signal so that subjects' results can be compared. The most common method is to represent the EMG activity as a percentage of activity recorded during a maximum voluntary contraction (MVC) of the muscle or during a standardised contraction, reference voluntary exertion (RVE). RVE's are used where it is impracticable to determine MVC's, as can be the case with larger muscles. In this study RVE was used for the trapezius muscles of the shoulder and MVC was used for the forearm and hand muscles.

Procedure for muscle activity measurement
At the beginning of the recordings the subjects performed standardised MVC's or RVE's to obtain the maximal or reference voluntary electrical activity (MVE/RVE). To set EMG baselines, subjects were instructed to relax for 30 seconds before the registrations and again after finishing the last test. When EMG registration was finished, data were transferred from the measuring equipment (ME3000) to a personal computer for analysis.

Trapezius (shoulder) muscles
The RVE contraction was performed with a 1 kg dumbbell in each hand, the subject sitting without back support, arms abducted 90º and the head in a neutral posture looking straight ahead. Each of the three contractions was performed over a 15 second period. The mean was then calculated from the three recordings to use for normalisation. The subject rested for one minute between the contractions.

Forearm muscles
When performing the MVC's for the forearm, the subject was sat with a neutral shoulder position, elbow flexed 90º and the forearm fully supported on the table, making sure the subject did not lift the forearm from the table. The contraction was performed while the researcher applied manual resistance to the fingers and hand.

Hand muscles
When performing the MVC's of the hand, the subject sat with a neutral shoulder position, elbow flexed 90º and the forearm fully supported on the table. The subject then applied force against the researcher's hand, keeping the arm on the table.

The contractions for the forearm and hand were performed three times with a minimum rest of 2 minutes between the contractions. The contraction was performed over a 5 second period each time. The mean activity was then calculated using the highest of the three MVC's to normalize subsequent data.

For general information on electromyography and its use the reader is directed to Chaffin *et. al.* (1999).

Subjective Ratings

Subjects were asked to rate the perceived effort (RPE) required to carry out each of the work methods in the experiment, using a modified Borg scale ranging 0 to 14 (0=no effort, 14=maximal effort), in six different body locations:

- Neck
- Shoulder (scapular)
- Right shoulder (upper arm)

- Right forearm
- Right wrist
- Right hand/fingers

Subjects were also asked to rate their comfort on a scale of -4 (poor comfort) to +4 (excellent comfort). Subjects were asked to report their comfort overall and for the following regions:

- Neck
- Right & left shoulder (scapular)
- Right & left shoulder (upper arm)
- Right forearm
- Right wrist
- Right hand/fingers

Verbal Protocol

During the trials subjects were asked to describe what they were doing when performing the tasks and provide comments with regard to the tasks, device, comfort and layout.

Treatment of Data

Paired t-tests were used to examine differences in means between samples. The paired Bonferroni Technique was applied to adjust the significance threshold to reduce the possibility of Type 1 errors occurring with repeated comparisons (Norusis, 1997). This yields the equivalent of the $p=0.05$ threshold usually used for a single comparison.

The non significant results for some comparisons may appear surprising (e.g. for right shoulder comfort, straight desk condition, table 53, and forearm comfort, straight desk condition, table 57). It should be remembered that the Bonferroni Technique leads to conservative significance thresholds, so as to reduce the likelihood of non significant differences being identified as significant by mistake. Also, paired t-tests take into account differences between individual paired raw scores. The pattern of these is not apparent when looking only at means and standard deviations.

Additional detail is given for significant comparisons in Appendix 6.

RESULTS

Twenty subjects took part in the experimental trials, 5 male and 15 female. All subjects were right handed. Anthropometric details and background information for the subjects are presented in table 39.

Table 39
Subject anthropometry and device usage (means for 20 subjects)

	Mean (mm)	Range (mm)
Hand length	176	110-215
Hand breadth	106	90-170
Forearm to hand length	271	240-315
Shoulder to elbow length	335	290-420
Shoulder breadth	404	350-480
Stature	1704	1537-1900
Sitting height	1313	1250-1420
Eye height	1208	1100-1300
Shoulder height	1035	900-1120
Elbow height	697	640-790

	Yes	No
Wears spectacles	7	13
Wears contact lenses	2	18
	Mean (years)	**Range (years)**
Number of years experience in using an input device	8	5-11
	Mouse	
Current device used most frequently	20	

The mean height to which subjects adjusted the seat was 490 mm (range 430-550 mm). Table 40 gives the mean distance at which the mouse was located from the midline of the subject for each experimental condition. Subjects were instructed to position the device in a comfortable position for them while working. For the forearm fully supported condition, the distance at which the device was located could be dependent on the forearm length of the subject. At the L-shaped desk, however, subjects often held their forearm at an angle, reducing the distance.

Table 40
Distance from subject to device (means for 20 subjects)

	L-shaped desk			Straight desk		
Distance from user to device	**Forearm fully supported**	**Wrist supported**	**No support**	**Forearm fully supported**	**Wrist supported**	**No support**
Mean (mm)	452	447	471	512	469	489
Range (mm)	180-550	330-590	330-580	430-690	330-550	200-640

Summary of Results for L-shaped Desk with Fully Supported Forearm Condition

Figure 3
Example of support and desk condition from the workplace and user trial (forearm supported)

Muscle Loading (n=15)	(Means)		**Effort*** (n=20)	
			Right shoulder	1.2
Hand	5	(%MVE)	Left shoulder	0.2
Forearm	6	(%MVE)	Neck	0.7
Right shoulder	11	(%RVE)	Right forearm	1.6
Left shoulder	5	(%RVE)	Right wrist	2.2
			Right hand & fingers	1.6
Movements of Wrist and Fingers (n=20)			**Comfort**** (n=20)	
			Overall	2.9
(Means in degrees)			Neck	2.4
			Right shoulder (scapular)	2.6
Wrist extension		46	Right shoulder (upper arm)	2.6
Wrist radial deviation		22	Left shoulder (scapular)	3.5
Thumb flexion		37	Left shoulder (upper arm)	3.5
Finger flexion		36	Right forearm	2.9
			Right wrist	2.4
			Right hand & fingers	2.7

* Higher score indicates increased effort
** Higher score indicates greater comfort

This configuration appeared to have low levels of muscle activity but increased wrist extension.

Summary of Results for L-Shaped Desk with Wrist Supported Condition

Figure 4
Example of support and desk condition from the workplace and user trial (wrist supported)

Muscle loading (n=15)	(Means)		**Effort*** (n=20)	
			Right shoulder	1.4
Hand	10	(%MVE)	Left shoulder	0.3
Forearm	6	(%MVE)	Neck	0.7
Right shoulder	20	(%RVE)	Right forearm	1.4
Left shoulder	8	(%RVE)	Right wrist	2.1
			Right hand & fingers	1.9
Movements of Wrist and Fingers (n=20)			**Comfort**** (n=20)	
			Overall	2.5
(Means in degrees)			Neck	2.4
			Right shoulder (scapular)	2.5
Wrist extension		36	Right shoulder (upper arm)	2.6
Wrist radial deviation		27	Left shoulder (scapular)	3.3
Thumb flexion		37	Left shoulder (upper arm)	3.5
Finger flexion		36	Right forearm	2.6
			Right wrist	2.2
			Right hand & fingers	2.6

* Higher score indicates increased effort
** Higher score indicates greater comfort

This arrangement appeared to increase the muscle activity of the hand and right shoulder, while decreasing the extent of wrist extension.

Summary of Results for L-Shaped Desk with No Support (Hand On Mouse Only) Condition

Figure 5
Example of support and desk condition from the workplace and user trial (no support)

Muscle loading (n=15)	(Means)		**Effort**[*] (n=20)	
			Right shoulder	2.0
Hand	12	(%MVE)	Left shoulder	0.4
Forearm	4	(%MVE)	Neck	1.0
Right shoulder	46	(%RVE)	Right forearm	2.4
Left shoulder	19	(%RVE)	Right wrist	2.8
			Right hand & fingers	2.5
Movements of Wrist and Fingers (n=20)			**Comfort**[**] (n=20)	
			Overall	2.5
(Means in degrees)			Neck	2.3
			Right shoulder (scapular)	2.0
Wrist extension	45		Right shoulder (upper arm)	1.8
Wrist radial deviation	25		Left shoulder (scapular)	3.3
Thumb flexion	37		Left shoulder (upper arm)	3.3
Finger flexion	37		Right forearm	2.4
			Right wrist	2.2
			Right hand & fingers	2.0

[*] Higher score indicates increased effort
[**] Higher score indicates greater comfort

This configuration appeared to have increased muscle activity for both shoulders. Wrist postures were similar to having the wrist only supported.

Summary of Results for Straight Desk with Fully Supported Forearm Condition

Figure 6
Example of support and desk condition from the workplace and user trial (forearm supported)

Muscle loading (n=15)	(Means)		**Effort*** (n=20)	
			Right shoulder	1.8
Hand	5	(%MVE)	Left shoulder	0.3
Forearm	10	(%MVE)	Neck	0.8
Right shoulder	3	(%RVE)	Right forearm	2.1
Left shoulder	10	(%RVE)	Right wrist	3.0
			Right hand & fingers	2.6
Movements of Wrist and Fingers (n=20)			**Comfort**** (n=20)	
			Overall	2.6
(Means in degrees)			Neck	2.3
			Right shoulder (scapular)	2.3
Wrist extension		44	Right shoulder (upper arm)	2.2
Wrist radial deviation		20	Left shoulder (scapular)	3.2
Thumb flexion		38	Left shoulder (upper arm)	3.2
Finger flexion		40	Right forearm	2.3
			Right wrist	1.8
			Right hand & fingers	2.1

* Higher score indicates increased effort
** Higher score indicates greater comfort

This arrangement appeared to have increased effort and reduced comfort ratings compared to the same arm support condition with the L-shaped desk.

Summary of Results for Straight Desk with Wrist Supported Condition

Figure 7
Example of support and desk condition from the workplace and user trial (wrist supported)

Muscle loading (n=15)	(Means)		**Effort**[*] (n=20)	
			Right shoulder	3.4
Hand	7	(%MVE)	Left shoulder	0.6
Forearm	11	(%MVE)	Neck	1.5
Right shoulder	15	(%RVE)	Right forearm	3.5
Left shoulder	10	(%RVE)	Right wrist	3.2
			Right hand & fingers	2.5
Movements of Wrist and Fingers (n=20)			**Comfort**[**] (n=20)	
			Overall	1.8
(Means in degrees)			Neck	1.9
			Right shoulder (scapular)	0.7
Wrist extension		36	Right shoulder (upper arm)	0.8
Wrist radial deviation		23	Left shoulder (scapular)	2.9
Thumb flexion		37	Left shoulder (upper arm)	2.9
Finger flexion		41	Right forearm	0.7
			Right wrist	1.2
			Right hand & fingers	1.5

[*] Higher score indicates increased effort
[**] Higher score indicates greater comfort

This configuration seemed to result in a raised level of effort for the right forearm and right shoulder compared to working with the forearm supported.

Summary of Results for Straight Desk with No Support (Hand On Mouse Only) Condition

Figure 8
Example of support and desk condition from the workplace and user trial (no support)

Muscle loading (n=15)	(Means)		**Effort*** (n=20)	
			Right shoulder	3.3
Hand	7	(%MVE)	Left shoulder	0.5
Forearm	9	(%MVE)	Neck	1.4
Right shoulder	42	(%RVE)	Right forearm	3.3
Left shoulder	36	(%RVE)	Right wrist	3.3
			Right hand & fingers	2.9
Movements of Wrist and Fingers (n=20)			**Comfort**** (n=20)	
			Overall	1.3
(Means in degrees)			Neck	1.2
			Right shoulder (scapular)	0.9
Wrist extension		39	Right shoulder (upper arm)	0.9
Wrist radial deviation		24	Left shoulder (scapular)	3.0
Thumb flexion		37	Left shoulder (upper arm)	3.1
Finger flexion		39	Right forearm	1.5
			Right wrist	1.3
			Right hand & fingers	1.8

* Higher score indicates increased effort
** Higher score indicates greater comfort

This arrangement appeared to result in higher levels of muscle activity in the shoulders, compared with the forearm supported and the wrist supported conditions.

Muscle Loading

Data from 5 subjects had to be excluded from the muscle activity analysis due to the electromyograms being of poor quality.

The tables below present the results of all conditions as a percentage of MVE or RVE, as appropriate (mean and sd for 15 subjects). The adjusted significance thresholds (adjusted using the paired Bonferroni Technique to allow for the multiple comparisons) are indicated in the tables. Significant pairings are indicated with *, with the significant pairs for support conditions identified with a square bracket. Further details for significant pairs can be found in Appendix 6.

EMG results are presented in tables 41 – 44 (see also table 1, Appendix 6).

Table 41
Muscle loading of the right first interossei (hand)

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	5	2	5	2	NS
Wrist only supported	10	3	6	2	NS
No support	12	4	7	2	*
Significance	*		NS		*p <0.001*

Table 42
Muscle loading of the right extensor digitorum (forearm)

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	6	3	11	3	*
Wrist only supported	6	2	11	3	*
No support	4	2	9	2	*
Significance	NS		NS		*p <0.001*

Table 43
Muscle loading of the right trapezius (right shoulder)

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	11	5	3	1	*
Wrist only supported	20	2	15	3	*
No support	46	11	42	6	NS
Significance	*		*		*p <0.001*

Table 44
Muscle loading of the left trapezius (left shoulder)

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	5	2	10	3	*
Wrist only supported	8	3	10	2	*
No support	19	2	36	3	*
Significance	*		*		*p <0.001*

Key observations:

- Working at the L-shaped desk generated lower muscle activity for the forearm and left shoulder

- The L-shaped desk had increased muscle activity for the hand and right shoulder

- Working with the forearm fully supported had the lowest muscle activity for the hand, right shoulder and left shoulder

- The no support condition had the highest muscle activity for the hand, right shoulder and left shoulder, but was lowest for the forearm

There is only limited scope to compare the findings of this study with those of others, due to differences in experimental arrangements. Wahlström *et. al.* (2000) investigated whether different methods of operating a computer mouse affected performance and musculoskeletal load. They found highest occurring muscle activity in the right and left trapezius (shoulder) while subjects worked with only their wrist supported. Lowest activity occurred when the forearm was fully supported. This is in line with our findings for the right shoulder but not the left, where no difference was present.

Table 45 presents muscle loading results for each measurement site from lowest to highest. Working at the L-shaped desk with the forearm fully supported consistently had low muscle activity compared with other experimental conditions. This suggests this configuration to be beneficial with respect to muscle fatigue.

Table 45
Muscle loading in order of activity (%MVE/RVE)

	Muscle			
	Hand	**Forearm**	**Right Shoulder**	**Left Shoulder**
Lowest Activity	**LF**	**LN**	**SF**	**LF**
	SF	LF	LF	LW
	SW	LW	SW	SF & SW
	SN	SN	LW	-
	LW	SF	SN	LN
Highest Activity	**LN**	**SW**	**LN**	**SN**

L= L-Shaped desk W= Wrist Supported F = Fully supported
S= Straight desk N= No support

Movement of the Wrist and Fingers

The means, standard deviations and indications of significance for wrist, thumb and finger postures are shown in tables 46-49 (see also tables 2-3, Appendix 6).

Table 46
Mean wrist posture (extension)

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	46	7	44	10	NS
Wrist only supported	36	14	36	9	NS
No support	45	10	39	12	NS
Significance	*		NS		*p<0.01*

Table 47
Mean wrist posture (radial deviation)

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	22	6	20	4	NS
Wrist only supported	27	3	23	4	*
No support	25	3	24	5	NS
Significance	*		NS		*p<0.01*

Table 48
Mean thumb posture (extension)

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	37	12	38	13	NS
Wrist only supported	37	16	37	14	NS
No support	37	13	37	15	NS
Significance	NS		NS		*p<0.01*

Table 49
Mean index finger posture (flexion)

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	36	10	40	10	NS
Wrist only supported	36	9	41	10	NS
No support	37	9	39	12	NS
Significance	NS		NS		*p<0.01*

Key observations:

- Wrist extension was prevalent in all conditions, although was least for the wrist only supported situation

- The forearm fully supported condition had least radial deviation, although differences between conditions were small

- Working at the L-shaped desk had slightly reduced finger flexion than for the straight desk, although differences were small and statistically non significant

- Thumb extension appeared unaffected by experimental condition

A neutral (or straight) wrist posture is likely to minimise the stress on tissues passing through the wrist. Of particular concern for upper limb disorders are the tendons and median nerve where they pass through the carpal tunnel. Probable mechanisms leading to the syndrome include stretching or compression of the median nerve at the wrist and ischemia (Buckle, 1997). There is also good evidence that the pressure in the carpal tunnel increases greatly with the wrist in extreme postures (Hagberg *et. al.*, 1995). Wrist postures where there is inward or outward rotation, with the wrist bent, excessive palmar flexion or extension, ulnar or radial deviation, or pinching or high finger forces with any of these postures, should be avoided (OSHA, 1991).

Hünting *et. al.* (1981) found wrist extension of greater than 20º to increase pain and pathological findings. Burgess-Limerick *et. al.* (1999) defined extreme wrist extension as that being greater than 30º. All experimental conditions had wrist extension exceeding these criteria. If the wrist postures found in this experiment were maintained for prolonged periods of time, the results suggest musculoskeletal discomfort or injury could occur.

Table 50 gives the wrist, thumb and index finger movements, as measured by the electrogoniometers, from lowest to highest movement. No particular pattern is apparent across conditions.

Table 50
Highest and lowest levels of wrist, thumb and index finger movements

	Movement			
	Wrist Flexion & Extension	**Wrist Ulnar and Radial Deviation**	**Thumb Flexion & Extension**	**Index finger Flexion and Extension**
Lowest Activity	LW	SF	LF, LW, SN	LF, LW
Highest Activity	LF	LW	SF	SW

L= *L-Shaped desk*
S= *Straight desk*
F = *Fully supported*
W= *Wrist Supported*
N= *No support*

Comfort

Results of the subject's comfort ratings are presented in tables 51-59 (see also tables 4-6, Appendix 6). Comfort scores range from -4 (poor comfort) to +4 (excellent comfort).

Table 51
Mean overall comfort scores

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	2.9	1.4	2.6	1.5	NS
Wrist only supported	2.5	1.7	1.8	1.4	NS
No support	2.5	1.8	1.3	2.2	NS
Significance	NS		NS		*p<0.001*

Table 52
Mean comfort scores for the neck

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	2.4	1.9	2.3	1.7	NS
Wrist only supported	2.4	1.8	1.9	1.9	NS
No support	2.3	1.9	1.2	2.0	NS
Significance	NS		NS		*p<0.001*

Table 53
Mean comfort scores for the right shoulder (scapular)

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	2.6	1.4	2.3	1.4	NS
Wrist only supported	2.5	1.9	0.7	1.7	NS
No support	2.0	2.2	0.9	2.4	NS
Significance	*		NS		*p<0.001*

Table 54
Mean comfort scores for the right shoulder (upper arm)

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	2.6	1.8	2.2	1.6	NS
Wrist only supported	2.6	2.3	0.8	1.7	NS
No support	1.8	2.3	0.9	2.6	NS
Significance	*		*		*p<0.001*

Table 55
Mean comfort scores for the left shoulder (scapular)

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	3.5	0.6	3.2	1.1	NS
Wrist only supported	3.3	0.9	2.9	0.9	NS
No support	3.3	1.4	3.0	1.0	NS
Significance	NS		NS		*p<0.001*

Table 56
Mean comfort scores for the left shoulder (upper arm)

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	3.5	0.6	3.2	0.9	NS
Wrist only supported	3.5	0.9	2.9	1.1	NS
No support	3.3	1.3	3.1	0.9	NS
Significance	NS		NS		*p<0.001*

Table 57
Mean comfort scores for the forearm

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	2.9	1.2	2.3	1.1	NS
Wrist only supported	2.6	1.5	0.7	1.4	NS
No support	2.4	1.9	1.4	1.9	NS
Significance	*		NS		*p<0.001*

Table 58
Mean comfort scores for the wrist

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	2.4	1.4	1.8	1.4	NS
Wrist only supported	2.2	1.6	1.1	1.7	NS
No support	2.2	1.9	1.3	2.0	NS
Significance	NS		NS		*p<0.001*

Table 59
Mean comfort scores for the hand and fingers

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	2.7	1.1	2.1	1.2	NS
Wrist only supported	2.6	1.6	1.5	1.7	NS
No support	2.0	1.9	1.8	2.0	NS
Significance	NS		NS		*p<0.001*

Key observations:

- The highest overall comfort score was obtained for the L-shaped desk, with the forearm fully supported

- Working at the L-shaped desk generally yielded higher comfort ratings than the straight desk, although in no instance was the difference statistically significant

- Working with the forearm fully supported was consistently most comfortable, with differences statistically significant for the right shoulder and forearm body areas

- The no support condition was least comfortable overall, while the combination of straight desk with wrist only supported was least comfortable for many body regions

Table 60 gives the conditions having the highest and lowest comfort ratings. In this trial, the L-shaped desk and fully supported forearm proved most comfortable.

Table 60
Conditions with highest and lowest levels of comfort

	Highest comfort rating	**Lowest comfort rating**
Overall	**LF**	**SN**
Neck	LF, LW	SN
Right Shoulder (scapular)	LF	SW
Right Shoulder (upper arm)	LF, LW	SW
Left shoulder (scapular	LF	SW
Left Shoulder (upper arm)	LF, LW	SW
Forearm	LF	SW
Wrist	LF	SW
Hand & Fingers	LF	SW

L= *L-Shaped desk*
S= *Straight desk*
F = *Fully supported*
W= *Wrist Supported*
N= *No support*

Effort

Results of the subject's effort ratings are presented in tables 61-66 (see also tables 7-8, Appendix 6). Effort scores on the 14 point modified Borg scale ranged from 0 (no effort) to 14 (maximal effort).

Table 61
Mean effort scores for the right shoulder

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	1.2	1.5	1.8	1.2	NS
Wrist only supported	1.4	1.6	3.4	1.7	NS
No support	2.0	1.5	3.3	1.7	NS
Significance	*		NS		*p<0.01*

Table 62
Mean effort scores for the left shoulder

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	0.2	0.4	0.3	0.6	NS
Wrist only supported	0.3	0.8	0.6	0.6	NS
No support	0.4	1.0	0.5	0.8	NS
Significance	NS		NS		*p<0.01*

Table 63
Mean effort scores for the neck effort ratings

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	0.7	1.1	0.8	1.1	NS
Wrist only supported	0.7	1.2	1.5	1.4	NS
No support	1.0	1.6	1.4	1.5	NS
Significance	NS		NS		*p<0.01*

Table 64
Mean effort scores for the forearm effort ratings

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	1.6	1.2	2.1	1.1	NS
Wrist only supported	1.4	1.2	3.5	1.5	NS
No support	2.4	1.0	3.3	1.3	NS
Significance	*		*		*p<0.01*

Table 65
Mean effort scores for the wrist

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	2.2	1.2	3.0	1.3	NS
Wrist only supported	2.1	1.4	3.2	1.7	NS
No support	2.8	1.4	3.3	1.7	NS
Significance	*		NS		*p<0.01*

Table 66
Mean effort scores for the hand and fingers

	Desk shape				
	L-shaped desk		Straight desk		**Significance**
Support method	Mean	SD	Mean	SD	
Forearm fully supported	1.6	1.1	2.6	1.4	NS
Wrist only supported	1.9	1.5	2.5	1.6	NS
No support	2.5	1.5	2.9	1.9	NS
Significance	*		NS		*p<0.01*

Key observations:

- Effort ratings were low in all conditions
- The L-shaped desk consistently had lower effort ratings than the straight desk, although none of the comparisons was statistically significant
- Working with the forearm fully supported was perceived as requiring least effort of the arm support conditions, with differences for the right shoulder, forearm, wrist, hand and fingers being significant

The pattern of highest and lowest effort ratings is presented in table 67.

Table 67
Conditions rating highest and lowest levels of effort

	Right Shoulder	Left Shoulder	Neck	Forearm	Wrist	Hand & Fingers
Lowest effort rating	LF	LF	LF	LW	LW	LF
Highest effort rating	SW	SW	SW	SW	SN	SN

L= *L-Shaped desk*
S= *Straight desk*
F = *Fully supported*
W= *Wrist Supported*
N= *No support*

Verbal Protocol

Common remarks made by subjects during the experiment are given in tables 68-69, separated by method of arm support and desk.

Table 68
Examples of comments concerning different methods of arm support

No support: Very uncomfortable in shoulder, neck and arm Can feel more discomfort or is it effort in my arm Feels so much more different in the top of my arm and in my shoulder
Forearm fully supported: Need to sit differently for this method Can move my mouse around much better now Have to extend your arm for this one to get arm on the desk
Wrist supported: This is more comfortable, don't know why I don't have to move my arm as much for this method although I still think I'd prefer more support This is nearer the way I'd normally work

Subjects were asked to state their preferred method of support after completing all six experimental trials. 12 subjects preferred working with full arm support, 4 with the wrist supported, 3 said they would prefer a compromise somewhere between having the wrist supported and the forearm fully supported, and 1 subject was undecided.

Working without support was not satisfactory for any of the subjects, with many finding this method extremely uncomfortable or difficult to adopt. This was the case for both the L-shaped and straight desk.

When asked which desk they would prefer to work at, 18 of the 20 subjects stated the L-shaped desk.

Table 69
Examples of comments concerning alternative desks

L-shaped desk: Generally feels better Can get mouse closer to me Can rest left hand on desk if working for a longer period
Straight desk: I would have to move the keyboard if I was working at this desk for longer to get mouse in a good place After working at curved this feels less comfortable There's just not as much room (as with the L-shaped desk)

CONCLUSIONS

Our subjects preferred the L-shaped desk and working with the arm fully supported. Overall, this combination had best comfort and effort scores and lowest muscle activity. Although wrist extension was greatest in this situation, undesirable wrist extension was present across all experimental conditions. This may cause problems with prolonged exposure.

User Trial Limitations

The data collection for each condition was made during a period of two minutes. While this was sufficient to collect valid data for muscle activity and posture, it is quite possible that comfort and effort ratings would have deteriorated with longer use.

The trial did not consider the interaction between user anthropometry and desk radius of curvature. It is possible that different body sizes may require different desk dimensions for the L-shaped desk to retain its advantages.

SUMMARY

- A laboratory based user trial examined muscle activity, posture, subjective comfort and effort, using a standard two button mouse, for two desk shapes and three methods of arm support
- The different conditions replicated those observed in workplace assessments undertaken during a previous stage of the research
- The L-shaped desk generally had lower levels of muscle activity for the right forearm and left shoulder, but slightly higher levels for the right shoulder and right hand
- Muscle activity was least when working with the arm fully supported on the desk and greatest when working with the arm unsupported, although differences were found between muscle locations, e.g. forearm muscle activity appeared lowest working with no support

- Mouse operation always required an extended wrist posture and this is a cause for concern
- For the short duration exposures in this experiment, subjects generally rated the L-shaped desk as most comfortable and preferred to have the forearm fully supported on the desk
- Working with the arm unsupported was generally rated as least comfortable
- Least effort was reported when subjects worked at the L-shaped desk and with the forearm fully supported

TOUCHSCREEN CASE STUDY

Touchscreens are increasingly found in control room and call centre operations and it seems likely that their use will increase in future. In view of this, a case study was undertaken to explore particular issues surrounding touchscreen use. Although work has been conducted on touchscreen design in the past (e.g. Cakir *et. al.*, 1980), there are few recent studies addressing their use or the implications for users.

The touchscreen evaluation took place at a fire control room, with five multi-user workstations (figure 9). Although use of the touchscreens is an integral part of the fire control operators' work, use of the screen is not intensive. The screen is used to receive and end fire calls, involving two touches of the screen. Searches through databases and other administrative tasks (e.g. making phone calls) require greater usage of the screen. In addition to the touchscreen, there were two other VDUs on each desk (and an additional monitoring screen on the supervisor's desk). Interaction with one of the other VDUs was by mouse, the other using the keyboard. Due to the workstation layout, the operator used the touchscreen with the left hand and interaction with the other VDUs/devices was with the right hand.

Figure 9
Touchscreen workstation in fire control room

METHODS

Four female operators, on duty at the time of the site visit, completed the questionnaire developed for stage 4 of this study (user questionnaire survey). This questionnaire focussed on the extent to which different types of NKID are used, their applications, where the equipment is positioned on the workstation and problems associated with device use. User interviews were also conducted (as per stage 3, workplace interviews and assessments). The interview concentrated on satisfaction with the position of the screen on the desk (i.e. height, reach), environmental problems (i.e. reflections and glare), adjustability, degree of force required to operate the screen, the design and layout of the touchscreen and any pain or discomfort experienced. Direct postural observations were made while the operator was using the touchscreen. Video footage and photographs were taken during the shift to enable additional examination of posture off-site. The use of electromyography (EMG) was explored within this setting and appeared to be a suitable methodology for future studies of touchscreen operation. The limited EMG data collected are not suitable for presentation in this report.

RESULTS

Workstation and Touchscreen Assessment

The workstations were L-shaped with 3 screens on each desk. Two screens were in front of the operator and the touchscreen was placed to the left. The desk dimensions met the requirements of the Display Screen Equipment (DSE) Regulations and guidelines for office furniture in terms of length, depth, height and available legroom. Cable management was satisfactory. The users sat in large chairs with armrests. The chairs were difficult to move around at the workstation.

The dimensions of the VDUs complied with the DSE Regulations, but were placed only 290mm and 320mm from the desk edge. A greater distance from the screen to the users eyes is desirable. The mouse in use with one VDU required the user to reach to operate it (approximately 900mm from the shoulder to the device).

The CIM touchscreen had a black and grey background with little use of colour (figure 10). The screen was relatively small at 240 x 295 mm. The size of the screen buttons (areas the operator needs to press) varied and some were considered small for fingers (e.g. 18mm x 14mm). ISO 9241-9 (2000) states that the size of touch sensitive areas should be at least equal to the size of the ninety-fifth percentile male distal (digit 2) joint breadth. Data from Adultdata (DTI, 1998) indicate this would require a button size of at least 20x20 mm.

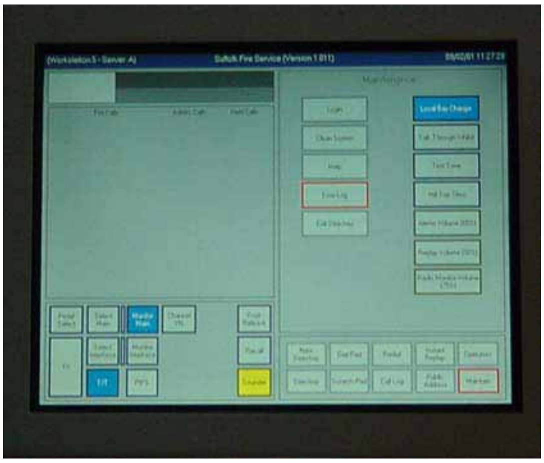


Figure 10
CIM touchscreen interface

Users are required to scroll through screens for some tasks. This action takes time due to a poorly designed scroll function in this implementation.

The screen was adjustable in tilt and to a small extent in height (about 60mm). However, the adjustment mechanism was difficult to operate. The mean distance of the touchscreen from the user's eyes was 608mm. Mean screen height (measured at the top of the readable part of the screen) was 320mm above the desk surface.

Questionnaire Data

Biographical
The mean age of the four female fire control operators on duty was 35 years (sd=13.7). All were right-handed. Their mean height was 1660 mm (sd=40). The mean length of time in post was 10.7 years (sd=6.7). All were full time employees, working an average of 45 hours, over four days a week.

Workstation
All workstations were L-shaped, with the supervisor workstation larger to accommodate an extra display screen.

One user considered the chair to be uncomfortable and two did not think the chair provided sufficient back support. All had sufficient foot support and their equipment was within easy reach on the desk. Two users thought desk space was insufficient. None had been consulted over how the desk had been arranged. All appeared to be satisfied with the set-up of the screens. Two mentioned that equipment was not cleaned regularly.

Computer and NKID usage
The mean number of years using computers was 12.8 (sd=5.3), with NKID used for 8.3 years (sd=2.6). The mean number of hours worked on the computer per day was 10.5 (operators' typical shift length being 12 hours).

The CIM touchscreen (used with the left or sometimes either hand) and the 2 button mouse (used with right hand), were used on a daily basis.

Mouse
All were happy with the size and shape of the mouse. All found it easy to operate and control. One person mentioned it was not smooth to use. Two users said it was difficult to reach the mouse on the desk. Two users said the mouse was not cleaned regularly. Two mentioned pain or discomfort in relation to mouse use. All used a mouse mat but three did not think it was large enough.

Touchscreen
All operators were happy with the size and shape of the touchscreen, although two said the buttons were difficult to operate. Two operators thought the screen was jittery. One said it was difficult to control. All could reach the touchscreen easily. None reported having any pain or discomfort in relation to touchscreen use.

Work organisation
In general, the operators took breaks and had reasonable choice over when they were taken. Two said they frequently had to work fast and intensively; two said this was a requirement sometimes. Others could help out if time was limited. It was evident that the operators had little choice in deciding what they did at work or how it was done. All said they were only occasionally dissatisfied with their job. All were satisfied with the help and support given by their supervisor and colleagues.

Pain or discomfort
Two operators reported pain or discomfort in the last 12 months (right shoulder, elbow, forearm, right and left wrist/hand, upper and lower back, finger/thumbs). One had pain

or discomfort in the last 7 days (lower back). One thought the pain or discomfort was related to work.

Visual problems
Three operators reported that they experience tired eyes and one said she had had more serious problems, with impaired visual performance, sore eyes and headaches during the last 12 months. This individual reported having had headaches in the last 7 days. Three operators thought their eye problems were related to work.

Interview Data

Screen position
Generally, the operators said they do not move the touchscreens. It was mentioned that it is difficult to move the screen due to the awkward adjustment mechanism. The touchscreen height was considered adequate by the users. Reflection and glare was a problem on the screens near the windows, although the curtains were sometimes closed to counteract this. The users mentioned the constant requirement to move quickly from one screen to another. One user mentioned that she would prefer a bigger workstation in order to have more space to deal with other administrative work.

Screen design
It was apparent that there had been little user input or consultation over the screen design.

Fonts and function
The operators thought the screen characters and fonts could be larger/bolder, with greater control over screen contrast desirable. It was easy to accidentally touch the wrong button on the screen, resulting in errors.

System speed
The touchscreen was sometimes slow to respond and the user could be unsure if an operation had actually registered.

Screen order
The flow of information/order of screens was not always sensible. Some simple tasks required the operator to negotiate several screens.

Force
All operators mentioned that, depending on the touchscreen they were using, they sometimes needed to exert undue pressure to operate screen buttons. They said they 'sometimes really have to push very hard to operate the screen'.

Other
Subjects mentioned the need to use wipes to clean the screen. It was not clear whether these were always available. Problems were highlighted with pain or discomfort occurring when hands and fingers are cold.

Postural Observations

The chairs were large with deep seat pans (although actual dimensions were not measured). This resulted in operators often sitting forward, receiving no back support. One operator had the chair set low, which meant that her arms were extended when using the keyboard. As the chairs were heavy, they were difficult to move around.

Due to the layout of the three screens on the desk, the operator had to rotate the neck (up to 40º depending on the layout of the desk) to move from one screen to the next. This was necessary every time a call was answered, as the operator needed information from all screens. With the touchscreen located at a distance of 580-620 mm from the shoulder, interaction required operators to reach to touch it. The length of this reach could sometimes be considerable, as they were sometimes looking and typing at one of the other VDUs when needing to operate the touchscreen.

The index finger was used most of the time to operate the touchscreen. There appeared to be slight extension of the wrist, with an elbow angle of 120-125º when using the screen. The arm/elbow was sometimes supported on the desk. The upper arm was never vertical when using the touchscreen, with both flexion and abduction occurring (figure 11).

Figure 11
Typical posture arising during touchscreen operation

SUMMARY

- A case study examination has been presented of a control room touchscreen implementation
- Some touchscreen button sizes were too small
- Some touchscreens required undue force to operate
- Order of screens and presentation of information was cumbersome in some instances
- Certain touchscreen functions were poorly implemented (e.g. scrolling)
- Problems were mentioned with slow system response and user uncertainty over registering of interactions
- Poor touchscreen location and interaction with other tasks resulted in users having to stretch excessively to operate the screen
- Touchscreen position was difficult to adjust due to an awkward adjustment mechanism
- The multi-user workstations may have further impeded users adjusting the equipment to suit their needs
- Operators reported receiving no advice on how to configure and use their workstations appropriately

- Problems specific to the touchscreen were exacerbated by other DSE issues (e.g. inadequate seating, problems with reflections and glare)
- There appeared to have been little user involvement in either the design process or specification and purchase of equipment

STAGE SIX

EXPERT MEETING ON CURRENT NKID ISSUES

Complementing the investigations reported in previous sections of this report, a meeting was organised on Computers, Health, Ergonomics and Work (CHEW). The aim of the meeting was to bring together international experts conducting research relevant to the design and use of non-keyboard computer input devices (NKID). The meeting considered use of NKID and behaviour of users, health and other problems, and methodological issues connected with undertaking NKID research.

The event allowed the present study to consider, briefly, other aspects of equipment used with NKID, such as support appliances and software. The meeting also provided a forum for discussing the importance of wider issues such as work organisation, gender and international differences.

The meeting took place over two days (18-19 October 2000) at the University of Surrey.

SUMMARY OF RESEARCH PRESENTED

Use of Computer Aids

Software to enable/encourage work pauses

De Looze (TNO - Netherlands Organisation for Applied Scientific Research) presented an ongoing study evaluating software programmes designed to stimulate pauses and physical exercise at VDU work. A number of studies have shown a positive relationship between the daily amount of time spent conducting VDU work and the prevalence of repetitive strain injury (Punnet and Bergqvist, 1997). Many strategies for reducing problems have focussed on reducing the magnitude of the physical load with new designs of input device, keyboard and workstations. The absence of time to recover from the load rather than the intensity of the load is stressed in various etiological theories (Armstrong *et. al.*, 1993). The thinking behind the study is that interventions aimed at recovery might be more effective than the load reducing strategies. As the ergonomics literature indicates that short rest breaks are important, it may be important to remind workers when to take breaks. This study continues to evaluate a variety of software pause programs to determine their effect on those experiencing musculoskeletal problems.

Wrist support appliances

Brace (Loughborough University) presented work on support appliances for use with the mouse. A range of support appliances are available for use with input devices to reduce fatigue and muscle tension. The results of this study indicated various problems and benefits perceived with the use of support appliances, including both improved and reduced comfort and speed of task execution. The most commonly used products found in workplaces were foam/gel wrist support appliances, for use with a keyboard or mouse. A laboratory trial was conducted to examine the benefits of the gel and foam mouse support appliances. No significant differences between the angles of the wrist were identified. Subjective results indicated that the gel support appliance was preferred for comfort. The study concluded that currently user requirements are not adequately met with respect to safety, comfort and performance.

Trackballs
Haward (DERA - Defence Evaluation and Research Agency, England) described an intervention study where trackballs were introduced into a workplace. In the workplace, intensive computer mouse users were observed to develop work related musculoskeletal disorder symptoms more frequently than keyboard only users. As an intervention measure to assist users with symptoms, a mouse alternative, a trackball had been used, but never properly evaluated. It was hypothesised that substitution of a mouse for a trackball would result in no significant difference in posture, work organisation or perceptions of fatigue and discomfort. This workplace study was carried out with experienced mouse users performing their normal work activities, using a questionnaire to elicit information and to select subjects for further study. The follow up study used a combination of objective and subjective methods to gain information regarding the subjects' perceptions when using the different device types. Twelve-month prevalence of musculoskeletal symptoms for the initial population (n=34) was 83% with neck, back and right wrist symptoms found to be statistically significant for this population, although no relationships were found between mouse use, number and length of work breaks taken and musculoskeletal symptom occurrence, which did not concur with previous research. In the small follow up study, changing the mouse for the trackball had little observable effect on subjects' perceptions of tiredness and changes in tiredness level. Body part discomfort and work practices did not indicate major differences between the devices. One reason proposed was, that as subjects were symptom free, they had no need to modify their work behaviour to cope with symptoms. Wrist mid line position indicated more ulnar deviation when using the mouse compared to the trackball. Previous studies have highlighted this as a risk factor for discomfort and pain. Subjects perceived fatigue and discomfort as related to work loads and long working hours rather than to the input device. This, associated with observations on their motivation levels and degree of control over their work, indicates the importance of psychosocial factors in the work system. Based on these findings the study hypothesis was accepted (i.e. that substitution of a mouse for a trackball would result in no significant difference in posture, work organisation or perceptions of fatigue and discomfort), however some recommendations were made for future use of trackballs and further research.

Working Time and Work Organisation

Hanson (IOM – Institute of Occupational Medicine, Edinburgh) presented findings from a six year study on upper limb disorders in keyboard users to identify work, workplace, postural, psychosocial and personal factors associated with the risk of symptoms of upper limb disorders. A cross-sectional questionnaire study of 3500 keyboard workers was conducted. A case-control study investigated in detail the factors associated with the symptoms in groups of respondents with problems. 55% of respondents had experienced symptoms of ULDs at some time, with 49% experiencing symptoms in the last 3 months. Both the number of hours spent using a keyboard and the length of time spent at the keyboard without a break were particularly strongly associated with case status. Many factors that were associated with symptoms of ULD could be related to psychosocial stresses at work and to unsuitable equipment. Few postural factors were found to be significant.

Musculoskeletal Health of Mouse Users

Woods (University of Surrey) and Hastings (Loughborough University) presented work from the current study looking at the ergonomics of using the mouse and other non-keyboard input devices.

Hagberg (Goteborg University, Sweden) reported findings from a study looking at musculoskeletal health of computer mouse users in the Swedish workforce with regard to gender and psychosocial factors. In all eleven economic activities examined, the prevalence ratios (female/male) exceeded 1 for neck symptoms. Gender differences were persistent even when psychosocial and other job characteristics were included in a logistic regression. The prevalence of symptoms was almost twice as high in the neck/shoulder and forearm/hand regions among women when compared with men.

Individual Differences in Mouse Use

Jensen (National Institute of Occupational Health, Denmark) spoke about sensory perception and mechanical muscle function of the forearm and hand among computer users with and without symptoms compared to a control group. No differences in performance during standardised computer work were found between the three groups. Increased perception threshold values, indicating entrapment of median nerve and ulnar nerve, were found for computer users with symptoms. Only a few differences in mechanical muscle performance were found between the three groups. Computer users with symptoms had lower pinch grip strength when measured in the pronated hand position and further, the results indicated shorter muscle endurance among computer users with symptoms compared to the non-symptomatic groups.

Johnsson (Occupational Medicine Goteborg, Sweden) reported on the measurement and characterisation of force exposure during computer mouse use. In order to understand the relationship between mouse use and the increasing prevalence of musculoskeletal disorders, the biomechanical components and patterns of mouse operation must be assessed. The purpose of this study was to develop and validate a sampling strategy for characterising the finger force exposure associated with computer mouse use. During regular work the mouse was used 78 (sd=40.7) times per hour, accounting for 34% of the work time. The mean forces applied to the mouse were low, averaging 0.6% MVC and 0.8% MVC for the side and the button respectively. With respect to performing exposure assessment studies, the three major findings were: 1) mouse force measurements should be made while subjects perform their actual work in order to accurately characterise the absolute applied force; 2) the force applied to the mouse during a short battery of standardised tasks can be used to characterise relative exposure and identify operators or work situations where high forces are applied to the mouse and 3) subjects cannot accurately simulate mouse forces.

Wahlström (Goteborg University, Sweden) investigated whether different work methods with the computer mouse had an effect on musculoskeletal load and whether there were any gender differences in performance and/or musculoskeletal load. Thirty experienced computer mouse users (15 men and 15 women) performed a text-editing task using two different work methods (1) a wrist-based method where the forearm was fully supported on the desk and the mouse was moved by lifting and sweeping the mouse across the surface using the wrist and 2) an arm-based method where only the wrist was supported on the work-surface and the mouse was moved using movements initiated from the shoulder) to operate the mouse. Women worked with higher muscular activity in the forearm, applied higher relative forces to the sides and button of the mouse and worked with more extreme postures in the wrist than men. Differences were also found between the two different work methods used to operate the mouse.

Richardson (University de Paris Sud, France) spoke of the importance of movement patterns for arm related musculoskeletal disorders. After reviewing the commonly accepted biomechanical risk factors for work-related musculoskeletal disorders, he suggested that industry is becoming more and more subject to work demands that impose spatial and temporal constraints on operators working patterns. The effects of repetition and the lack of spatial variability in gestures employed in work activities can result in higher load on specific anatomical structures. The question is does this in turn lead to a higher risk of upper limb disorders? A laboratory study to evaluate spatial variability in upper limb gestures employed in simulation of work tasks is being carried out at the University of Surrey.

Assessing the Work System and Future Studies

Devereux (University of Surrey, England) presented work on an ongoing study investigating the link between work-related stress and musculoskeletal disorders. A large questionnaire study of 7000 workers was planned. It will determine whether those with severe work stress reactions at the beginning of the 14 month follow up period are more at risk of developing musculoskeletal disorder symptoms than those with no significant indicators of work stress. The study will also investigate beliefs of work stress in the context of musculoskeletal disorders and interaction between physical and psychosocial workplace risk factors. The study objective is to produce results that will contribute to improving the management of work stress and work related musculoskeletal disorders.

SUMMARY

- There appears to be international concern over health problems arising from use of NKID

- The importance of studying the health implications of NKID design and use was highlighted in view of the very large (and increasing) number of workers exposed

- Individual variations in work method have been recorded and are considered important with respect to exposure to risk, although the full health implications of these differences are not yet understood.

- Gender differences were also reported. Women have been found to work with higher muscular activity in the forearm, applying greater relative forces to the sides and buttons of the mouse and working with more extreme postures of the wrist than men. However, these gender differences might be explained by physical differences (e.g. anthropometry)

- Additional issues of particular importance to this study included consideration of the long-term implications of low force repetitive exertions and the importance of variability between individuals (e.g. % of MVC required to hold a particular posture) on fatigue and possible health outcomes. Research is ongoing in this area

- Meeting participants identified methodological problems they had encountered during their studies. There is a need to control variables in a laboratory but while still ensuring that results have ecological validity regarding "real life" settings

- There were a number of variables that meeting participants thought could be excluded from many laboratory trials of tools (e.g. day to day variation in use)

- A need for laboratory friendly tools for classification of symptoms was identified. Currently, if looking at 'sufferers' in the laboratory there is little knowledge of their real condition and the assumption is one of homogeneity

- It was acknowledged that there was no perfect methodology and no standardised set of methods to investigate NKID. For example it would be interesting to look at the force levels required to use different models of NKID (see Johnsson, above, who used a specially adapted mouse) but there is currently no available instrumentation to do so

- The importance of triangulation of methods to increase confidence in study findings was stressed. Where epidemiological or survey data, field and laboratory studies all produce similar findings (despite methodological weaknesses), researchers can have greater confidence in the results

DISCUSSION AND CONCLUSIONS

There were nine primary research objectives for this study. These have been investigated using a carefully selected range of techniques and methods, including a literature review (stage 1), manager questionnaire survey (stage 2), workplace interviews and assessments (stage 3), user questionnaire survey (stage 4), laboratory investigation (stage 5) and an expert meeting (stage 6). Following a review of methodological considerations, results from the various study stages are drawn together in the sections below, addressing the research questions.

METHODOLOGICAL CONSIDERATIONS

It is likely that the survey components of the project will have been affected by selection bias. It is possible there was over representation of organisations or individuals that had experienced problems with NKID. It is also likely that the surveys attracted those finding the research interesting for other reasons. These organisations or individuals may not be representative of the wider NKID user population. Where possible, sources of potential bias have been examined and commented upon.

The manager survey (stage 2) used a quasi-quota sampling approach (making use of existing contacts known to the researchers, with a subsequent review to ensure a spread of respondents across industrial sectors) and achieved a response rate close to 50%. No obvious systematic bias was detected in this survey, beyond the possible factors mentioned above.

Potential interviewees were identified for the workplace assessment interviews (stage 3) by a contact person within each organisation and, despite guidelines issued to avoid bias, it is known that in some instances the contacts selected individuals they thought would be interested in or interesting to the research. Contacts were also asked to provide access to individuals using NKID other than the mouse. In a small number of cases these were users that had been provided with alternative NKID due to complaints of pain or discomfort. Despite these sampling limitations, the workplace assessments provided valuable information on how users use NKID, the configuration of workstations and work organisation.

The user questionnaire survey (stage 4) encompassed a larger number of organisations (n=33) and respondents (n=848). Although the response rate for this postal return questionnaire was low (24%), there was no evidence of any systematic bias.

The laboratory work embraced an expert assessment, a user trial and a touchscreen case study (stage 5). Expert assessments collate subjective views of persons with relevant knowledge or experience. The value of the data from this component of the project was enhanced by having a structured approach to the assessment and the large number of experts participating (n=27). The user trial allowed a controlled laboratory assessment of alternative workstation arrangements and working postures. The main limitation with the user trial was the short duration of each experimental condition (2 minutes). While this was sufficient to collect valid data for muscle activity and posture, it is likely that the subjective ratings of effort and comfort would vary with longer exposure. The touchscreen case study identified important issues concerning use of this category of NKID. However, as only a small number of users were examined, the conclusions must be regarded as tentative.

Previous studies of NKID have had a more narrow focus, comparing a limited number of devices or examining a single workplace location. Our approach used a combination of methods in different settings to achieve a balance between depth and breadth of investigation. Triangulation of methods is used extensively in many areas of research, including human computer interaction. Despite weaknesses in individual methods, the combined results allow increased confidence with respect to validity (and reliability) of the conclusions.

EXTENT TO WHICH DIFFERENT NKID ARE IN USE

The questionnaire survey of managers showed that the mouse is by far the most commonly used NKID device for computers used at a desk in the UK; other NKID are used, but to a much lesser extent. Desktop computers are most often used with a mouse, followed by trackball. Laptop computers used at a desk are most often used with a mouse, followed by touchpad and trackball. The majority (90%) of survey respondents (both workplace assessment and user questionnaire survey participants) used the mouse and operated the device (mainly two button) with their right hand. A small percentage of other NKID were also in use in the organisations surveyed (e.g. touchscreens, barcode wands, tablet and puck) and many managers and users envisaged that a wider variety of NKID would be in use in the future.

PATTERNS OF NKID USE

The manager questionnaire, workplace assessments and user questionnaire all indicated that use of NKID was greatest when word processing, reading or sending email, working with spreadsheets, accessing database information, data entry and information searching (e.g. internet use).

Six hours per day was the average amount of time spent conducting computer work, with the workplace assessments and user questionnaire survey finding that a large percentage of daily work time is spent using an input device. Diary respondents indicated the mean percentage of daily work time (assessed as working with an input device) to be 64%. This was similar to other studies that have tried to quantify the extent to which the mouse is used, with mouse usage found to account for up to two-thirds of computer operation time, depending on the software used and the task performed (Johnson *et. al.*, 1993; Karlqvist *et. al.*, 1994).

The user questionnaire respondents considered that their mouse and touchscreen use was ‘regular’ i.e. their hand moved between keyboard to device throughout the task. Trackball, joystick mouse and CAD tablet users mostly reported their device use as ‘continual’ (i.e. where the hand was on the device the majority of time during the computer task). Some computer pen and touch pad users considered themselves continual users, while others thought their use was regular.

RANGE OF WORKSTATION CONFIGURATIONS OCCURRING IN PRACTICE

Desk Shapes

The workplace assessments and user questionnaire highlighted a move away from the standard rectangular office desk to L-shaped desks (67% of user questionnaire respondents). The majority of user questionnaire respondents (55%) had L-shaped desks with the computer positioned in the deep curve of the desk and the NKID located to the right hand side of the keyboard. As observed at the workplace, this configuration means the forearm has more available support from the desk when using the NKID than at a traditional rectangular desk. Although not investigated in this study, it is possible that the larger size and shape of L-shaped desks may restrict positioning of the desk, reducing scope to avoid screen glare and reflections.

A further 12% of user questionnaire respondents had L-shaped desks but placed the computer on the narrow part of the desk. As a result they do not receive the benefit of extra support for the forearm. 27% of questionnaire respondents had a traditional rectangular desk and 3% had a separate VDU table in addition to their work desk. 32% worked at more than one workstation. 8% had more than one screen on their desk.

Device Positioning

The majority of user questionnaire respondents, including left handed users, had their input device positioned on the right side of the keyboard. The numeric keypad on this side of most keyboards means that NKID are positioned further away from the user than would otherwise be necessary. In view of the low reported use of the numeric keypad, it would seem sensible for smaller keyboards without a numeric keypad to be readily available.

Other problems concerning positioning of NKID were identified during the workplace assessments and with the user questionnaire. Workstations were often cluttered, leading to NKID being placed where space permitted. This resulted in users sometimes stretching to use the device. Although not quantified in the research, it appeared that frequently the provision of desks, shelving and storage to users had taken little account of the tasks they would be performing. Often organisations seem to supply staff with a standard desk specification, regardless of the work they will be doing. The availability of a variety of furnishing specifications is desirable to ensure users have storage and desk space sufficient for their tasks.

Other Issues

Ease of configuration is important for multi-user workstations, with a requirement for adjustment that is intuitive and convenient. We found little evidence of consideration having been given to the need to accommodate different users at multi-user workstations. Multi-computer workstations are also a special case. Although purpose built multi-computer workstations were observed during the workplace assessments, it is often the situation that additional computing equipment is merely added alongside computers on an existing desk. This leads to insufficient desk space and limits placement of NKID.

One quarter of individuals in the user questionnaire survey use wrist rests (24%) when working at a keyboard. 13% use an arm/wrist support when using the mouse. 10% have support built into the mouse mat. It was not possible to examine potential benefits or disadvantages of support appliances used with input devices in this investigation. However, discussion and presentation on this topic at the international meeting of experts arranged specifically for this study (CHEW) indicated various problems and benefits with the use of support appliances. Some users reported improved comfort with certain appliances, particularly mouse mats incorporating gel filled wrist support (Brace, 2001). Disadvantages included some users finding support appliances uncomfortable and insufficient mousing area.

A number of workstation problems emerged from the workplace assessments and the user questionnaire. Areas of concern identified were:

- Insufficient back support from chairs
- Unsupported feet
- Lack of desk space
- Poor set-up of screen (i.e. too low)
- Screen reflections and glare
- Poor position of NKID on desk (e.g. too far away from the user)
- Poor dissemination of health and safety advice
- Lack of cleaning of equipment
- Poor maintenance of equipment
- Poor cable management

INDIVIDUAL VARIATION IN THE USE OF NKID

The user questionnaire survey and the workplace assessments revealed variation in how standard tasks are completed (e.g. open and close files; cut, paste and highlight data; save and print documents). Users tend to have their preferred methods of operation, often incorporating more than one approach.

Although keyboard shortcuts were reported as being used to execute some tasks, the majority of respondents use NKID with pull down menus or on-screen icons. In particular these are used for opening and closing files and saving and printing documents. With this style of working, the hand is in frequent use to manipulate the device, moving the cursor around the screen. This method of operation generally seems to be preferred over accessing menus at the cursor position using a secondary device button (eg the right button on a two button mouse). Reasons for this varied, but lack of awareness of alternative options was apparent.

PREVALENCE OF MUSCULOSKELETAL COMPLAINTS ASSOCIATED WITH NKID

From the questionnaire sent to managers, 20% of organisations were found to have received reports of neck, shoulder or arm pain or discomfort related to the use of NKID. Of those organisations able to provide the information (59% of responding organisations), 1 in 5 reported staff absence related to neck, shoulder or arm pain in the previous 12 months.

67% of workplace respondents and 37% of users in the questionnaire survey had aches and pains they thought were related to things they do or equipment used at work e.g. using the mouse for long periods and intensive typing. 17% of questionnaire survey respondents thought their pain or discomfort was related to using the mouse.

2% attributed pain or discomfort to use of other NKID. Among user questionnaire respondents, 9% had been absent from work in the last year as a result of aches and pains.

The prevalence of musculoskeletal symptoms reported by user questionnaire respondents was compared with data for the Nordic reference set (Ydreborg & Kraftling, 1987) (comprising assistant cooks, cleaners, nursery/outpatient nurses and secretaries). This comparison suggests that, for both sexes, the musculoskeletal problems were generally less or comparable to the Nordic reference group. Exceptions relate to the upper back and, for males, the neck and shoulder regions, where pain or discomfort was significantly higher among this study group than the Nordic population. Overall, it seems the extent of musculoskeletal pain or discomfort among the NKID users that responded to the user questionnaire survey was broadly at the same high level as found in the general working population.

The figure of one in five organisations in the manager survey having received complaints of pain or discomfort among their staff attributed to NKID seems surprisingly low. With one in five users reporting NKID related pain or discomfort in the user questionnaire, it might be expected that many more organisations would have had reports. This could indicate extensive under reporting of the condition within organisations.

It should be borne in mind when interpreting the prevalence findings that widespread use of NKID is still a relatively new phenomenon. It is only during the last ten years that computer interfaces requiring NKID operation have become the norm. Also, the number of computer users and the extent of computer use has increased markedly with the advent of email and the internet. Given the current limited understanding of injury mechanisms, dose-injury relationships and the latency period for symptoms to develop, a precautionary approach to reducing risk seems advisable.

Patterns of Pain or Discomfort

The main sites of pain or discomfort identified in both workplace assessment interviews and user questionnaire survey were the lower back, neck, right shoulder, right wrist and hand. This coincides with concerns highlighted by the postural observations in the workplace: neck flexion, static postures and deviated wrist postures.

An analysis of intensity of computer use in the last seven days among the user questionnaire respondents found a statistical association between pain and discomfort and length of time spent using the computer each day. This finding is supported by the work of other researchers (Punnett & Bergqvist, 1997; Karlqvist *et. al.*, 1996). Karlqvist *et. al.* reported a relationship between neck and upper extremity symptoms and hours per week of mouse use, with more than 5.6 hours of mouse time per week having increased risk of upper limb symptoms. A general association between length of time spent at the computer and increasing upper limb musculoskeletal symptoms was also found by Hanson *et. al.* (1999) in their study of keyboard operators.

Further inspection of our data also indicates differences in prevalence of pain or discomfort between the left and right side of the body for the wrist, forearm, shoulder and elbows. Increased prevalence of pain or discomfort in the right wrist was statistically significant ($p<0.05$). It is thought this difference is likely to be related to equipment used in the workplace (i.e. NKID).

It is interesting that in the laboratory user trial, some subjects reported discomfort in certain conditions after using NKID for only very short periods of time (2 minutes), suggesting even short duration use may lead to problems. The experimental conditions were based on actual situations observed during the workplace assessments.

Other Problems

In addition to musculoskeletal problems, a high prevalence of visual symptoms (e.g. tired and sore eyes) and headaches were identified among user questionnaire respondents. 52% of respondents reported visual symptoms considered to be work related (e.g. arising from looking at a computer screen most of the day, poor lighting, or poor air conditioning).

INFLUENCE OF PRIOR MUSCULOSKELETAL PROBLEMS

In instances where pain or discomfort amongst computer users had been recognised, a common response from employers was to provide an alternative device (e.g. joystick mouse or trackball) in an attempt to reduce the problem. Interviews at the workplace indicated that users with pain or discomfort tended to give more thought to how they organised their work (e.g. length of time using NKID, length of time they worked on the computer, and frequency of work breaks). In addition, they indicated greater awareness of postures adopted at the workstation. In some cases they had changed their desk equipment. Information from the user questionnaire indicated that although some workers had changed their tasks, work pace and equipment, as a result of pain or discomfort, the most common reported change was to posture.

ISSUES FOR CONSIDERATION IN NKID DESIGN AND SELECTION

The following ergonomics issues emerged during the study as areas for consideration. They have implications for design with respect to usability, functionality and comfort.

Shape and size of device

The shape and size of a device are important, as awkward postures and discomfort may result from a poor fit to the user. Handedness can also be an issue, with some devices designed and contoured for right handed use. Such devices may be awkward to use with the left-hand.

A number of trackballs incorporate built-in support on the device itself, where the user rests the full hand on the trackball. This may result in postures of the hand and wrist away from neutral and additional postural demands due to the height of the device (e.g. one device investigated in the expert assessment was 70 mm high above the work surface).

Achieving a good fit of device to individual users may require NKID of varying size to be available. This has implications for both suppliers and purchasers. An interesting observation is that while there is considerable scope to specify other features when making computer purchases (e.g. memory, monitor etc.) there is often only limited, if any, choice with respect to pointing device.

Jittery device movement

Concern was expressed by users regarding the movement of some devices. This appears to be related to the size of the device and whether the user can reach all of the controls to operate them adequately. For example, rolling of some trackballs is difficult as the trackball is too large.

Control and precision

The expert assessment found devices to vary in terms of their accuracy. Selection of a device should take account of the extent of manipulation or precision required. Devices such as touchscreens or those requiring a power grip (e.g. certain designs of joystick mouse) may afford less precision than a conventional mouse. It is desirable that users have confidence in their control over a device and can point to and select information easily. The size of a device is again important in this respect, as is the extent to which hand-eye coordination is facilitated.

Button forces

No attempt was made in this study to quantify the forces used or considered desirable to operate NKID controls. Others have suggested this may be a factor affecting pain or discomfort (Wahlström *et. al.*, 2000). At a qualitative level, the level of force required to operate NKID controls should be comfortable, while offering a degree of resistance and feedback to the user. Designers should be made aware of the current research on force application.

Ease of use

The expert assessment found some devices to be easier and more intuitive to use than others. Some were thought too complex. A number of devices had up to 5 buttons and/or controls for the user to work with. Additional buttons or controls may be beneficial in providing alternative modes of operation, but a prerequisite is that the user understands their purpose.

Interaction with hardware and software

It is important that the device is compatible with all software that the user works with. Users need to be given information on how to access and change settings of the device e.g. pointer speed and button function.

Introducing alternative devices (e.g. touchscreens) that mimic features of the mouse (e.g. scrolling) is often not appropriate.

Cleaning and maintenance

Users should be provided with cleaning materials appropriate to their NKID. Mechanical mice and trackballs need cleaning to prevent sticking and to avoid unnecessary repeated operation. Touchscreens are prone to finger marks and smears, interfering with their function and causing visual difficulties. Regular maintenance should be in place to ensure devices are working properly. Some devices require less maintenance than others and this should be a purchasing criterion (e.g. light operated versus mechanical mice).

Lack of training or information on device use

Devices should be as intuitive to use as possible and accompanied by clear information on how to use them. Training should be given to NKID users to ensure they know how to use facilities on a device.

Suitable accessories

The provision of a suitable mouse mat may be beneficial in aiding smooth operation, especially with mechanical devices. Mats should be of an adequate size to allow the user to move the cursor easily around the screen; sometimes long travel distances of the device are required e.g. when moving from the bottom to the top of the screen. Different user techniques for working with devices may mean the mouse mat is too small i.e. some people move the mouse around the mat more than others.

How important any of these issues are depends on the length of time and intensity with which devices are used. The findings have been incorporated into a Device Assessment Checklist (Appendix 4) and a Device Purchasing Checklist (Appendix 5).

COLLATION OF BEST PRACTICE ADVICE

NKID are generally operated in predominately static postures. The movements required to operate devices are small and arise from the musculature of the fingers, wrist, arm and shoulder. It is apparent from other studies that different devices require different postures to operate them, a consequence of their design. The mouse requires ulnar deviation of the wrist, the trackball greater wrist extension. However, as well as device design, the postures adopted to use NKID also depend on the size and shape of the device, the position of the device, workstation set-up, the user's anthropometry and individual operating technique.

Upper limb support during NKID use

The benefit of support for the arm or the wrist while working with NKID has been explored by others to some extent. Cooper and Straker (1998) reported less upper trapezius muscle activity when mouse use was compared with keyboard use. The authors related this to possible unloading of the trapezius due to arm support during mouse operation. Aarås *et. al.* (1997) performed a lab study measuring EMG from the upper part of the musculus trapezius and from the lumbar part of musculus erector spinae during mouse use. The muscle load was significantly less with supported forearms compared to working without forearm support.

The present research confirmed that the support method used when operating a mouse affects muscle activity. Working with a supported forearm resulted in lowest muscle activity in those muscles used for recording purposes, suggesting this support method to be preferable. For the short durations of the laboratory trials, subjects preferred working at a L-shaped desk, with the arm fully supported.

Research carried out in Sweden by Wahlström *et. al.* (2000) investigated whether different methods of operating a computer mouse or gender have an effect on performance and musculoskeletal load. While there were differences between their study and ours, some comparison of results is possible. Wahlström *et. al.* found highest muscle activity in the right and left trapezius while subjects worked with wrist only supported and lowest when the forearm was fully supported. This is compatible with our finding of lowest muscle activity when subjects worked with the forearm fully supported.

While the arm support offered by L-shaped desks may be beneficial, the fit to the user is likely to be important. This will depend on the anthropometry of the user, the radius of curvature of the desk and any desk handedness that may be present. These factors have not been evaluated in this study.

NKID position

Previous studies have indicated that positioning the mouse away from the midline of the body results in users working with the arm unsupported, shoulder abducted and externally rotated and arm in forward flexion (Franzblau *et. al.*, 1993; Karlqvist *et. al.*, 1994 & 1996; Cooper and Straker, 1998; Aaras *et. al.*, 1997; Fernstrom and Ericson, 1997; Harvey and Peper, 1997; Cook and Kothiyal, 1998). Observation during the present research revealed that some users had the NKID positioned at some distance from their keyboard, requiring an extended arm posture when operating.

With regard to mouse position, there is evidence that placement allowing a near neutral posture is preferable (Karlqvist *et. al.*, 1996; Karlqvist, 1997). Keyboards incorporating a numeric keypad may impede right-sided mouse users, increasing the distance of the mouse from the body midline, resulting in shoulder abduction and flexion (Cook and Kothiyal, 1996; Cook *et. al.*, 2000). Increased activity in the shoulder muscles has been found when the mouse is used to the side of the keyboard (Harvey and Peper, 1997; Cook and Kothiyal, 1998), and when mouse use was compared to keyboard use (Karlqvist *et. al.*, 1994; Cooper and Straker, 1998).

Procedure for common tasks

Users appear to prefer to use pull down menus and screen icons to conduct common computing tasks as opposed to device buttons and keyboard shortcuts. However, it was evident that some users did not know they could perform these common tasks in any other way. As postural variety is important to avoid prolonged static postures, a combination of modes of use should be encouraged.

Keir *et. al.* (1999) measured carpal tunnel pressures and wrist postures in users of different devices performing different tasks. Activity was found to have an effect, with repeated dragging increasing carpal tunnel pressure more than pointing tasks. This finding suggests a need to reduce sustained ‘button down’ activities, to work with NKID for shorter durations and to interrupt use with other tasks for the device hand.

Breaks from NKID/computing

The effects of poor posture and static load on the muscles of the neck and shoulders during upper extremity work were well documented prior to the advent of the mouse. Maeda (1977) and Westgaard *et. al.* (1985) reported a relationship between low level prolonged static muscle load on the neck and shoulders and musculoskeletal injuries. Work requiring positions of shoulder flexion and abduction has been identified as contributing to symptoms in the neck and trapezius region (Hagberg, 1981; Kilbom and Persson, 1987; Kilbom, 1988; Schuldt *et. al.*, 1987).

As noted previously, the definition of ‘break’ was left to respondents and interpretation of what constitutes a break is likely to have varied. Nevertheless, the findings of the present research indicate individuals are working at the computer for long periods of time (i.e. an average daily use of 6 hours). Many respondents reported that they often worked for two hours or more at the computer without taking a break (41%). Among user questionnaire respondents, two thirds (67%) reported that they usually have discretion over how they work and when to take breaks. It would appear from this that users often choose to work more intensively than might be desirable with respect to their comfort and health.

As well as scheduled breaks, it is important for users to take short ‘micro-breaks’ from computer and NKID work. This does not have to be a break from work but the user should be encouraged to conduct other tasks, requiring different postures. A presentation at the CHEW meeting (Michiel de Looze, TNO, The Netherlands) concerned an ongoing investigation evaluating software programmes designed to stimulate pauses and physical exercise at VDU work. Studies such as this are desirable to determine whether software of this nature provides protection.

Hand Alternation

Some users alternated the hand used for NKID work, varying posture. Peters and Ivanoff (1999) found that although subjects may perceive the non-preferred hand as clumsier, in performance terms the difference is small. As a result they recommended alternating use of the non-preferred and preferred hand for intensive mouse users.

GUIDANCE ON THE SUITABILITY OF DIFFERENT NKID FOR GENERIC TASKS (E.G. WORD PROCESSING, CAD)

It proved difficult to explore this objective to the extent originally envisaged. With the mouse used by the majority of participants, it was not possible to collect data on the suitability of other NKID for different tasks. The following remarks should be interpreted in this context. Currently it is not possible to differentiate between situations where it may be preferable to use a conventional mouse or a trackball. Touchscreens may be limited by precision and the need to operate them with the arm unsupported (as seen in the touchscreen examples available to this research). Touchscreens of this nature are unsuitable for tasks involving prolonged manipulation of objects on screen (drawing, dragging etc) and their use should be confined to operations such as selection of menu items. Graphics tablets and pens offer increased precision and this may be advantageous for tasks such as CAD, although the pinch grip required to hold the pen may cause problems with extended use.

SUMMARY

The primary conclusions arising from this research are:

- While only one in five organisations surveyed had received complaints of pain or discomfort among their staff attributed to NKID, one in five users reported pain or discomfort thought to be due to use of NKID. This suggests there is much under reporting of the condition within organisations.

- Increasing computer use was associated with higher prevalence of reported symptoms in the hands, wrists, forearms and shoulders. Prevalence of pain or discomfort was greater on the right side of the body for the wrist, forearm, shoulder and elbows. It is thought this difference is likely to be related to equipment used in the workplace, including NKID

- The mouse is currently the input device used with most computers used at a desk. Other devices are found to a much lesser extent, sometimes integrated into laptop computers, occasionally provided as a substitute to users who have experienced problems with the mouse, or found with specialist applications such as CAD. Many users are unhappy with aspects of the device they use

- Features of NKID identified as being of consequence for user comfort and health include: device shape and size, especially fit of device to the individual user, control and precision, reliability of operation, and extent to which use and configuration are intuitive. Cleaning and other maintenance may be necessary to ensure effective operation of NKID. Frequently this does not happen in practice

- Most NKID use takes place when undertaking general office computing tasks, including wordprocessing, email, spreadsheet and database work, and information searching. Device use occurs regularly when performing these activities. Computer work involving pointing and manipulation is most often performed using NKID. Keyboard shortcuts are used less frequently

- Variation exists between individuals in the manner in which NKID are used, with respect to both the method of performing computing tasks and postures adopted. Users tend to have their preferred method of working, either through habit or because they are unaware of alternative possibilities

- The majority of users use NKID with their right hand, including those who are left-handed. The numeric keypad found on the right of the majority of keyboards affects NKID positioning on this side. NKID placement is often also limited due to other items on the desk restricting space available. NKID design, location and orientation on a desk affect posture of the hand, wrist, arm and shoulder. Undesirable wrist and shoulder postures occur frequently in practice

- A minority of participants in this research (one in ten) used a mouse mat incorporating wrist support. Further research is needed to evaluate the benefits of these appliances

- A majority of users now seem to work at L-shaped desks. Depending on the shape and size of the desk, the fit of the desk to the user, and the positioning of computing equipment, L-shaped desks may provide beneficial arm support when operating NKID. Otherwise, most workstations do not incorporate arm support. A significant proportion of users are not consulted over the choice and arrangement of the workstation with which they are provided

- Although not quantified by this study, a proportion of users work at shared workstations. In these circumstances, users are likely to be constrained in adjusting the position of computing equipment to suit their needs

- Users often work at their computers for prolonged periods, taking infrequent breaks. This was despite the majority of survey participants in this study having at least some freedom over the way they organise their work

- The majority of participants in this research said they had not received any health and safety advice concerning use of their computer or any guidance in the use or configuration of their NKID

It is important to remember that widespread use of NKID is a relatively new phenomenon and detailed understanding of the relationship between exposure and experience of pain or discomfort does not exist at present. There is, therefore, a strong case for a precautionary approach to risk reduction.

RECOMMENDATIONS

The health of NKID users is influenced by a wide range of interacting factors. In view of this, an ergonomics approach to risk reduction is important, a method which looks at the user-computer interaction as a whole. The aim is to fit the work to the person, rather than the person to the work.

A systematic risk assessment for NKID must consider the:

- nature of the task, including software design
- NKID design and operation
- workstation configuration
- working environment
- work organisation
- training
- cleaning and maintenance
- procedures for musculoskeletal health monitoring
- specific needs of individual users (e.g. those with existing health problems)

An important principle is that the process should involve users: users are able to provide valuable information on their experiences with their NKID. User participation also helps encourage ownership of solutions and is beneficial in relation to psychosocial aspects of musculoskeletal pain or discomfort.

The following recommendations are based on the findings of this research and evidence from the literature. In some instances the recommendations are generic to other aspects of computer use and already feature in guidance accompanying the Health and Safety (Display Screen Equipment) Regulations (HSE, 1992). The advice given below forms the basis of the Device Assessment Checklist (Appendix 4) and Device Purchasing Checklist (Appendix 5).

NATURE OF THE TASK

Tasks should avoid a requirement for intensive NKID use over long durations. Where intensive NKID work is unavoidable, it may be necessary to share a task across several people, reducing individual exposure.

The nature of computing tasks is to a large extent determined by the software in use. Software should be designed, wherever practicable, to minimise the need for unnecessary or long-lasting manipulation of objects on screen. Program developers should seek to reduce distances on screen between interactive elements used in conjunction or in sequence (e.g. program controls or items within dialogue boxes). It is important that prolonged device operation with depressed finger buttons is avoided (e.g. as can be the case when dragging, moving objects or drawing). Software should permit alternative methods of undertaking selection or manipulation tasks (e.g. keyboard shortcuts). These need to be accessible and intuitive. Users should be encouraged to experiment and vary the way they perform pointing, selection and manipulation actions.

NKID DESIGN AND OPERATION

NKID should be comfortable to hold and operate, providing a good fit to each individual user's anthropometry. Frequently this will mean that NKID need to be available in a range of sizes, with users able to experiment to find the size they find most comfortable. NKID manufacturers should increase user involvement in the design process and organisations should involve users when choosing and evaluating devices for purchase.

Device design should be ambidextrous. Where this is not possible, left-handed versions should be readily available. In addition to accommodating the 10% of users whom are left-handed, some individuals find it beneficial to learn to use NKID with either hand. There may be benefit in having devices designed to be held and used in a variety of different ways, encouraging users to vary their posture. This is a matter for NKID designers to explore.

The design of NKID should help encourage a straight wrist, while avoiding excessive finger flexion and static loading of the arm and shoulder. Buttons should be located so that users do not have to stretch fingers to reach them. The force required to operate buttons should be sufficient to provide feedback to the user and avoid accidental action, while not being excessive.

NKID should be selected to provide precision and accuracy appropriate to the task, with operation that is consistent and predictable. Currently, finger operated touchscreens offer lower precision than mice or trackballs. Cables connecting a device to the computer should be arranged so they do not interfere with the device placement or movement. Device design should minimise the need for maintenance and cleaning. NKID and their accompanying software need to be intuitive to use and configure.

NKID designers should consider the findings of this research.

WORKSTATION CONFIGURATION

Workstations should be arranged with the aim of encouraging relaxed, comfortable postures.

Workstation provision should consider the tasks users will perform, taking into account the equipment (e.g. telephones, manuals, books, papers) and the working area that will be needed. Adequate shelving and storage should be available, so that items do not have to be left on the desk surface.

Users should adjust their workstations to comply with DSE guidance (HSE, 1992), e.g. so that they are seated with feet on floor, back fully supported by backrest, no restriction on chair movement with respect to the desk. Users should also aim to have support for their arm while using the NKID.

L-shaped (curved) desks can provide beneficial arm support when arranged appropriately. To achieve this, computing equipment needs to be located in the curved region of the desk (but with the desk located to avoid screen glare).

NKID should be positioned on the desk close to the user, avoiding the need for stretching. Placement should be such as to avoid users resting their wrist on the desk edge.

It would be better if keyboards were routinely be supplied without a numeric keypad, reducing keyboard asymmetry and space occupied by the keyboard on the desk.

Wrist support appliances should be available to users who want them.

Multi-user workstations are only suitable for computer work involving short-term, non-intensive NKID use, unless it is easy for users to change, reconfigure and reposition NKID. Multi-computer workstations need to be designed to ensure each computer installation meets the requirements for NKID use set out in this report.

WORKING ENVIRONMENT

Lighting provision and VDU positioning should be such as to avoid glare and screen reflections. NKID interactions are heavily screen dependent.

The temperature of the environment needs to be comfortable for sedentary work. Upper limb disorders may be exacerbated by working in cool or cold conditions.

It can be difficult to operate NKID where mechanical vibration is present (e.g. mobile workstations). In situations where this may be a problem, particular attention must be given to ensuring users know how to operate software using non-NKID alternatives.

WORK ORGANISATION

Tasks should be organised to avoid intensive NKID use over extended periods.

Users should be encouraged to take regular breaks from computer work. Frequent breaks of shorter duration (e.g. 5 minutes in every hour) are more beneficial than longer breaks taken less often. Jobs should be designed so that workers have a mixture of computing and non-computing tasks to perform.

Musculoskeletal conditions are known to be exacerbated by psychosocial factors (e.g. lack of control over job demands or procedures and organisations with little social support for workers), features of a work situation that influence job satisfaction and morale. Organisations can begin to address issues by following HSE guidance concerning workplace stress (HSE, 2001).

TRAINING

It is recommended that computer users receive induction and refresher training regarding use of NKID. Training should cover device selection and set-up, workstation configuration, posture, work organisation and breaks, NKID cleaning and maintenance and the importance of reporting problems. In particular, users need to be shown how to configure device settings, introduced to keyboard alternatives that reduce device dependency, and encouraged to incorporate a mix of computing and non-computing activities in their daily work routine.

Organisations should assess training needs and evaluate delivery to ensure effectiveness. Organisations need to ensure that training actually happens and occurs without delay when new workers commence their duties.

It is important to emphasise that training, however effective, will not overcome inherent risks in either equipment design or in the system of work. Training should only be regarded as a complementary component of establishing safe working procedures.

The need for training also extends to other groups besides users, e.g. managers, supervisors and purchasers, to raise awareness of issues affecting NKID health and safety among staff.

CLEANING AND MAINTENANCE

Most of the current generation of NKID require regular cleaning and maintenance to ensure correct operation. Employers should provide materials to enable users to clean their own devices. NKID should also be checked alongside other equipment, as a part of routine inspections.

The supply chain should be encouraged to provide NKID requiring a minimum of maintenance. Purchasers should be educated to take this into account when selecting NKID.

MUSCULOSKELETAL HEALTH MONITORING

At present, it is not possible to predict which users will have problems with which NKID. In view of this, it is important for organisations to have procedures in place which encourage users to report NKID problems at an early stage. A protocol for responding to individuals reporting pain or discomfort should deal with all aspects of the work situation, in addition to considering the device itself.

HSE guidance on reducing risk of upper limb disorders should be noted (HSE, 2002).

RECOMMENDATIONS FOR FURTHER RESEARCH

Additional epidemiological evidence is needed to improve understanding of the relationship between risk and injury from NKID use. Of particular interest are the consequences for younger and older workers, those exposed to other workplace stressors and job insecurity.

The interaction between user anthropometry and radius of curvature of L-shaped desks and the effects on user posture requires more investigation.

Wrist supports appear to benefit some users. Research is needed to determine optimum configurations.

In view of the influence software design has on NKID use, it is desirable that approaches to reducing NKID interaction are identified and communicated to software designers.

Research is needed to identify optimal strategies for work organisation in tasks requiring intensive NKID use.

REFERENCES

Aarås, A., Fostervold, K., Ro, O., Thorenson, M. and Larsen, S. 1997, Postural load during VDU work: a comparison between various work postures, **Ergonomics**, 40, 11, 1255-1268.

Department of Trade and Industry (DTI) 1998, **AdultData - The handbook of Adult Anthropometric and Strength Measurements - Data for Design Safety**. London: Department of Trade and Industry.

Andre, AD. and English, JD. 1999, Posture and web browsing: an observational study, **Proceedings of the Human Factors and Ergonomics Society 43rd Annual Meeting**, Houston, Texas, September 27-October 1, Volume 1, 568-572.

Armstrong TJ., Buckle, P. and Fine, LJ. 1993, A conceptual model for work-related neck and upper-limb musculoskeletal disorders**, Scandinavian Journal of Work, Environment & Health**, 19, 73-84.

Armstrong, TJ., Martin, BJ., Franzblau, A., Rempel, DM. and Johnson, PW. 1995, Mouse input devices and work-related upper limb disorders, **Work with Display Units 94**, Eds A. Grieco, G. Molteni, B. Piccoli and E. Occhipinti, pp375-380.

Bergqvist, U., Wolgast, E., Nilsson, B. and Voss, M. 1995, The influence of VDT work on musculoskeletal disorders, **Ergonomics,** 38, 754-762.

Bongers, PM., de Winter, CR., Kompier, MA. and Hildebrandt, VH. 1993, Psychosocial factors at work and musculoskeletal disease, **Scandinavian Journal of Work Environment and Health**, 19, 297-312.

Buckle, P. 1997, Work related upper limb disorders, **British Medical Journal**, 315, 1360-1363.

Burgess-Limerick, R., Shemmell, J., Scadden, R. and Plooy, A. 1999, Wrist posture during computer pointing device use, **Clinical Biomechanics**, 14, 280-286.

Burgess-Limerick, R. and Green, B. 2000, Using multiple case studies in ergonomics: an example of pointing device use, **International Journal of Industrial Ergonomics**, 26, 381-388.

Cakir, A., Hart, DJ. and Stewart, TFM. 1980, **Visual Display Terminals**. Wiley.

Card, SK., English, WK. and Burr, BJ. 1978, Evaluation of mouse, rate-controlled isometric joystick, step keys, and text keys for text selection on a CRT, **Ergonomics**, 21, 601-613.

Carnahan, H., Goodale, MA., Marteniuk, RG. 1993, Grasping versus pointing and the differential use of visual feedback, **Human Movement Science**, 12, 219-234.

Carter, JB. and Banister, EW. 1994, Musculoskeletal problems in VDT work: a review, **Ergonomics**, 37, 1623-1648.

Chaffin, DB., Andersson, GBJ. and Martin, BJ. 1999, **Occupational Biomechanics**. New York: Wiley-Interscience, 3rd edition.

Cook, C. and Kothiyal, K. 1996, Does a keyboard numeric pad adversely affect muscular activity and symptoms in the neck, shoulder and arm in computer mouse users? **Ergonomics - Enhancing Human Performance**, Proceedings of the 32nd Annual Ergonomics Society of Australia and the Safety Institute of Australia National Conference.

Cook, C. and Kothiyal, K. 1998, Influence of mouse position on muscular activity in the neck, shoulder and arm in computer users, **Applied Ergonomics**, 29, 439-443.

Cook, CJ., Burgess-Limerick, R. and Chang, S. 2000, The prevalence of neck and upper extremity musculoskeletal symptoms in computer mouse users, **International Journal of Industrial Ergonomics**, 26, 347-356.

Cooper, A. and Straker, L. 1998, Mouse versus keyboard use – a comparison of shoulder muscle load, **International Journal of Industrial Ergonomics**, 22, 351-357.

Damann, EA. and Kroemer, KHE. 1995, Wrist posture during computer mouse usage, **Proceedings of the Human Factors 39th annual meeting**, Oct 9-13, San Diego, 625-629.

De Krom, MC., Knipschild, PG., Kester, AD., Thijs, C., Boekkooi, PF. and Spaaris, F. 1992, Carpal tunnel syndrome: prevalence in the general population, **Journal of Clinical Epidemiology**, 45, 373-376.

Douglas, SA. & Mithal, AK. 1997, **The Ergonomics of Computer Pointing Devices. Advanced Perspectives in Applied Computing**. London: Springer-Verlag.

Faucett, J. and Rempel, D. 1996, Musculoskeletal symptoms related to video display terminal use, **AAOHN Journal**, 44, 33-39.

Fernström, E. and Ericson, MO. 1997, Computer mouse or trackpoint - effects on muscular load and operator experience, **Applied Ergonomics**, 28, 347-354.

Fogleman, M. and Brogmus G, 1995, Computer mouse use and cumulative trauma disorders of the upper extremities, **Ergonomics**, 38, 2465-2475.

Franzblau, A., Flaschner, D., Albers, JW., Blitz, S., Werner, R. and Armstrong, T. 1993, Medical screening of office workers for upper extremity cumulative trauma disorders, **Archives of Environmental Health**, 48, 164-170.

Gerr, F., Marcus, M. and Ortiz, DJ. 1996, Methodological limitations in the study of video display terminal use and upper extremity musculoskeletal disorders, **American Journal of Industrial Medicine**, 29, 649-656.

Hagberg, M. 1981, Work load and fatigue in repetitive arm elevations, **Ergonomics**, 24, 543-555.

Hagberg, M. 1988, Occupational musculoskeletal disorders - a new epidemiological challenge? In C. Hogstedt and C. Reuterwall (Eds), **Progress in Occupational Epidemiology**, 15-26. Elsevier Science Publisher.

Hagberg, M. 1995, The “mouse-arm syndrome” – concurrence of musculoskeletal symptoms and possible pathogenisis among VDU operators, **Work with Display Units 94**, Eds A. Grieco, G. Molteni, B. Piccoli and E. Occhipinti, pp381-385.

Hagberg, M., Morgenstern, H. and Kelsh, M. 1992, Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome, **Scandinavian Journal Work Environment and Health**, 18, 772-780.

Hagberg, M., Silverstein, B., Wells, R., Smith, MJ., Hendrick, HW., Carayon, P. and Perusse, M. 1995, **Work related musculoskeletal disorders (WMSDs): A reference book for prevention**. Eds I Kuorinka and L Forcier. London: Taylor and Francis.

Hamilton, N. 1996, Source document position as it affects head position and neck muscle tension, **Ergonomics**, 39, 593-610.

Hanson, MA., Donnan, PT., Graveling, RA., Maclaren, WM., Butler, DO., Butler, MP., Hurley, JF., Kidd, MW., Lancaster, RJ., Prescott, G., Soutar, CA., Symes, AM. and Tesh, KM. 1999, **Epidemiological and ergonomics study of occupational factors associated with symptoms of upper limb disorders in keyboard operators**. IOM Research Report TM/99/04.

Hanson, M., Graveling, R. and Donnan, P. 1997, Investigation into the factors associated with symptoms of ULDs in keyboard users, **Contemporary Ergonomics**, 435-430.

Harvey, R. and Peper, E. 1997, Surface Electromyography and mouse use position, **Ergonomics**, 40, 781-789.

Health and Safety Commission (HSC). 1997, **Health and Safety Statistics 1997/98**. HSE Books.

Health and Safety Executive (HSE). 1992, **Display Screen Equipment Regulations, 1992: Guidance on Regulations**. HSE Books.

Health and Safety Executive (HSE). 1998, **Working with VDUs**. HSE Books.

Health and Safety Executive (HSE). 2001, **Tackling work-related stress: a managers’ guide to improving and maintaining employee health and well-being**. HSE Books.

Health and Safety Executive (HSE). 2002, **Upper limb disorders in the workplace**. HSG60. HSE Books.

Heasman, T., Brooks, A. and Stewart, T. 2000, **Health and safety of portable display screen equipment**. CRR 304/2000. HSE Books.

Hoffman, ER., Chang, WY. and Yim, KY. 1997, Computer mouse operation: is the left-handed user disadvantaged? **Applied Ergonomics**, 28, 245-248.

Hünting, W., Laubli, TH. and Grandjean, E. 1981, Postural and visual loads at VDT workplaces. I. Constrained postures. **Ergonomics**, 24, 917-931.

Ichikawa, H., Homma, M. and Umemura, U. 1999, An experimental evaluation of input devices for pointing work, **International Journal of Production Economics**, 235-240.

ISO 9241-9:2000 2000, **Ergonomic requirements for office work with visual display terminals (VDTs). Requirements for non-keyboard input devices.** International Organization for Standardization.

Johnson, P., Dropkin, J., Hewes, J. and Rempel, D. 1993, Office Ergonomics: Motion analysis of computer mouse usage**, Proceedings of the American industrial Hygiene conference and Exposition**, VA: AIHA.

Karlqvist, L. 1997, Assessment of physical work load at visual display unit workstations ergonomic applications and gender aspects, **PhD Thesis**, Department of Occupational Health, Karolinska Hospital, Stockholm, Sweden.

Karlqvist, L., Hagberg, M. and Selin, K. 1994, Variation in upper limb posture and movement during word processing with and without mouse use, **Ergonomics**, 37, 1261-1267.

Karlqvist, L., Hagberg, M., Wenemark, M. and Anell R. 1996, Musculoskeletal symptoms among computer assisted design (CAD) operators and evaluation of a self-assessment questionnaire, **International Journal of Occupational and Environmental Health**, 2, 185-194.

Keir, PJ., Bach, JM. and Rempel, DM. 1998, Fingertip loading and carpal tunnel pressure: differences between a pinching and pressing task, **Journal of Orthopaedic Research**, 16, 112-115

Keir, PJ., Bach, JM. and Rempel, D. 1999, Effects of computer mouse design and task on carpal tunnel pressure, **Ergonomics**, 42, 1350-1360.

Kilbom, A. 1988, Isometric strength and occupational muscle disorders, **European Journal of Applied Physiology and Occupational Physiology,** 57, 322-326.

Kilbom, Å. and Persson, J. 1987, Work technique and its consequences for musculoskeletal disorders, **Ergonomics**, 30, 273-279.

Kourinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Bierig-Sorenson, F., Anderson, G. and Jorgenson, K. 1987, Standardised Nordic questionnaire for the analysis of musculoskeletal symptoms, **Applied Ergonomics**, 18, 233-237.

Mackay, C., Burton, K., Boocock, M., Tillotson, M. and Dickinson, C. 1998, **Musculoskeletal Disorders in Supermarket Cashiers**. HSE Books.

Mackinnon, SE. and Novak. CB. 1997. Repetitive use and static postures: a source of nerve compression and pain, **Journal of Hand Therapy**, 10, 151-159.

Maeda, K. 1977, Occupational cervicobrachial disorder and its causative factors, **Journal of Human Ergology**, 6, 193-202.

Matias, AC., Salvendy, G. and Kuczek, T. 1998, Predictive models of carpal tunnel syndrome causation among VDT operators, **Ergonomics**, 41, 213-226.

Norusis, MJ. 1997, SPSS® 7.5. **Guide to Data Analysis**. New Jersey: Prentice-Hall.

Occupational Safety & Health Administration, 1991. U.S. Department of Labour. Ergonomics report – 3714.

(http://www.osha-slc.gov/SLTC/ergonomics/ergonomicreports_pub/nat910328.html)

Paul, R., Lueder, R., Selner A. and Limaye, J. 1996, Impact of new input technology on design of chair armrests: investigation on keyboard and mouse use**, Key to the Future,** Proceedings of the Human Factors 40th annual meeting, Oct, Philadelphia, pp380-384.

Peters, M. and Ivanoff, J. 1999, Performance symmetrics in computer mouse control of right-handers, and left-handers with left and right-handed mouse experience, **Journal of Motor Behaviour**, 31, 86-94.

Punnett, L. and Bergqvist, U. 1997, **Visual display unit work and upper extremity musculoskeletal disorders. A review of epidemiological findings**, National Institute for Working Life - ergonomic expert committee document no 1, Solna: National Institute for Working Life.

Rempel, D., Serina, E., Klineberg, E., Martin, BJ., Armstrong, TJ., Foulke, JA. and Natarajan, S. 1997, The effect of keyboard keyswitch make force on applied force and finger flexor muscle activity, **Ergonomics***,* 40, 800-808.

Schuldt, K., Ekholm, J., Harms-Ringdahl, K., Nemeth, G. and Arborelius, UP. 1987, Effects of arm support or suspension on neck and shoulder muscle activity during sedentary work, **Scandinavian Journal of Rehabilitation Medicine**, 19, 77-84.

Smith, MJ. and Carayon, P. 1996, Work organization, stress, and cumulative Trauma disorders, In **Beyond Biomechanics: Psychosocial Aspects of Musculoskeletal Disorders in Office Work**, Edited by S.D. Moon and S.L. Sauter. London: Taylor & Francis. pp23-42.

Smutz, P., Serina, E., Rempel, D. 1994, A system for evaluating the effect of keyboard design on force, posture, comfort, and productivity, **Ergonomics**, 37, 1649-1660.

Taylor, RG. and Hinson, N. 1988, Individual differences in the use of a pointing device, **Contemporary Ergonomics**, Proceedings of the Ergonomics Society's 1988 Annual Conference Manchester, England, 11-15 April, 521-525.

Wahlström, J., Svensson, J., Hagberg, M. and Johnson. P. 2000, Differences between work methods and gender in computer mouse use, **Scandinavian Journal of Work Environment and Health**, 26, 390-397.

Weiss, ND., Gordon L., Bloom, T., So, Y. and Rempel, DM. 1995, Position of the wrist associated with the lowest carpal tunnel pressure: implications for splint design, **Journal of Bone and Joint Surgery**, 77-A, 1695-1699.

Werner, R., Armstrong, TJ., Bir, C. and Aylard, MK. 1997, Intracarpal canal pressures: the role of finger, hand, wrist, and forearm position, **Clinical Biomechanics**,12, 44-51.

Westgaard, R., Waersted, M., Jansen, T. and Aaras, A. 1985, Muscle load and illness associated with constrained body postures. In: Corlett N and Wilson J (Eds), **The Ergonomics of Working Postures** (pp 5-18). London: Taylor and Francis.

Woods, V., Buckle, P. and Haisman, M. 1999, **Musculoskeletal Health of Cleaners**. HSE Books.

Woods, V. and David, G. 2000, **A study of eyestrain and musculoskeletal disorders among video coders**, Proceedings of the XIVth triennial Congress of the International Ergonomics Association and 44th meeting of the Human Factors and Ergonomic Society, July 29-August 4 San Diego, California, pp5-573-576 .

Ydreborg, B. and Kraftling, A. 1987, **Referensdata Till Formularen FHV 001 D, FHV 002 D, DHV 003 d, FHV 004 D och FHV007 D. Rapport 6**. The Foundation for Occupational Health Research and Development. Orebro.

Appendix 1

IT Managers Questionnaire

Non-keyboard computer input devices questionnaire

This questionnaire is part of a study for the Health and Safety Executive looking at the design and use of non-keyboard computer input devices (e.g. mouse, joystick, touch screen and touch pad). The Universities of Surrey and Loughborough are conducting the study.

This questionnaire has been sent to IT, Health and Safety and Occupational Health managers in organisations throughout the UK.

We would like you to complete the questionnaire which will provide us with vital background information for the study. It should take about 10 minutes.

The questionnaire is confidential and will only be seen by our research team. It will not be used for marketing purposes and summary report information will only be presented to the Health and Safety Executive in anonymous form.

Thank you for your help.

Please return the questionnaire to us as soon as possible in the FREEPOST envelope

If you would like any more information about the study, contact:

Valerie Woods, University of Surrey, Guildford GU2 5XH.
Telephone: 01483 259213 or email: v.woods@surrey.ac.uk.

Or have a look at our study web site:

http://www.eihms.surrey.ac.uk/robens/erg/NKID.html

UniS

Loughborough University

Name of your organisation	
Primary function of your organisation	
Your job title	
Number of employees at your site	
Number of employees who use only desktop computers	
Number of employees who use only laptop computers	
Number of employees who use both desktop and laptop computers	
Total number of employees who use computers	

- **What percentage of desktop and laptop computer users in your organisation use the following computer input devices?**

	% of desktop computer users	% of laptop computer users
Mouse		
Touch screens		
Touch pads		
Trackerballs		
Joysticks		

- **Write down any other (non-keyboard) computer input devices in use in your organisation and specify the application/purpose for which they are used.**

- **Tick the applications or type of work conducted with these input devices.**

	Mouse	Touch screen	Touch pad	Trackball	Joystick	Laptop mini joystick
Word processing						
Accounting or other specialised software						
Accessing database information						
Computer aided design (CAD)						
Programming						
Spreadsheets						
Control operation e.g. machines, labelling, EPOS						
Games development						
Other: please specify						
Other: please specify						

- **Are you aware of any problems related to the use of non-keyboard computer input devices in your organisation?** (e.g. ease of use, workstation set-up, user complaints, maintenance issues)

Mouse	
Touch screen	
Touch pad	
Trackball	
Joystick	
Laptop mini joystick	
Other:	

- **Describe any new non-keyboard input devices that will be used in your organisation in the near future**

- **If your organisation would be willing to assist in the further stages of the study, please provide us with a contact name and address below**

Thank you! Please post this questionnaire to us in the FREEPOST envelope

Appendix 2

Health and Safety Managers Questionnaire

Non-keyboard computer input devices questionnaire

This questionnaire is part of a study for the Health and Safety Executive looking at the design and use of non-keyboard computer input devices (e.g. mouse, joystick, touch screen and touch pad). The Universities of Surrey and Loughborough are conducting the study.

This questionnaire has been sent to IT, Health and Safety and Occupational Health managers in organisations throughout the UK.

We would like you to complete the questionnaire which will provide us with vital background information for the study. It should take about 10 minutes.

The questionnaire is confidential and will only be seen by our research team. It will not be used for marketing purposes and summary information will only be presented to the Health and Safety Executive in anonymous form.

Thank you for your help.

Please return the questionnaire to us as soon as possible in the FREEPOST envelope

If you would like any more information about the study, contact:

Valerie Woods, University of Surrey, Guildford GU2 5XH.
Telephone: 01483 259213 or email: v.woods@surrey.ac.uk.

Or have a look at our study web site:
http://www.eihms.surrey.ac.uk/robens/erg/NKID.html

UniS

Loughborough University

Name of your organisation	
Primary function of your organisation	
Your job title	
Number of employees at your site	
Number of employees who use only desktop computers	
Number of employees who use only laptop computers	
Number of employees who use both desktop and laptop computers	
Total number of employees who use computers	

Computer Usage

- **What percentage of desktop and laptop computer users in your organisation use the following computer input devices?**

	% of desktop computer users	% of laptop computer users
Mouse		
Touch screens		
Touch pads		
Trackerballs		
Joysticks		

- **Write down any other (non-keyboard) computer input devices in use in your organisation and specify the application/purpose for which they are used.**

- **Tick the applications or type of work conducted with these input devices.**

	Mouse	Touch screen	Touch pad	Trackerball	Joystick	Laptop mini joystick
Word processing						
Accounting or other specialised software						
Accessing database information						
Computer aided design (CAD)						
Programming						
Spreadsheets						
Control operation e.g. machines, labelling, EPOS						
Games development						
Other: please specify						
Other: please specify						

- **Are you aware of any problems related to the use of non-keyboard computer input devices in your organisation?** (e.g. ease of use, workstation set-up, user complaints, maintenance issues)

Mouse	
Touch screen	
Touch pad	
Trackball	
Joystick	
Laptop mini joystick	
Other: please specify	
Other: please specify	

- **Describe any new non-keyboard computer input devices that will be used in your organisation in the near future**

Health Information

- **Are you aware of any reports of neck, shoulder or arm pain:**

a) From anyone in your organisation? ☐ *yes* ☐ *no*

If YES, how many reports in the last 12 months?

b) Associated with the use of computers in general in your organisation? ☐ *yes* ☐ *no*

If YES, how many reports in the last 12 months?

c) Associated specifically with non-keyboard computer input devices in your organisation? ☐ *yes* ☐ *no*

If YES, how many reports in the last 12 months?

- **What was the total sickness absence for neck, shoulder or arm pain in the past 12 months in your organisation?** *Number of days*

- **If you wish to expand on any of the health problems associated with computer usage in your organisation, please provide details below**

- **If your organisation would be willing to assist in the further stages of the study, please provide us with a contact name and address below**

Thank you! Please post this questionnaire to us in the FREEPOST envelope.

Appendix 3

User Questionnaire

Computer input devices questionnaire

This questionnaire is part of a study for the Health and Safety Executive looking at the design and use of non-keyboard computer input devices (e.g. mouse, joystick, touch screen and touch pad). The Universities of Surrey and Loughborough are conducting the study.

We are interested in finding out about the extent to which different types of computer input devices are used, their applications, where the equipment is positioned on the workstation and problems associated with device use.

We would like you to complete this questionnaire. It should take you about 20 minutes. Most of the questions require a quick YES or NO answer or a tick in a box. In some cases you will be asked to provide a little more information.

The questionnaire is **confidential and anonymous** and will only be seen by our research team. It will not be used for any other purposes.

A donation will be made to the UK registered charity (no. 1061934) Express Link-Up for every questionnaire that is returned to us. This charity provides computers in childrens hospitals.

Thank you for your help. Please return the questionnaire to us by 25 August in the FREEPOST envelope provided

If you would like any more information about the study, contact:

Valerie Woods, University of Surrey, Guildford GU2 7TE
Telephone: 01483 876738 or email: v.woods@surrey.ac.uk
Or have a look at our study web site:
http://www.eihms.surrey.ac.uk/robens/erg/nkidpage.htm

UniS

Loughborough University

Background questions

Please circle the appropriate answer and provide extra information where you can

Are you :	**Male / Female**	
What is your age?		**Years**
Are you right or left handed?	**Right / Left**	
What height are you?		**cm or Feet/Inches**
Do you smoke?	**Yes / No**	
What is your job title?		
What is the main business sector of the company in which you work e.g. health, retail, finance?		
Number of years in this job		**Years**
Do you work full or part time?	**Full time / Part time**	
How many days do you work in an average WEEK?		**Days per WEEK**
Hours worked in an average WEEK		**Hours per WEEK**
Are your working hours flexible or fixed?	**Flexible / Fixed**	

Your workstation

Circle either Yes, No, DK (Don't know) or NA (Not applicable) to each question. If you have more than one workstation, please answer these questions in relation to the one you use most often.

Your chair

Is your chair comfortable?	**Yes / No**
Does the chair support your back adequately while working?	**Yes / No**
Can you adjust your chair to suit you during the working day?	**Yes / No**
If applicable, are the armrests comfortable?	**Yes / No / NA**
Are your feet comfortably supported on the floor or footrest?	**Yes / No**

Your desk

Do you work at more than one workstation?	**Yes / No**
Is all the equipment you use regularly within easy reach on your desk?	**Yes / No**
Is there sufficient legroom under the desk?	**Yes / No**
Do you have adequate space on your desk?	**Yes / No**
Did you have a say in how your workstation was arranged?	**Yes / No**

Your keyboard

Is there space in front of your keyboard to rest your hands/arms occasionally?	**Yes / No**
Do you use a wrist rest when using the keyboard?	**Yes / No**
Is the keyboard in a comfortable position for typing?	**Yes / No**

Your screen

Do you have more than one screen on your desk?	**Yes / No**
Is the height of the screen satisfactory for you?	**Yes / No**
Is the position of the screen satisfactory for you?	**Yes / No**
Is the screen image stable?	**Yes / No**
Are screen characters easy to read i.e. adequate size and space?	**Yes / No**
Are there reflections and glare on the screen?	**Yes / No**
If YES, can you take any actions to change this?	**Yes / No**

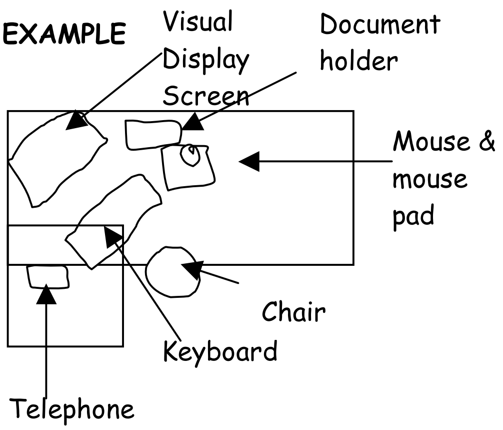
General

Is the equipment you use on your desk maintained adequately?	**Yes / No / DK**
Is the equipment (including keyboard & input device) you use on your desk adequately cleaned?	**Yes / No / DK**
Is there a reporting system for equipment faults?	**Yes / No / DK**
Have you received advice on health and safety on using a display screen?	**Yes / No / DK**

Please draw the outline of your desk in the space below

On the outline you have drawn, please indicate where each of the following is located: Visual Display Screen (VDU), Main processor unit/Hard drive, Keyboard, Input device, Chair, Ancillary equipment (i.e. document holder, wrist rest). Please label each item.

EXAMPLE



Use of computers & non-keyboard input devices (NKID) e.g. mouse, trackball

What year did you first start using computers?	
How long have you used computers in THIS job?	

Use of PCs

About how many hours do you spend working on your desktop PC **per day at work** (or weekly if you do not use a PC daily at work)?		**Hrs per day**
		Hrs per week

About how many hours do you spend working on your desktop PC **per day at home** (or weekly if you do not use a PC daily at home)?		**Hrs per day**
		Hrs per week

Use of laptops

About how many hours do you spend working on your laptop **per day at work** (or weekly if you do not use a laptop daily)?		**Hrs per day**
		Hrs per week

About how many hours do you spend working on your laptop **per day at home** (or weekly if you do not use a laptop daily at home)?		**Hrs per day**
		Hrs per week

How long have you been using non-keyboard input devices (NKID)?	**Years**

Is your future **NKID** use likely to increase (I), decrease (D) or stay the same (S)? *Please circle* **I / D / S**

Please give details of future NKID use if it is likely to change

Place a tick on EACH line to indicate how often you use the following devices on your desktop PC at work and circle Right (R), Left (L) or Both (B) to indicate the hand you use

Device	Never used	Use once per week	Use 2-3 times per week	Use daily	Hand Used *Please circle*
Mouse					**R / L / B**
Trackball					**R / L / B**
Touchpad					**R / L / B**
Touch screen					**R / L / B**
Joystick					**R / L / B**
Puck & digitiser (for CAD*)					**R / L / B**
Computer pen					**R / L / B**
Optical/remote mouse					**R / L / B**
Spaceball mouse					**R / L / B**
Voice input					
Other: *specify*					**R / L / B**
Other: *specify*					**R / L / B**

CAD = Computer Aided Design

On a typical day, how long (in minutes) do you spend on the following tasks at your desktop PC, what device do you use and how intensively do you use your device using the following scale:

(C) = Continual: Rarely taking hand from device during task
(R) = Regularly: Hand moving between device and keyboard
(O) = Occasional: Device used only occasionally

	Minutes spent on task	**Device used**	Intensity of use *Please circle*		
Example: Word processing	*240*	*mouse*	*C*	*R*	*O*
Word processing			**C**	**R**	**O**
Spreadsheets			**C**	**R**	**O**
Accessing database information			**C**	**R**	**O**
Data entry			**C**	**R**	**O**
Statistics (i.e. data processing)			**C**	**R**	**O**
Creating graphics			**C**	**R**	**O**
Computer aided design (CAD)			**C**	**R**	**O**
Programming			**C**	**R**	**O**
Accounting/other specialised software			**C**	**R**	**O**
Control operation e.g. EPOS**			**C**	**R**	**O**
Games development			**C**	**R**	**O**
Information search (e.g. internet)			**C**	**R**	**O**
email			**C**	**R**	**O**
Other: *specify*			**C**	**R**	**O**
Other: *specify*			**C**	**R**	**O**

** EPOS = Electronic Point Of Sale

Some people open files using the mouse and a pull down menu. We would like to know how you do the following tasks. Please place a tick (or ticks if you do a task in a number of ways) on EACH line.

	Keyboard & shortcut keys e.g. page up/down	**Mouse or other device & ......**		
		Pull down menu	**Toolbar/icons /pictures**	**Device button e.g. right click or similar**
Opening files				
Closing files				
Cutting				
Pasting				
Highlighting				
Saving				
Printing				

Please answer the following questions if you use a mouse.

If not go to the next section below

Who is the manufacturer?	
How many buttons does the mouse have?	
Does it have a scroll button?	**Yes / No**
Is the size of the mouse suitable for you?	**Too big / Just right / Too small**
Is the shape of the mouse comfortable for you?	**Yes / No**
Are the buttons easy to operate?	**Yes / No**
Do you find the movement of the mouse…..?	**Smooth / Jittery**
Do you find the mouse easy to control?	**Yes / No**
Are you able to reach the mouse easily e.g. no stretching?	**Yes / No**
Are you happy with how your workstation is set up to use the mouse?	**Yes / No**
Do you use an arm/wrist support when using the mouse?	**Yes / No**
If YES, please specify what you use	
Do you clean or is the mouse cleaned regularly?	**Yes / No**
Did you receive any training in how to use the mouse?	**Yes / No**
Has there been any maintenance/modification of the mouse?	**Yes / No**
Do you have any problems using the mouse now or in the past?	**Yes / No**
If YES, please specify any problems	
Have you had any pain/discomfort that you think may be related to the mouse?	**Yes / No**
If YES, what problems have you had and what do you think has caused these problems e.g. buttons, size?	
Do you use a mouse mat?	**Yes / No**
Do you think the mat is large enough?	**Yes / No**
Does the mouse mat include a wristrest?	**Yes / No**

If you use another non-keyboard input device…e.g trackball, touchpad, touch screen

If not, please go to work organisation questions

Please specify what the device is	
Who is the manufacturer?	
Is the size of the device suitable for you?	**Too big / Just right / Too small**
Is the shape of the device comfortable for you?	**Yes / No**
Are the buttons easy to operate?	**Yes / No / NA**
Do you find the movement of the device…..?	**Smooth / Jittery**
Do you find the device easy to control?	**Yes / No**
Are you able to reach the device easily e.g. no stretching?	**Yes / No**

Are you happy with how your workstation is set up to use the device?	**Yes / No**
Do you use an arm/wrist support when using the device?	**Yes / No**
If YES, please specify what you use	
Do you clean or is the device cleaned regularly?	**Yes / No**
Have you had any training in how to use the device?	**Yes / No**
Has there been any maintenance/modification of the device?	**Yes / No**
Do you have any problems using the device now or in the past?	**Yes / No**

If YES, please specify what

Have you had any pain and discomfort that you think may be related to the device?	**Yes / No**

If YES, what problems have you had and what do you think has caused these problems e.g. button size?

Work organisation

Please answer the following questions by ticking a box on EACH line

Do you take a lunch break?		**Always**		**Sometimes**		**Never**
Do you take other rest breaks?		**Always**		**Sometimes**		**Never**
Do you take breaks from your computer work?		**Always**		**Sometimes**		**Never**
What is the longest period of time (in minutes) you spend at the VDU without break?						
How often do you do this?		**Daily**		**1 per week**		**Monthly**

During your working day: please tick a column on EACH line

	Often	**Sometimes**	**Never**
Do you have to work very fast?			
Do you have to work intensively?			
Do you have enough time to do everything?			
Can others help you if you do not have enough time?			
Do you have a choice in deciding HOW you do your work?			
Do you have a choice in deciding WHAT you do at work?			
Can you decide when to take your breaks?			

No job is perfect but how often do you feel dissatisfied with your job? *Please circle*

Never Occasionally Frequently Always

How satisfactory are the following for you at work? Tick *a* box on EACH line under the face that seems most suitable for you.

	☺	😐	😐	😐	☹
The help & support given to you by supervisors					
The help & support given to you by colleagues					
Your work as a whole					

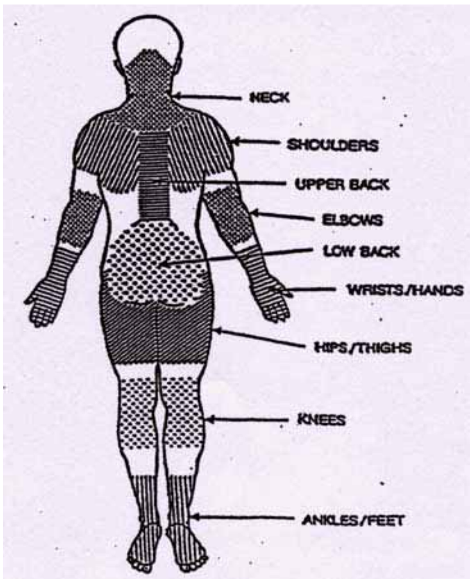
Your health

Have you had any muscular aches, pains or discomfort during the last 12 months? **Yes / No**

Have you had any muscular aches, pains or discomfort during the last 7 days? **Yes / No**

IF No, go to last page

If **YES**, please tick the box where you have had muscular aches, pains or discomfort, using the picture as a guide.



	Last 12 months	**Last 7 days**
Neck		
Right shoulder		
Left shoulder		
Right elbow		
Left elbow		
Right forearm		
Left forearm		
Right wrist & hand		
Left wrist & hand		
Upper back		
Lower back		
Hips/thighs		
Knees		
Ankles/feet		
Fingers/thumbs		

Have you taken medical advice for these aches and pains in the last 12 months? **Yes / No**

Have these aches and pains been diagnosed as a medical condition? **Yes / No**

If YES, what?

Do your symptoms change over the day? **Yes / No**

If YES, which symptoms and how do they change?

Did you have these aches and pains before you originally started to use computers? **Yes / No**

Do you think these aches/pains are related to anything you do or equipment you use **AT** work?	**Yes / No**
If YES, what?	
Do you think these aches and pains are related to anything you do **AWAY** from work?	**Yes / No**
If YES, what?	
In the last 12 months, have you been away from work because of these aches and pains?	**Yes / No**
In the last 7 days, have you been away from work because of these aches and pains?	**Yes / No**

We are particularly interested in the back and the upper limbs.

The following questions are about the effects of BACK PAIN & DISCOMFORT. During the last YEAR, has this back pain affected .... please place a tick on EACH line.

	No effect	Some effect	Considerable effect	Don't know
Your work performance in general				
Your work using the keyboard				
Your work using mouse/other device				
Housework				
Leisure time				
Socialising				
Sleep				

Have you changed your **work tasks** because of this back pain?	**Yes / No**
Have you changed your **work pace** because of this back pain?	**Yes / No**
Have you changed your **work posture/movement** because of this back pain?	**Yes / No**
Have you changed your **computer equipment or furniture** because of this back pain?	**Yes / No**
Have you changed your **non-keyboard input device** because of this back pain?	**Yes / No**
If YES to any of the above questions, what have you changed? Does this help and how?	

The following questions are about the effects of UPPER LIMB (neck, shoulder, arms and hands) PAIN & DISCOMFORT. During the last YEAR, has this upper limb pain affected .... please place a tick on EACH line.

	No effect	Some effect	Considerable effect	Don't know
Your work performance in general				
Your work using the keyboard				
Your work using mouse/other device				
Housework				
Leisure time				
Socialising				
Sleep				

Have you changed your **work tasks** because of the upper limb pain?	**Yes / No**
Have you changed your **work pace** because of the upper limb pain?	**Yes / No**
Have you changed your **work posture/movement** because of the upper limb pain?	**Yes / No**
Have you changed your **computer equipment or furniture** because of the upper limb pain?	**Yes / No**
Have you changed your **non-keyboard input device** because of these the upper limb pain?	**Yes / No**

If YES to any of the above questions, what have you changed? Does this help and how?

Eyestrain & headaches

Please tick the box(es) below describing any eye discomfort you have experienced

	In the last 12 months	In the last 7 days
Tired eyes		
Impaired visual performance eg. difficulty focussing: double or blurred vision		
Red or sore eyes		
Headaches		
Other related problems: please specify:……………………………....................		

Do you think these problems are related to anything you do or equipment you use **AT** work? **Yes / No**

If YES, what?

Do you think these problems are related to anything you do **AWAY** from work? **Yes / No**

If YES, what?

Have these problems affected how you set up your workstation? **Yes / No**

If YES, how?

Thank you for completing the questionnaire! Please return it to us in the envelope provided

Appendix 4

Device Assessment Checklist

Device Assessment Checklist

The following items might be useful in assessing the use of any computer input device. This may form part of a display screen assessment at work. This checklist has been found to be helpful in comparing input devices during use and in assessing individual preferences.

Name:	**Job:**
Dominant hand:	**PC or laptop or both:**
Device in use:	**Wrist support (e.g. gel pad):**
Time using this device:	**More than one desk:**
Desk layout (e.g. L-shape, standard, VDU table)	

Research shows that if any of the bottom row of the following table applies to a user, they require particular attention although any user is at potential risk.

Time working on computer	**Intensity of use**	**Breaks from computer**
Less than 2 hours	Occasional (hand on device from time to time during work tasks)	Regularly (more than 2 in hour)
2-4 hours	Regular (hand moving between keyboard and device during work tasks)	Occasional (less than 2 in hour)
4 hours or more	Continual (hand constantly on device during work tasks)	Very rarely (not every hour)

User questions

Any answer circled in the second column could be a problem

Have you had training to use the device?	**Yes**	**No**
Is the device within easy reach on the desk?	**Yes**	**No**
Device performance		
Does the device respond as you would expect, i.e. in the same manner for similar tasks?	**Yes**	**No**
Does the device give you adequate feedback when you press a button?	**Yes**	**No**
Is the device responsive and sensitive enough?	**Yes**	**No**
Do you have adequate control of the device, i.e. easy to place/move pointer to select information, no unintended pointer movement?	**Yes**	**No**
Does the device (including buttons, trackball) move smoothly and easily?	**Yes**	**No**
General operation		
Is the device easy and intuitive to use?	**Yes**	**No**
Do you know the function of all buttons/controls on the device?	**Yes**	**No**
Can you work at the speed you want to when using the device?	**Yes**	**No**
Does the device require an acceptable amount of effort to operate it?	**Yes**	**No**
Do the cables interfere with the operation of the device?	**No**	**Yes**
Do you find that the device works well with the software you use?	**Yes**	**No**
Is the size of the mouse mat appropriate?	**Yes**	**No**
Is the material of the mouse mat appropriate?	**Yes**	**No**

Device design

Is the size of the device suitable for your hand?	**Yes**	**No**
Is the shape of the device satisfactory for you?	**Yes**	**No**
Is the grip comfortable i.e. does not slip, can be grasped easily?	**Yes**	**No**
Can the device be positioned easily and quickly?	**Yes**	**No**
Is inadvertent button activation a problem with this device?	**Yes**	**No**
Can you easily reach all the device buttons or other controls?	**Yes**	**No**
Is the device stable i.e. does not slip/rock?	**Yes**	**No**

User device comfort

Are your hand/fingers in an uncomfortable position using the device?	**No**	**Yes**
Does the device cause pressure points that result in discomfort?	**No**	**Yes**
Do you experience finger fatigue when using or after using the device?	**No**	**Yes**
Do you experience wrist fatigue when using or after using the device?	**No**	**Yes**
Do you experience arm fatigue when using or after using the device?	**No**	**Yes**
Do you experience shoulder fatigue when using or after using the device?	**No**	**Yes**
Do you experience neck fatigue when using or after using the device?	**No**	**Yes**

Expert questions

Does the worker use keyboard shortcuts?	**Yes**	**No**
Does the worker use all buttons/controls on the device?	**Yes**	**No**

Comment on method of device use (e.g. long travel distances, use of right button etc)

Will the device be easy to keep clean and maintain?	**Yes**	**No**
Is the device suitable for the dominant hand of the subject?	**Yes**	**No**
Is the device suitable for the layout of the desk?	**Yes**	**No**
Is there sufficient space for the device on the desk?	**Yes**	**No**
Does the device encourage a relaxed arm and a straight wrist?	**Yes**	**No**
Can the device be operated without undue deviations of wrist from neutral?	**Yes**	**No**
Can the device be operated without undue deviations of fingers from neutral?	**Yes**	**No**
Can the device be operated without undue deviations of arm from neutral?	**Yes**	**No**
Can the device be operated without undue deviations of shoulder from neutral?	**Yes**	**No**
Can the device be operated without undue deviations of neck from neutral?	**Yes**	**No**
Is the user stretching to use the device?	**No**	**Yes**
Is the user’s arm or wrist supported on the desk or chair?	**Yes**	**No**

Comment on support for arm or wrist

Summary of points

Action

Appendix 5

Device Purchasing Checklist

Device Purchasing Checklist

Based on the finding of various parts of this study, the following points are considered essential for anyone considering the purchase of a new device at home or at work. It is important those responsible for equipment purchasing within organisations are aware of the following 10 point checklist

1. **Try before you buy**
2. **Does the device fit your hand/the hand of the user?**
3. **Does the device encourage a relaxed arm and a straight wrist?**
4. **Can you/the user reach all the controls on the device?**
5. **Is inadvertent button activation a problem?**
6. **Is it intuitive to use?**
7. **Can you/the user be accurate with the device?**
8. **Are you just buying it for 'looks'?**
9. **Is it suitable/compatible for all the software applications required?**
10. **Will the device be easy to keep clean and maintain?**

Appendix 6

Tables of statistical results for user trials

Key to abbreviations used in results tables

Abbreviation Used	Explanation
L	**L-shaped desk**
S	**Straight desk**
Fore	**Forearm**
F	**Forearm fully supported**
W	**Wrist only supported**
N	**No support**
RS	**Right shoulder**
LS	**Left shoulder**
WURDEV	**Wrist ulnar and radial deviation**
WFE	**Wrist flexion and extension**
OVERAL	**Overall comfort**
SCAP	**Scapular**
UPPER	**Upper arm**
WTEFF	**Wrist - effort**
HFEFF	**Hand and fingers - effort**

Example

LFFOREAR - LWFORE

L-shaped desk with forearm fully supported – forearm compared with L-shaped desk with wrist only supported - forearm

Table 1
Paired samples tests for muscle loading of the hand, forearm and shoulders - all conditions
(Tables 40-43 in Stage 5, User trial)

Pair No.	Pair description	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
1	LFHAND - LWHAND	-5.6	3.4	0.9	-7.5	-3.7	-6.4	14	.000
2	LFHAND - LNHAND	-7.4	5.0	1.3	-10.2	-4.6	-5.7	14	.000
3	LWHAND - LNHAND	-1.8	5.8	1.5	-5.1	1.4	-1.2	14	.243
4	LFFOREAR - LWFORE	-.80	2.0	0.5	-1.9	0.3	-1.6	14	.131
5	LFFOREAR - LNFORE	1.5	3.3	0.9	-0.4	3.3	1.7	14	.107
6	LWFORE - LNFORE	2.3	2.5	0.6	1.0	3.7	3.6	14	.003
7	LFRS - LWRS	-9.5	5.3	1.4	-12.4	-6.6	-6.9	14	.000
8	LFRS - LNRS	-35.7	12.1	3.1	-42.4	-28.9	-11.3	14	.000
9	LWRS - LNRS	-26.1	11.7	3.0	-32.6	-19.6	-8.7	14	.000
10	LFLS - LWLS	-2.9	2.8	0.7	-4.5	-1.3	-4.0	14	.001
11	LFLS - LNLS	-14.1	2.8	0.7	-15.6	-12.5	-19.2	14	.000
12	LWLS - LNLS	-11.1	4.5	1.1	-13.6	-8.6	-9.6	14	.000
13	SFHAND - SWHAND	-1.2	3.0	0.8	-2.9	0.5	-1.6	14	.139
14	SFHAND - SNHAND	-2.1	2.1	0.5	-3.3	-1.0	-3.8	14	.002
15	SWHAND - SNHAND	-0.88	2.8	0.7	-2.4	0.6	-1.2	14	.236
16	SFFORE - SWFORE	-0.32	4.7	1.2	-2.9	2.3	-0.3	14	.796
17	SFFORE - SNFORE	1.8	2.5	0.7	0.4	3.3	2.8	14	.014
18	SWFORE - SNFORE	2.2	3.8	1.0	8.1	4.2	2.2	14	.043
19	SFRS - SWRS	-12.17	3.3	0.9	-14.0	-10.3	-14.0	14	.000
20	SFRS - SNRS	-39.6	6.4	1.6	-43.1	-36.0	-24.0	14	.000
21	SWRS - SNRS	-27.4	6.2	1.6	-30.8	-24.0	-17.0	14	.000
22	SFLS - SWLS	-0.63	2.9	0.0	-2.2	1.0	-0.8	14	.412
23	SFLS - SNLS	-26.6	4.6	1.2	-29.1	-24.0	-22.3	14	.000
24	SWLS - SNLS	-26.0	4.0	1.0	-28.1	-23.7	-25.2	14	.000
25	LFHAND - SFHAND	-0.5	2.6	0.7	-2.0	1.0	-0.8	14	.433
26	LWHAND - SWHAND	3.8	3.4	0.8	1.9	5.7	4.3	14	.001

Pair No.	Pair description	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
27	LNHAND - SNHAND	4.8	3.6	1.0	2.8	6.8	5.2	14	.000
28	LFFOREAR - SFFORE	-5.2	3.8	1.0	-7.4	-3.1	-5.4	14	.000
29	LWFORE - SWFORE	-4.7	3.3	1.0	-6.6	-2.9	-5.6	14	.000
30	LNFORE - SNFORE	-5.0	1.8	0.5	-6.0	-4.0	-10.3	14	.000
31	LFRS - SFRS	7.2	4.7	1.2	4.7	9.8	6.0	14	.000
32	LWRS - SWRS	4.6	3.1	0.8	2.8	6.3	6.0	14	.000
33	LNRS - SNRS	3.3	13.1	3.4	-3.9	10.6	1.0	14	.343
34	LFLS - SFLS	-4.4	2.9	0.8	-6.0	-2.8	6.0	14	.000
35	LWRS - SWLS	9.4	4.1	1.1	7.1	11.7	9.0	14	.000
36	LNLS - SNLS	-16.9	4.2	1.1	-19.2	-14.6	-16.0	14	.000

Table 2
Paired samples tests for movement of wrist and fingers measurements at the L-shaped desk and straight desk for all support conditions. (Tables 45-48 in Stage 5, User trial)

Pair No.	Pair description	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
1	LFWFE - SFWFE	2.1	11.4	2.5	-3.1	7.2	1.0	19	.417
2	LFWURDEV - SFWURDEV	1.8	7.6	1.7	-1.7	5.2	1.0	19	.300
3	LFTHUMB - SFTHUMB	-2.1	17.0	3.7	-9.8	5.5	1.0	19	.565
4	LFFINGER - SFFINGER	1.4	15.7	3.4	-5.7	8.5	0.4	19	.687
5	LWWFE - SWWFE	-11.2	20.4	4.4	-20.5	-2.0	-2.5	19	.020
6	LWWURDEV - SFWURDEV	6.7	5.7	1.2	4.1	9.3	5.4	19	.000
7	LWTHUMB - SWTHUMB	0.7	22.4	5.0	-10.8	9.5	-0.1	19	.891
8	LWFINGER - SFFINGER	-4.1	17.0	4.0	-11.8	3.5	-1.1	19	.270
9	LNWFE - SNWFE	5.8	11.0	2.4	1.0	10.8	2.4	19	.024
10	LNWURDEV - SNURDEV	0.7	6.1	1.3	-2.1	3.5	0.5	19	.606
11	LNTHUMB - SNTHUMB	0.3	18.6	4.0	-8.2	8.7	0.1	19	.946
12	LNFINGER - SNFINGER	-2.7	16.6	3.6	-10.2	5.0	-0.7	19	.467

Table 3
Paired samples tests for movement of wrist and fingers - all conditions
(Tables 45-48 in Stage 5, User trial)

Pair No.	Pair description	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
1	LFWFE - LWWFE	12.8	14.2	3.1	6.3	19.3	4.1	19	.001*
2	LFWFE - LNWFE	1.5	10.5	2.3	-3.2	6.3	0.7	19	.512
3	LWWFE - LNWFE	-11.2	15.7	3.4	-18.4	-4.0	-3.2	19	.004
4	LFWURDEV - LWWURDEV	5.0	6.0	1.2	-7.5	-2.4	-4.0	19	.001**
5	LFWURDEV - LNWURDEV	-2.9	5.4	1.1	-5.4	-0.4	-2.4	19	.023
6	LWWURDEV - LNWURDEV	2.0	4.5	0.9	-5.7	4.0	2.0	19	.056
7	LFTHUMB - LWTHUMB	-0.6	7.4	1.6	-4.0	2.7	-0.3	19	.712
8	LFTHUMB - LNTHUMB	-1.0	22.9	5.0	-11.3	9.5	-0.1	19	.856
9	LWTHUMB - LNTHUMB	-0.3	24.4	5.3	-11.4	10.8	-0.5	19	.955
10	LFFINGER - LWFINGER	5.5	8.2	1.8	1.7	9.3	3.0	19	.006
11	LFFINGER - LNFINGER	4.9	8.7	1.9	1.0	8.9	2.6	19	.016
12	LWFINGER - LNFINGER	-0.6	12.8	2.7	-6.4	5.2	-0.2	19	.839
13	SFWFE - SWWFE	-0.5	12.5	2.7	-6.2	5.1	-0.2	19	.845
14	SFWFE - SNWFE	5.3	13.1	2.8	-0.6	11.3	2.0	19	.077
15	SWURDEV - SNURDEV	-1.0	4.9	1.0	-3.2	1.2	-0.9	19	.350
16	SFTHUMB - SWTHUMB	0.8	21.2	4.6	-8.8	10.5	0.2	19	.854
17	SFTHUMB - SNTHUMB	1.5	23.5	5.1	-9.2	12.2	0.3	19	.772
18	SWTHUMB - SNTHUMB	0.6	18.6	4.0	-7.8	9.1	.158	19	.876
19	SFFINGER - SWFINGER	-0.9	17.0	3.7	-8.7	6.7	-0.2	19	.792
20	SFFINGER - SNFINGER	0.9	17.9	3.9	-7.2	9.0	0.2	19	.819
21	SWFINGER - SNFINGER	1.8	9.7	2.1	-2.5	6.3	0.8	19	.383

Table 4
Paired samples tests for 'overall' comfort ratings - all conditions
(Tables 50-58 in Stage 5, User trial)

Pair No.	Pair description	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
1	LFOVERAL - LWOVERAL	0.4	1.0	0.2	-4.1	0.9	1.9	19	.070
2	LFOVERAL - LNOVERAL	1.2	1.8	0.4	0.4	2.0	3.1	19	.006
3	LWOVERAL - LNOVERAL	0.8	1.7	0.3	-2.6	1.6	2.0	19	.057
4	SFOVERAL - SFFOREAR	-5.0	1.7	0.3	-0.8	0.7	-0.1	19	.899
5	SFOVERAL - SNOVERAL	1.2	1.7	0.3	0.4	2.0	3.1	19	.005
6	SWOVERAL - SNOVERAL	1.2	1.7	0.4	0.4	2.0	3.1	19	.005
7	LFOVERAL - SFOVERAL	0.4	1.2	0.2	-0.2	1.0	1.4	19	.176
8	LWOVERAL - SWOVERAL	-1.0	1.4	0.3	-0.7	0.5	-0.3	19	.755
9	LNOVERAL - SNOVERAL	0.3	1.0	0.2	-0.1	0.8	1.4	19	.167

Table 5
Paired samples tests for shoulders, forearm, wrist and hand and fingers comfort ratings - for L-shaped desk (Tables 50-58 in Stage 5, User trial)

Pair No.	Pair description	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
The shoulders									
1	LFRSCAPU - LWRSCAPU	0.3	1.2	0.2	-0.2	0.9	1.2	19	.217
2	LFRSCAPU - LNRSCAPU	2.0	2.0	0.5	1.0	2.9	4.2	19	.000
3	LWRSCAPU - LNRSCAPU	1.6	1.9	0.4	0.7	2.5	3.8	19	.001
4	LFRUPPER - LWRUPPER	0.8	1.0	0.2	0.3	1.2	3.3	19	.003
5	LFRUPPER - LNRUPPER	1.8	2.0	0.5	0.8	2.7	3.9	19	.001
6	LWRUPPER – LNRUPPER	0.9	1.9	0.4	5.8	1.8	2.2	19	.038
7	LFLSCAPU – LWLSCAP	0.2	0.7	0.1	-0.1	0.5	1.2	19	.214
8	LFLSCAPU – LNLSCAPU	0.6	1.1	0.2	4.4	1.1	2.2	19	.036
9	LWLSCAP – LNLSCAPU	0.4	0.8	0.2	-1.3	0.8	2.0	19	.057
10	LFLUPPER – LWLUPPER	0.2	0.7	0.1	-0.1	0.5	1.2	19	.214
11	LFLUPPER – LNLUPPER	0.6	1.1	0.2	9.6	1.2	2.4	19	.024
12	LWLUPPER - LNLUPPER	0.4	0.8	0.1	6.3	0.8	2.4	19	.025
The forearm									
13	LFFOREAR – LWFOREAR	0.5	1.2	0.3	-5.7	1.0	1.9	19	.076
14	LFFOREAR – LNFOREAR	2.3	1.6	0.4	1.5	3.0	6.5	19	.000
15	LWFOREAR – LNFOREAR	1.8	1.4	0.3	1.1	2.4	5.6	19	.000
The wrist									
16	LFWRIST – LWWRIST	0.2	1.06	.24	-.29	.69	0.8	19	.408
17	LFWRIST – LNWRIST	1.2	1.52	.34	.54	1.9	3.6	19	.002
18	LWWRIST – LNWRIST	1.0	1.39	.31	.40	1.7	3.3	19	.003
The hand and fingers									
19	LFHANDFI – LWHANDFI	0.6	1.4	0.3	-1.6	1.3	2.0	19	.055
20	LFHANDFI – LNHANDFI	1.1	1.5	0.3	0.3	1.8	3.2	19	.004
21	LWHANDFI - LNHANDFI	0.4	1.9	0.4	-0.4	1.3	1.0	19	.317

Table 6
Paired samples tests for shoulders, forearm, wrist and hand and fingers comfort ratings - for straight desk (Tables 50-58 in Stage 5, User trial)

Pair No.	Pair description	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
The shoulders									
1	SFRSCAPU - SWRSCAPU	0.1	1.0	0.2	-0.3	0.6	0.6	19	.527
2	SFRSCAPU - SNRSCAPU	1.6	2.1	0.4	0.5	2.6	3.3	19	.004
3	SWRSCAPU - SNRSCAPU	1.4	1.7	0.4	0.6	2.2	3.6	19	.002
4	SFRUPPER - SWRUPPER	0.3	1.1	0.2	-0.1	0.8	1.3	19	.185
5	SWRUPPER - SNRUPPER	1.3	2.1	0.4	0.2	2.3	2.6	19	.015
6	SFRUPPER - SNRUPPER	1.7	2.0	0.4	0.7	2.6	3.8	19	.001
7	SFLSCAPU - SWLSCAPU	0.1	1.2	0.2	-0.4	0.6	0.3	19	.716
8	SFLSCAPU - SNLSCAPU	0.3	0.8	0.1	-0.1	0.7	1.5	19	.137
9	SWLSCAPU - SNLSCAPU	0.2	1.2	0.2	-0.3	0.7	0.7	19	.479
10	SFLUPPER - SWLUPPER	0.2	1.0	0.2	-0.2	0.7	1.0	19	.309
11	SFLUPPER - SNLUPPER	0.3	0.6	0.1	7.5	0.6	2.6	19	.015
12	SWLUPPER - SNLUPPER	0.1	1.2	0.2	-0.4	0.6	0.3	19	.716
The forearm									
13	SFFOREAR - SWFOREAR	0.2	1.1	.25	-.27	0.77	1.0	19	.330
14	SFFOREAR - SNFOREAR	1.1	1.5	.34	.39	1.8	3.2	19	.004
15	SWFOREAR - SNFOREAR	0.8	1.7	.40	1.4	1.6	2.1	19	.047
The wrist									
16	SFWRIST - SWWRIST	0.4	1.0	.22	-6.5	0.9	1.7	19	.088
17	SFWRIST - SNWRIST	0.8	2.0	.46	-.11	1.8	1.8	19	.081
18	SWWRIST - SNWRIST	0.4	1.9	.43	-.45	1.3	1.0	19	.311
The hand and fingers									
19	SFHADNFI - SWHANDFI	0.5	1.4	0.3	-0.1	1.1	1.6	19	.126
20	SFHADNFI - SNHANDFI	0.8	1.6	0.3	8.7	1.6	2.3	19	.031
21	SWHANDFI - SNHANDFI	0.3	2.0	0.4	-0.6	1.3	0.7	19	.451

Table 7
Paired samples tests for shoulders, forearm, wrist and hand and fingers effort ratings - for L-shaped desk (Tables 60-65 in Stage 5, User trial)

Pair No.	Pair description	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
	The shoulders								
1	LFRSEFFO – LWRSEFF	-.7	1.2	0.3	-1.3	-0.1	-2.6	19	.015
2	LFRSEFFO – LNRSEFF	-2.3	1.7	0.4	-3.0	-1.4	-5.8	19	.000
3	LWRSEFF – LNRSEFF	-1.5	1.7	0.3	-2.3	-0.6	-4.0	19	.001
4	LFLSEFFO – LWLSEFF	-0.1	0.6	0.1	-0.5	0.1	-1.1	19	.273
5	LFLSEFFO – LNLSEFF	-0.4	1.0	0.2	-0.8	9.5	-1.6	19	.107
6	LWLSEFF – LNLSEFF	-0.2	0.6	0.1	-0.5	7.3	-1.5	19	.131
	The forearm								
7	LFFOREFF – LWFOREFF	-0.8	1.0	0.24	-1.0	-0.3	-3.2	19	.004
8	LFFOREFF – LNFOREFF	-1.9	1.3	0.30	-2.5	-1.3	-6.2	19	.000
9	LWFOREFF – LNFOREFF	-1.1	1.1	0.25	-1.6	-0.6	-4.4	19	.000
	The wrist								
10	LFWTEFF – LWWTEFF	-0.6	1.1	0.263	-1.1	-4.9	-2.3	19	.034
11	LFWTEFF – LNWTEFF	-1.0	1.3	0.3	-1.6	-0.4	-3.6	19	.002
12	LWWTEFF – LNWTEFF	-0.4	0.9	0.2	-0.8	2.6	-1.9	19	.063
	The hand and fingers								
13	LFHFEFF – LWHFEFF	-0.8	1.0	0.2	-1.3	-0.4	-3.8	19	.001
14	LFHFEFF – LNHFEFF	-0.9	1.1	0.2	-1.4	-0.3	-3.4	19	.003
15	LWHFEFF - LNHFEFF	-7.5	1.33	0.2	-0.6	0.5	-0.2	19	.804

Table 8
Paired samples tests for shoulders, forearm, wrist and hand and fingers effort ratings - for the straight desk (Tables 60-65 in Stage 5, User trial)

Pair No.	Pair description	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
The shoulders									
1	SFRSEFF - SWRSEFF	-0.4	1.323	0	-1.0	0.1	-1.6	19	.125
2	SFRSEFF - SNRSEFF	-2.0	1.4	0.3	-2.6	-1.3	-6.1	19	.000
3	SWRSEFF - SNRSEFF	-1.5	1.8	0.4	-2.3	-0.7	-3.8	19	.001
4	SFLSEFF - SWLSEFF	-2.5	0.3	7.6	-0.1	0.1	-0.3	19	.748
5	SFLSEFF - SNLSEFF	-0.2	0.5	0.1	-0.4	4.4	-1.7	19	.104
6	SWLSEFF - SNLSEFF	-0.1	0.3	8.3	-0.3	-6.2	-2.1	19	.049
The forearm									
7	SFFOREFF - SWFOREFF	-.7	1.2	0.3	-1.3	-0.1	-2.6	19	.015
8	SFFOREFF - SNFOREFF	-1.9	1.2	0.2	-2.4	-1.3	-7.0	19	.000
9	SWFOREFF - SNFOREFF	-1.1	1.3	0.3	-1.7	-0.5	-3.9	19	.001
The wrist									
10	SFWTEFF - SWWTEFF	-0.9	1.5	0.3	-1.6	-0.1	-2.6	19	.017
11	SFWTEFF - SNWTEFF	-1.2	1.9	0.4	-2.0	-0.3	-2.8	19	.011
12	SWWTEFF - SNWTEFF	-0.3	1.6	0.3	-1.0	0.4	-0.8	19	.424
The hand and fingers									
13	SFHFEFF - SWHFEFF	-0.7	1.1	0.3	-1.2	-0.1	-2.7	19	.013
14	SFHFEFF - SNHFEFF	-1.0	1.5	0.3	-1.7	-0.2	-2.7	19	.011
15	SWHFEFF - SNHFEFF	-0.2	1.1	0.2	-0.8	0.2	-1.0	19	.290

Printed and published by the Health and Safety Executive
C2 11/02

MAIL ORDER
HSE priced and free
publications are
available from:
HSE Books
PO Box 1999
Sudbury
Suffolk CO10 2WA
Tel: 01787 881165
Fax: 01787 313995
Website: www.hsebooks.co.uk

RETAIL
HSE priced publications
are available from booksellers

HEALTH AND SAFETY INFORMATION
HSE InfoLine
Tel: 08701 545500
Fax: 02920 859260
e-mail: hseinformationservices@natbrit.com
or write to:
HSE Information Services
Caerphilly Business Park
Caerphilly CF83 3GG

HSE website: www.hse.gov.uk

RR 045

£20.00

ISBN 0-7176-2162-6

9 780717 621620