Quantifying the Use of Keyboard/Mouse through Intranet

Final Report

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Table of Contents

List of Figures

List of Table

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Abstract

A software-based tool was developed in this study to quantify the use of keyboard and mouse through Intranet. The feasibility and utility of the software-based tool was demonstrated in a field study that profiled 98 non-clerical professionals' use of keyboard and mouse during the course of their workday. With the use of the software-based tool, the study quantified for each participant his/her computer-on duration, actual duration of keyboard and mouse usage, total number of keystrokes and mouse clicks, and total number of rest breaks from computer.

The results showed that these technical professionals had their computers on for duration ranging from 115 minutes to 700 minutes during the day of the study. However, the actual duration of VDT usage ranged from 3 minutes to 316 minutes. There was no significant gender difference in the computer-on duration or in the actual VDT usage duration. The total number of keystrokes made by these participants ranged from 203 keys to 18,242 keys (Mean: 5,086; SD: 4,386 keys). The total number of mouse clicks, including left and right, single and double clicks, made during the workday ranged from 27 clicks to 5,749 clicks (Mean: 1,045; SD: 940 clicks). There was a significant gender difference in the number of keystroke made during the day. Females made more than twice as many keystrokes as males during the workday, 5,957 vs. 2,794 keys, ($p < .01$). There was no statistically significant gender difference in the number of mouse clicks made in the workday. Participants also rated their musculoskeletal discomfort using a 10-point Borg scale. Mantel-Haenszel chi-square statistic showed that the prevalence of self-perceived wrist and back discomfort was associated with the actual VDT usage

duration and with the total number of mouse clicks made in a workday. The results of logistic regression analysis, however, did not show any statistically significant association between the prevalence of self-perceived discomfort and the exposure estimates.

Significant Findings:

A software-based tool was developed in this study to quantify the use of keyboard and mouse through Intranet. The feasibility and utility of the software-based tool was demonstrated in a field study that profiled 98 non-clerical professionals' use of keyboard and mouse during the course of their workday. With the use of the software-based tool, the study quantified for each participant his/her computer-on duration, actual duration of keyboard and mouse usage, total number of keystrokes and mouse clicks, and total number of rest breaks from computer work.

Usefulness of Findings:

This software-based tool can be used to improve the quality of exposure estimate in epidemiological study and to facilitate health surveillance in VDT work. In addtion, since this exposure assessment tool is software based, it can be distributed through Intranet and Internet at no cost. The software-based tool installs and runs with minimal user training and involvement. Data collection is relatively simple since the collection process is done automatically through Intranet and Internet.

Scientific Report

Quantifying the Use of Keyboard/Mouse through Intranet

I. Introduction

Musculoskeletal discomfort and pain in the shoulders, neck, back, and hand/wrist are common among visual display terminal (VDT) workers.[1-7] Hagberg and Wegman showed that use of VDT for more than 20 hours per week was associated with excessive risk for certain musculoskeletal endpoints.[8] Bergqvist reported that increased use of keyboard increased the risk of hand/wrist problems.[9] Foglman and Brogmus, based on workers' compensation data, found that musculoskeletal disorders associated with computer mouse use appeared to be a growing problem and deserved more research.[10]

However, field evaluation of the association between VDT work and musculoskeletal complaints is in general hindered by a lack of objective measurement of exposure. Self-reported VDT work duration tends to be the primary measure of the physical demands posed by VDT in most studies. Self-reported exposure is prone to bias. And work duration as a surrogate of exposure only gives a partial picture of the physical demands associated with VDT work, as intermittent short break and variation of office activities may reduce the total physical demands of VDT work.[11, 12]

An objective exposure assessment tool is needed to improve the quality of exposure estimate in epidemiological study and to facilitate health surveillance in VDT work. This ideal tool should have the following characteristics. First, it should be reasonably accurate in providing an estimate of not only the total duration of VDT work but also the pattern of the intermittent breaks. Second, it should be relatively inexpensive and easily installed in many VDT workstations so that exposure could be estimated for as many VDT operators as possible. Third, it should require minimal, if any, user training and involvement in using the surveillance tool. Fourth, it should not affect the productivity of VDT operators. Fifth, it should be relatively easy for data collection and analysis so that feedback to the VDT operators could be provided relatively quickly. As the keyboard and mouse represent two major input devices in personal computer-based VDT work, and as Intranet and Internet are becoming more prevalent in modern office environment, an exposure surveillance tool satisfying the above criteria may be developed. The primary goal of the study was to develop a software-based tool that would satisfy the above criteria.

This report consists of two parts. Part I describes the components of a software-based tool for VDT work environment. Part II gives the results of a field application of the software in profiling the usage of keyboard and mouse in a group of technical professionals.

II. Methods

II.1 Part I: Component of the Software-Based Tool

As shown in Figure 1, the software-based exposure assessment tool is comprised of three major components. The first component captures the signals from the keyboard and the mouse. The second component increases the cumulative counts of counters based on the keyboard and mouse signals captured. The third component of the software-based tool uploads individual exposure record from each VDT workstation to a central server.

<u>Component I. Capturing Keyboard and Mouse Signals</u>

The first component was developed by adapting an Object Link & Embedding

(OLE) program in Visual Basic 4.[13] This particular OLE program intercepts signals from a keyboard and a mouse; gives the necessary Window messages, including those messages specifically for keyboard and mouse signals; and returns a specific identification number of the message intercepted. Based on the identification number returned, keyboard and mouse signals were identified and recorded. In addition to tracking signals from the keyboard and the mouse, this OLE program also allowed us to track the active window, i.e., the active application software, for which the keyboard or mouse signals were intended. For example, if the VDT user was using a word processing program and entered several keys, not only the keyboard signals will be tracked but also the name of the word processing program and the file name of the document could be tracked.

"Keyboard Input"

A typical keyboard has 101 keys. These keys can also be differentiated as printable keys such as the "a" and "1", and non-printable keys such as the function keys "Escape" and "F1" and cursor movement keys "PageUp" and "PageDown". The printable keys are identified by comparing them directly with the characters represented by the ASCII code. The non-printable keys are identified using their individual virtual key code provided by the Windows message.

"Mouse Input"

The OLE program installed within the software-based tool also allows tracking the status of mouse movement, and the up and down states of each of the two buttons (left and right) of the mouse. Single click and double clicks can also be differentiated with the software-based tool.

Component II. Cumulative Counts of Keyboard and Mouse Usage

Fifteen counters are created in the software-based tool to store cumulative counts of keyboard and mouse signals. Ten of these counters are for keyboard signals and the other five counters are for mouse signals.

The counters for keyboard signals are classified into three groups. The first group consists of counters designated for keys made separately by the little finger, the ring finger, the middle finger, and the index finger of the left hand. The second group of counters is for the keys made separately by the little finger, the ring finger, the middle finger and the index finger of the right hand. The third group of counters includes one counter for keys made typically made by the thumbs of both hands and another counter for special keys such as "Shift", "Ctrl", and "Alt".

Keys and finger counters assignment was accomplished in two ways, depending on whether the user is a touch-typist. If the user of the keyboard is a touch-typist, keys and finger counters were assigned according to those shown in Table I. For example, cumulative counts of keystrokes made on "q, a, z, !, Q, A, Z," are stored in one counter created for the left little finger, while that for "2, @, w, W, s, S, x, X" are kept in another counter designated for the left ring finger. The cumulative count of keystrokes made on the "Space" key is kept in the ninth counter designated as "thumbs," since the space-bar on the keyboard can be triggered by either the right or the left thumb. The "Shift", "Ctrl", and "Alt" keys are three sets of keys that can be identified but can not be differentiated into left or right since they share the same function but located at opposite sides of the keyboard.

For a keyboard user who is not a touch-typist, the software-based tool allows the user to enter the specific fingers that he/she uses to key in each of the keys on the keyboard. A template, as shown in Figure 2, was created to facilitate the process. Each non-touch typist only needs to enter his/her unique pattern of key-finger assignment once, since the information is kept in a computer file. Subsequent counting of keyboard signals is based on each user's key-finger assignment pattern stored in the file.

Five counters are included in the software-based tool to store mouse signals, i.e., "Left Button - Single Click", "Left Button - Double Click", "Right Button - Single Click", "Right Button - Double Click", and " Mouse Movement."

Component III. Multiple VDTs Exposure Assessment – File Transfer to a Central Server

The third component of the software-based tool was developed using a File Transfer Program (FTP). This component facilitates collecting data from multiple VDT workstations. At the end of each data collection session, this component of the software-based tool initiates a file transfer program that uploads the resultant exposure file from individual workstation to a central server for data collection and analysis.

The process of transferring a data log file is automatically completed at the end of day through a script file generated by the software-based exposure assessment tool. The script file includes the date and time of exposure data collection, file name, user's login name, and a password, if required by the server's security.

II.2. Part II: Field Evaluation of the Software in an Engineering Firm

The software-based tool was applied in a field study that aimed at profiling engineers' usage of keyboard and mouse in their VDT-related work. The field study was conducted in an engineering firm that has been in operation for more than thirty-five years. At the time of the study more than four thousand employees were employed. The company had 4000+ personal computer in operation.

A list of all employees in the general category of engineering profession was obtained from the management of the company. Random samples of the male and female engineers were selected from the list. An email was sent to each person on the random list. As shown in Appendix I of this report, the email explained the purpose of the study and solicited each potential participant's participation in the study. Those employees that agreed to participate in the study were instructed to access through the company's Intranet a designated computer and to download the software-based tool.

Each participant then installed the software-based tool in his/her computer and ran the software-based tool for at least one day. Once initiated, the software-based tool guided the participant through the process. The software-based tool first asked the participant to review an "informed consent form" on his/her monitor. Figure 3 shows a sample of the informed consent form. If the participant does not accept the terms outlined in the consent form, the software-based tool terminates itself. No data will be collected.

If the participant accepts the terms of the informed consent form, the software-based tool continues to an "Introduction" page of the software-based tool. This "Introduction" page, shown in Figure 4, gives an overview of the steps involved in using the tool. Help menus are also provided in the "Introduction" page. Figure 5 shows a sample of the help menu. Guided by a screen shown in Figure 6, the participant then proceeds to initiate the data collection steps. The software-based tool first asks whether the participant is a touch-typist, using a screen as shown in Figure 7. If the participant is not a touch-typist, the software-based tool then asks the participant to enter through a template, as described in Part I of the report.

In the field study, the software-based tool also incorporated a feature that allowed each participant to rate the severity of any musculoskeletal discomfort in the upper extremity and in the back. This discomfort survey was accomplished by using a body diagram shown in Figure 8. Each participant was to enter the severity of any musculoskeletal discomfort felt at the moment using a 0-10 Borg scale,[14] as shown in Figure 9. Once the discomfort survey was completed, the software-based tool automatically minimized its active Window and stayed in the background of the current Windows session. The participant then continued his/her daily use of the VDT. At the end of the participant's work shift, he/she recalled the software-based tool and completed the discomfort survey again. The software-based tool then used a screen, as shown in Figure 10, to guide the user and send the data file through Intranet to a central server located in the company. The protocol of the study was reviewed and approved by the UCLA General Campus Research Subjects Protection Committee.

Data Analysis

A total of 591 emails were sent to 393 female and 198 male engineers of the company to solicit their participation in the study. The specific email message is listed in the appendix of the report. Two hundred and forty-seven of them (158 females and 89 males) did not respond to the email message. One hundred and thirty of them (75 females and 55 males) responded but declined to participate in the study. Two hundred and fourteen of them (160 females and 54 males) indicated an interest in participating in the study. However, only one hundred and fifteen people actually ran the software-based tool and sent at least one data file profiling their use of keyboard and mouse in a workday.

Not all of the 115 participants were performing engineering functions at the time of study. Having excluded those participants that performed only clerical work, such as data entry, data files from seventy-one females and twenty-seven males were included for analysis. For those participants that ran the tool for multiple days, the data file with the longest run time was kept for analysis. Actual duration of VDT usage, total number of keystrokes, total number of mouse clicks, and total number of rest breaks from VDT work were determined from each participant data log file.

In addition to descriptive summary statistic, Mantel-Haenszel chi-squares and logistic regression were conducted.[15] The Mantel-Haenszel chi-square analysis was used as a simplified crude analysis to provide a first step in evaluating the nature and extent of potential association between exposure estimates, such as VDT duration and total number of keystrokes and mouse clicks, and the prevalence of self-perceived musculoskeletal discomfort. For this portion of the analysis, each participant of the study was classified into a specific group, based on his/her actual VDT usage duration, the total numbers of keystrokes and mouse clicks made during the day, respectively. As for self-musculoskeletal discomfort, a case was defined in this study as an individual who reported experiencing at least "moderate" musculoskeletal discomfort, i.e., a rating of greater or equal to 3 on a 10-point Borg scale.

Logistic regression was also conducted to model the association between the exposure estimates and the prevalence of self-perceived discomfort in seven body parts, while controlling the potential confounding effect of gender and of self-perceived discomfort at the beginning of workday. The logistic model included gender, status of self-perceived discomfort at the beginning of the workday, VDT usage duration, total number of keystrokes, and total number of mouse clicks. All variables in the model were treated as categorical variables. Odds ratios were estimated as the antilog of the regression.(16,17) A 95% confidence interval was calculated as the antilog of the standard error coefficients multiplied by 1.96 and -1.96. All statistical analysis was conducted with software package SPSS on a personal computer.(18)

Results

Part I.

The software-based tool was first evaluated by the Information Technology (IT) group of the engineering firm. The IT personnel found the software-based tool easy to install and user-friendly, though they also identified one proprietary software package incompatible with the software-based tool. The proprietary software package was used only once or twice a day for several minutes. Therefore, the software-based tool was modified to include an option allowing the VDT user to temporarily terminate the software-based tool before running that particular software package.

Despite that each participant was asked to run the software-based tool for two days, 39 of the 115 participants ran the software-based tool for only one day. Forty-three participants ran the software-based tool for two days while the rest of the participants ran the software-based tool for days ranging from 3 to 32 days. A total of three hundred and eighteen data files were received.

Figure 11 shows a sample of the data file profiling a participant's use of keyboard over a period of 8.6 hours. More than 10,000 keystrokes were made during the workday.

However, almost all of the keystrokes were made during the first 4 hours. Figure 12 shows the use of mouse by the same individual during the course of the day. The individual single-clicked the left mouse button for more than 800 times. Almost all the single clicks of the left button were made during the first 4 hours of work. The individual double-clicked the left mouse button for about 100 times. The number of single-clicks of the right mouse button was slightly more than 100 times. This participant never used double-click of the right mouse button. Several long breaks from VDT work were obvious from the figures. One can also extract the exact number of breaks from each data file, given an operational definition of break, since the software-based tool records keyboard and mouse activities every second.

Part II.

II.1. Use of Keyboard and Mouse

Overall, the participants had their computers on for duration ranging from 115 minutes to 700 minutes during the day that they ran the software-based tool. More than 50% of the participants had their computers on for more than 480 minutes, since most of the participants worked on a 10-hour/day 4-day/week schedule. However, the results also showed that the participants spent only from 1% to 65% of the computer-on duration actively using the keyboard and the mouse. Sixty-seven participants (68.4%) actually worked on their computers for less than 2 hours, while 28 participants (28.6%) actively used their computers for between 2 to 4 hours. Only 3 individuals actively used their computers for more than 4 hours. There was no significant gender difference in the computer-on time or in the actual VDT usage duration.

To demonstrate that one can also use the software-based tool to estimate the number of rest breaks that a VDT user takes during a workday, this study arbitrarily defined a rest break from VDT work as a period of no keyboard nor mouse activities for greater than 30 seconds. Overall, 11.2% (n=11) of the participants took 0 - 300 breaks, while 23% (n=23) of the participants took between 300 - 500 breaks. A majority of the participants, 56.1% (n=55), took between 500 to 700 breaks. 9.2% (n=9) of the participants took more than 700 breaks from VDT works.

Overall, total number of keystrokes made by all participants ranged from 203 keys to 18,242 keys with a mean of 5,086 keys and a standard deviation of 4,386 keys. However, there was a statistically significant gender difference in the number of keystroke made during the day. Female participants made more than twice as many keys as males during the workday, 5,957 vs. 2,794 keys, ($p < .01$).

Overall, total mouse clicks including left and right, single and double clicks, made by these participants during the workday ranged from 27 clicks to 5,749 clicks with a mean of 1,045 clicks and a standard deviation of 940 clicks. However, there was no statistically significant gender difference in the number of mouse clicks made in the workday.

II.2. Self-Perceived Musculoskeletal Discomfort

Figure 13 shows the percentage of all participants reporting in seven body parts a self-perceived musculoskeletal discomfort level that was greater than or equal to 3 on a 10-point Borg scale. The rating of discomfort was done both before and after the workday. As shown, at the beginning of the workday, more than 10% of the participants reported feeling at least "moderate" discomfort in the neck, shoulders and back. At the end of the workday, more than 15% of the participants reported feeling at least "moderate" discomfort in the neck, shoulders, wrists, and back. There was no change in the percentage of participants feeling discomfort in the shoulders, however, there was an increase in the percentage of participants feeling discomfort in the neck, arms, wrist, hands, and back.

Figure 14 shows the percentage of female participants reported feeling at least "moderate" discomfort in seven body parts both at the beginning and at the end of the workday. At the beginning of the workday, problems with the neck, shoulders, and back affected more than 10% of the female participants. At the end of the workday, there was an increase in the percentage of female participants reporting discomfort in the neck, arms, wrists, hands, and back. At the end of the workday, more than 15% of the female participants reported discomfort in the neck, wrists, and back.

Figure 15 shows the percentage of male participants reported feeling at least "moderate" discomfort in seven body parts both before and after the workday. More than 10% of the male participants reported discomfort in the neck, shoulders, elbows, arms, wrists, and back. At the end of the workday, there was an increase in the percentage of male participants reporting discomfort in the neck, shoulders, and wrists. There was a decrease, however, in the percentage of male participants that reported discomfort in the elbows, arms, and back.

II.3. VDT Usage Duration and Prevalence of Self-Perceived Discomfort

To explore the association between VDT usage and the prevalence of self-perceived discomfort, this study classified the participants into three groups, 0-2 hours, 2-4 hours, and > 4 hours, based on their actual VDT usage duration. "0-2 hours" group has

67 people (48 females and 19 males); "2-4 hours" group has 28 people (21 females and 7 males); and ">4 hours" group has 3 people (2 females and 1 male).

Figures 16 through 22 show for each of the groups the percentage of participants that reported at least "moderate" discomfort in seven body parts. In general, as the VDT usage duration increased, there was an increase in the percentage of participants reporting discomfort. For example, in Figure 16, 25% of the participants in the "2-4 hours" group reported neck discomfort, compared to 16.4% of the participants in the "0-2 hours" group. In Figure 17, 28.6% of the participants in the "2-4 hours" group reported at least "moderate" discomfort in their shoulders, while 11.9% of the participants in the "0-2 hours" group reported shoulder discomfort. However, none of the three participants in the ">4 hours" group reported discomfort in the neck, shoulders, elbows, arms, and hands.

Chi-square analysis showed that for all participants and for females the association between the prevalence of self-perceived back discomfort and the actual VDT usage duration was statistically significant. A chi-square value of 5.09 ($p < .05$) was found for all participants, while a chi-square value of 6.38 ($p < .05$) was found for females. The apparent increase in the prevalence of self-perceived wrist discomfort for all participants and for females was not statistically significant at an alpha level of .05. There was no significant increase with VDT duration in the prevalence of self-perceived discomfort in the other body parts.

II.4. Total Keystrokes and Self-Perceived Discomfort

The participants were also classified into three groups based on the total number of keystrokes they made in a workday. The first group included those participants that made less than 2,000 keystrokes during the workday. Twenty-seven people (14 females and 12 males) were in the first group. The second group was comprised of participants that made between 2,000 to 6,000 keystrokes. Forty-three people (31 females and 12 males) were in this group. Those participants that made more than 6,000 keystrokes formed the third group. There were twenty-nine people (26 females and 3 males) in the third group.

Figures 23 through 29 show the percentage of participants reporting discomfort in each of the three groups. Overall, as the number of keystrokes made during a workday increased, there was an increase in the percentage of participants reporting discomfort in the neck, shoulders, wrists, and hands.

There was no significant increase in the prevalence of self-perceived discomfort as the total number of keystrokes made during the day increased. The chi-square values ranged from 0.03 to 2.38, none of these was significant at an alpha level of .05.

II.5. Total Mouse Clicks and Self-Perceived Discomfort

This study also classified the participants into four groups based on the total number of mouse clicks they made in a workday. The first group, consisting of participants that made less than 500 mouse clicks, had 32 people (23 females and 9 males). The second group, formed by the participants that made between 500 to 1,500 mouse clicks, had 42 people (30 females and 12 males). There were 19 people (14 females and 5 males) in the third group, consisting of participants that made between 1,500-2,500 mouse clicks. The fourth group had 5 people (4 females and 1 male). They made more than 2,500 mouse clicks during the workday.

Figures 30 through 36 show for each of the four groups the percentage of participants that reported discomfort. Overall, there was an increase in the prevalence of participants reporting discomfort in the wrists as the total number of mouse clicks made in the workday increased. Chi-square analysis showed that for all participants and for females there was a significant increase in the prevalence of self-perceived wrist discomfort as the total number of mouse clicks made during the workday increased. The chi-square value for all participants was 4.0 ($p < .05$), while that for females was 5.04 ($p < .05$). The prevalence of self-perceived back discomfort also increased significantly for all participants and for female participants only. The chi-square values were 7.37 and 10.49, respectively. Both were statistically significant at an alpha level of 0.05.

Logistic Regression Analysis

After controlling the potential confounding effect of gender and of self-perceived discomfort at the beginning of the workday, the logistic regression analysis did not show any statistically significant association between the prevalence of self-perceived discomfort and the exposure estimates.

Discussion

Part I. Software-based tool for exposure assessment

Through laboratory simulations and in a field study with 98 participants, this study demonstrated the feasibility and utility of a software-based tool for objective exposure assessment in VDT work environment. Since this exposure assessment tool is software based, it was distributed in the field study through Intranet with no cost involved. The software-based tool installs and runs with minimal user training and involvement. Data collection is relatively simple since the collection process is done automatically through Intranet.

In the field study, though the company's Information Technology (IT) group evaluated the software-based tool before data collection, 30 people still reported that they either ran into problems in program installation or their computers crashed after installation. The IT personnel could not explain as to the cause of these failures. Since the participating company utilized many proprietary software packages and handled classified information, actual causes of these computer problems could not be identified and resolved in the present study. More studies need to be conducted in other VDT work environment to test the software-tool's compatibility with other commonly used software packages.

Part II. Use of Keyboard and Mouse and the Prevalence of Self-Perceived Discomfort

The results showed that though more than 50% of the participants kept their computers on for more than eight hours, only three participants actively used their computers for more than 4 hours. Since the company implemented a flexible schedule, most employees were on a 10-hour workday 4-day week schedule. The majority, more than 60%, of the participants used their computers for less than 2 hours. This finding seems reasonable as the focus of the present study was on non-clerical personnel. Nonetheless, the finding was based on data collected in one workday, one should be cautioned in interpreting the data.

Overall, less than 20% of the participants reported musculoskeletal discomfort in the body parts considered. The prevalence of self-perceived discomfort seems low compared to that reported in literature for other types VDT work environments. The low prevalence of self-perceived discomfort found in the present study seems congruent with the fact that most participants used their keyboards and mice for less than 2 hours and that the company had been implementing ergonomics program for several years.

Nonetheless, more than 15% of the participants reported feeling of "moderate" discomfort in their neck, shoulders, wrists, and back at the end of the workday. The prevalence of self-perceived discomfort at the end of the workday was higher by about 4% to 8% than that at the beginning of workday for body parts such as neck, arms, wrists, hands and back. It was hypothesized that as the actual usage of keyboard and mouse in terms of VDT duration or total number of keystrokes and mouse clicks increased, there should be a concomitant increase in the prevalence of self-perceived discomfort. This hypothesis was partially supported by the statistically significant association between the prevalence of self-perceived back discomfort and actual VDT usage duration and the association between self-perceived wrist and back discomfort and the total number of mouse clicks. However, logistic regression analysis did not indicate any statistically significant association between the prevalence of self-perceived discomfort and the exposure estimates. Small sample size of the study and a lack of high exposure group may be the reasons for these negative statistical results. Large-scale studies are needed to determine a meaningful dose-response trend.

Low participation rate, 19.5%, hinders the generalization of current findings. Despite of the anonymous nature of the study, employees of the company still felt reluctant to participate in the study. This may have been caused by a concern of invasion of privacy. Use of the software-based tool in future studies will have to address this issue. The reporting habits of the participants may also have an effect on the results of the study. In general, factors such as gender, poor morale, personality, and other psychosocial variables could affect the reporting the experience of complaints. Workers experiencing musculoskeletal discomfort may be more willing to participate in the study than those not experiencing musculoskeletal discomfort may. This could potentially result in an over-representation of the proportion reporting musculoskeletal complaints.

Conclusion

This study demonstrated that an objective software-based tool for exposure assessment tool in the VDT work environment is not only useful but also feasible. The software-based exposure assessment tool developed in this project successfully profiled 98 VDT users' use of keyboard and mouse. With this software-based tool one can objectively quantify actual VDT usage duration, total number of keystrokes and mouse clicks, and number of rest breaks to improve the quality of future epidemiological study of VDT work-related musculoskeletal disorders/discomfort.

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Appendix

Email Message - to solicit participation

On behalf of the **Company_Name** Medical Department, I am pleased to inform you that you have been selected to participate in a major new study on the health effects of computer work. As at many companies, complaints of body aches and pains are not uncommon among Company_Name computer users. Despite the increased awareness of the importance of ergonomic factors in the workplace, it is still poorly understood as to which factors at Company_Name may lead to significant pain and discomfort related to computer use.

We are asking that you assist us in the following program in order to better understand the ergonomic factors at Company_Name. Even if you were not experiencing any difficulties, your help in this project would be valuable to us. In the first part of the program we will ask you to download a software program that measures your usage of the computer. Specifically, it will track your patterns of computer use based upon the number of keystrokes and mouse actions. This tracking program will only be used by the study to review patterns of computer use and it will not be used to look at the productivity of individuals.

The second part of the program is a survey that will take about 5 to 10 minutes to fill out. The survey will ask questions about your computer usage, areas of body discomfort and your significant activities outside of work. A shortened form of this survey will be sent to you yearly to look for changes in your activities and areas of body discomfort.

To participate in this study you need to review the informed consent form on the following page. Your agreement to participate in this study will be assumed by your compliance with the following steps for downloading the computer tracking software. Please note that you are free to choose whether or not to participate in this study. Your participation is entirely voluntary and your decision to participate will not affect your relationship or employment status with **Company_Name.**

Please accept our thanks in advance for your help in this project.

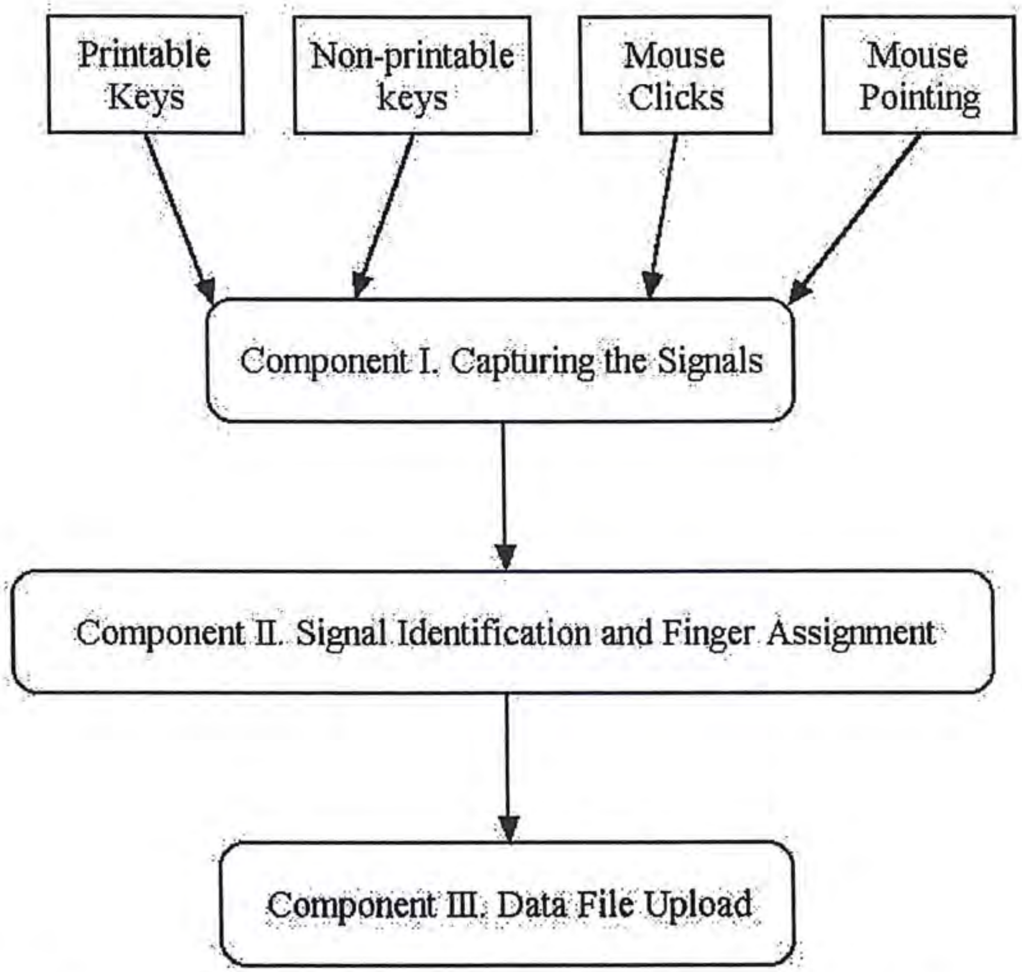


Figure 1. Components of the software-based exposure assessment tool.

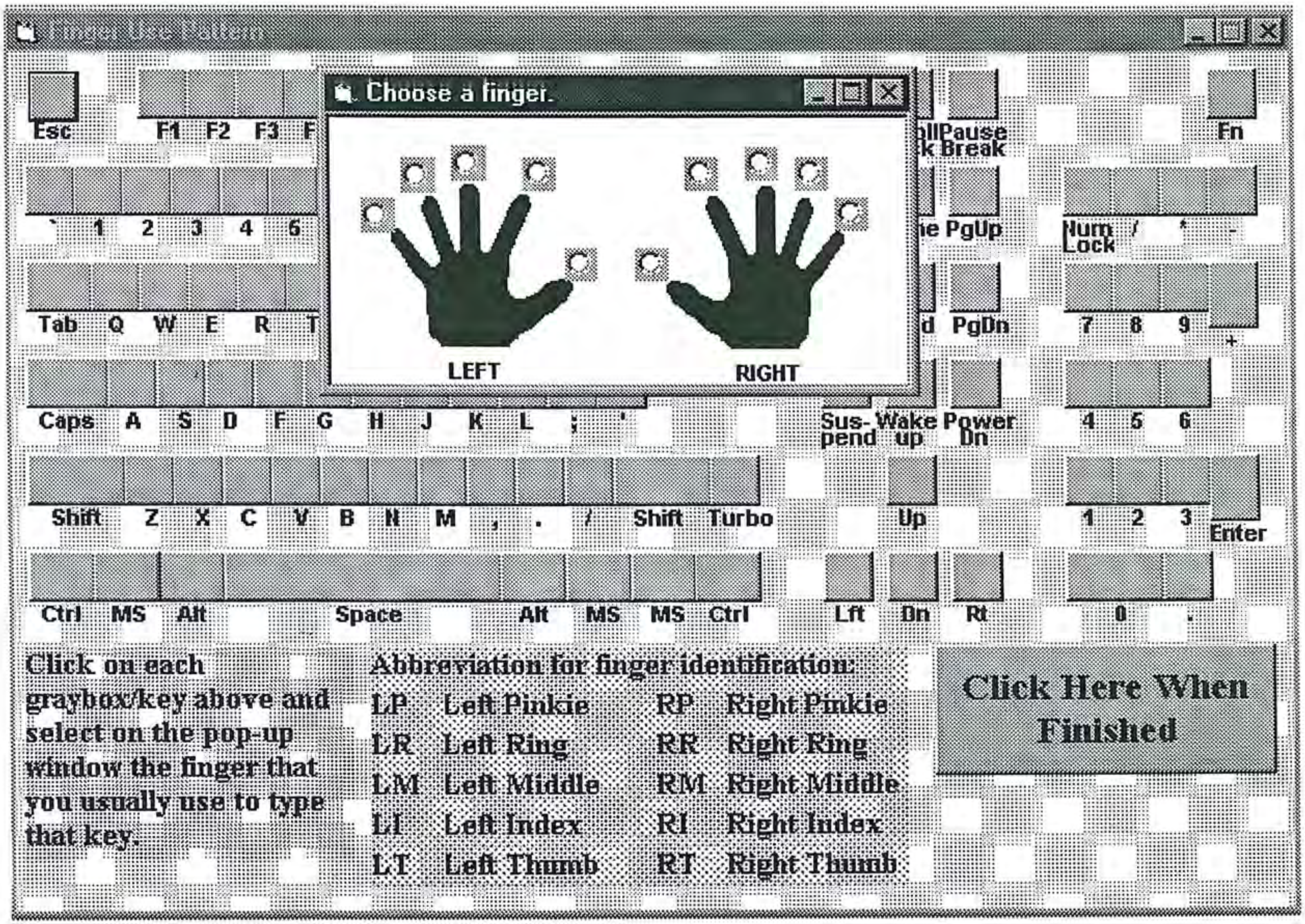
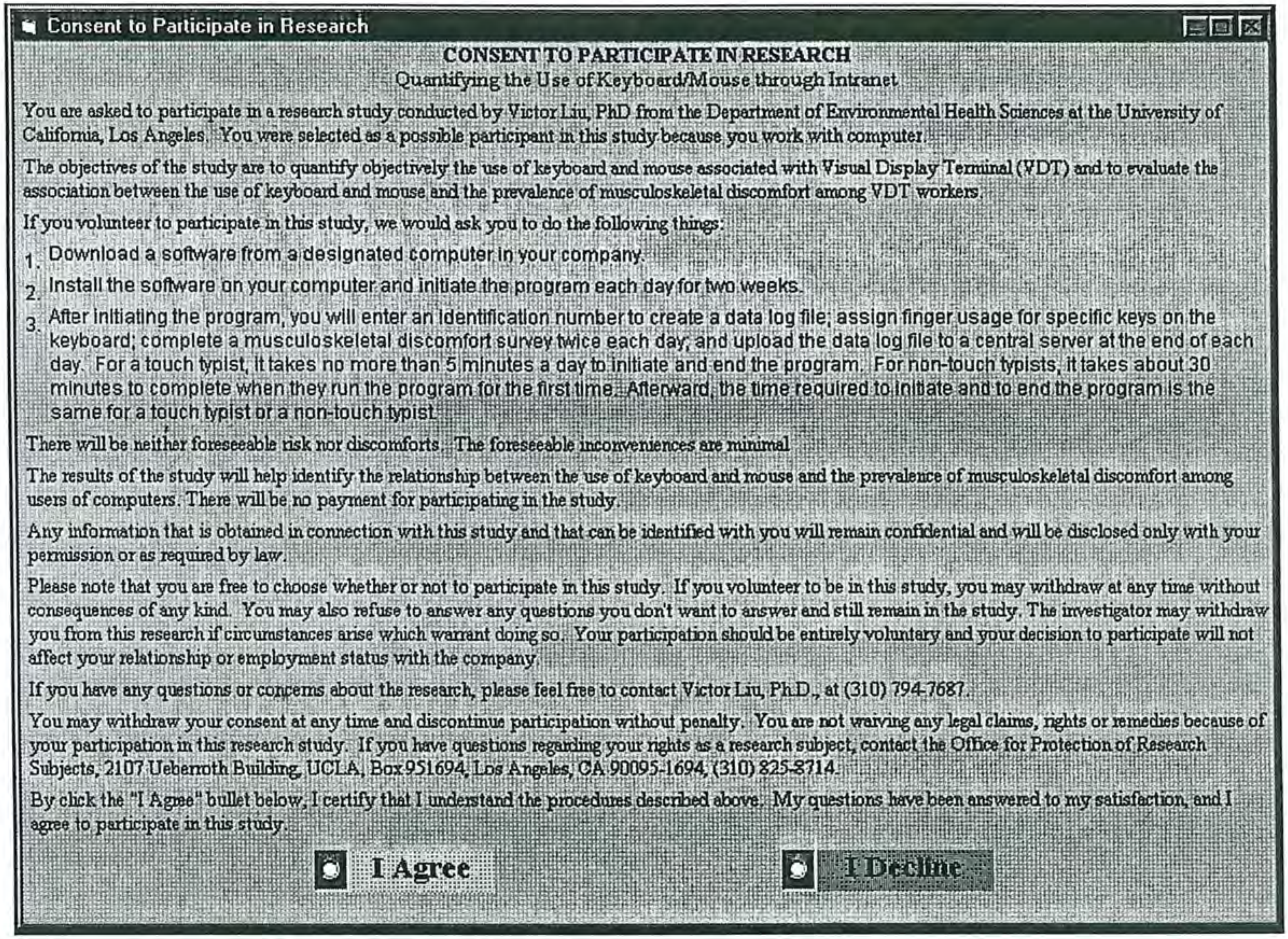


Figure 2. Figure assignment for a non-touch typist.



Consent to Participate in Research

CONSENT TO PARTICIPATE IN RESEARCH

Quantifying the Use of Keyboard/Mouse through Intranet

You are asked to participate in a research study conducted by Victor Liu, PhD from the Department of Environmental Health Sciences at the University of California, Los Angeles. You were selected as a possible participant in this study because you work with computer.

The objectives of the study are to quantify objectively the use of keyboard and mouse associated with Visual Display Terminal (VDT) and to evaluate the association between the use of keyboard and mouse and the prevalence of musculoskeletal discomfort among VDT workers.

If you volunteer to participate in this study, we would ask you to do the following things:

1. Download a software from a designated computer in your company.
2. Install the software on your computer and initiate the program each day for two weeks.
3. After initiating the program, you will enter an identification number to create a data log file; assign finger usage for specific keys on the keyboard; complete a musculoskeletal discomfort survey twice each day; and upload the data log file to a central server at the end of each day. For a touch typist, it takes no more than 5 minutes a day to initiate and end the program. For non-touch typists, it takes about 30 minutes to complete when they run the program for the first time. Afterward, the time required to initiate and to end the program is the same for a touch typist or a non-touch typist.

There will be neither foreseeable risk nor discomforts. The foreseeable inconveniences are minimal.

The results of the study will help identify the relationship between the use of keyboard and mouse and the prevalence of musculoskeletal discomfort among users of computers. There will be no payment for participating in the study.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law.

Please note that you are free to choose whether or not to participate in this study. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. Your participation should be entirely voluntary and your decision to participate will not affect your relationship or employment status with the company.

If you have any questions or concerns about the research, please feel free to contact Victor Liu, Ph.D., at (310) 794-7687.

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact the Office for Protection of Research Subjects, 2107 Ueberroth Building, UCLA, Box 951694, Los Angeles, CA 90095-1694, (310) 825-8714.

By click the "I Agree" bullet below, I certify that I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study.

I Agree

I Decline

Figure 3. Informed consent form.

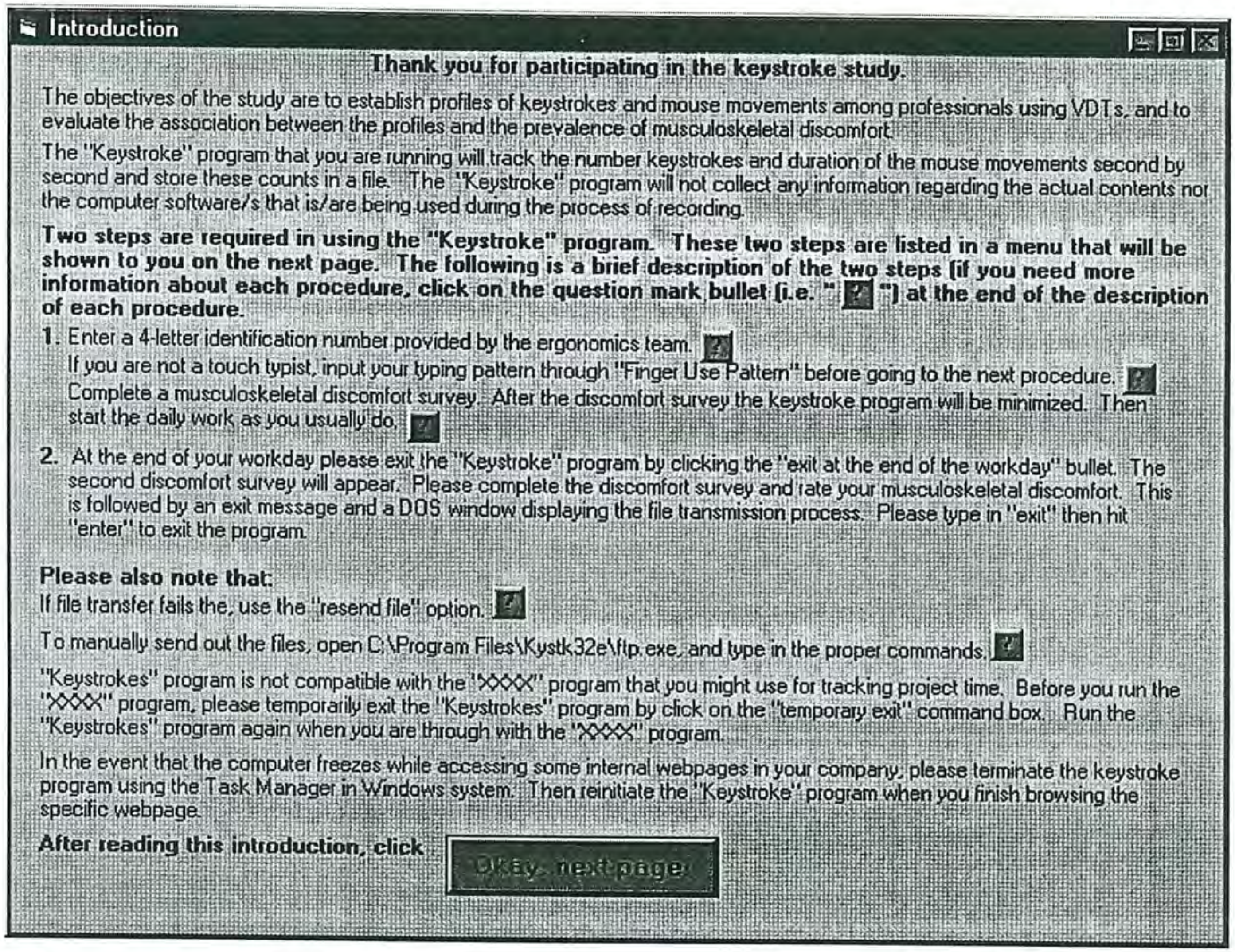


Figure 4. Introduction page of the software-based tool.

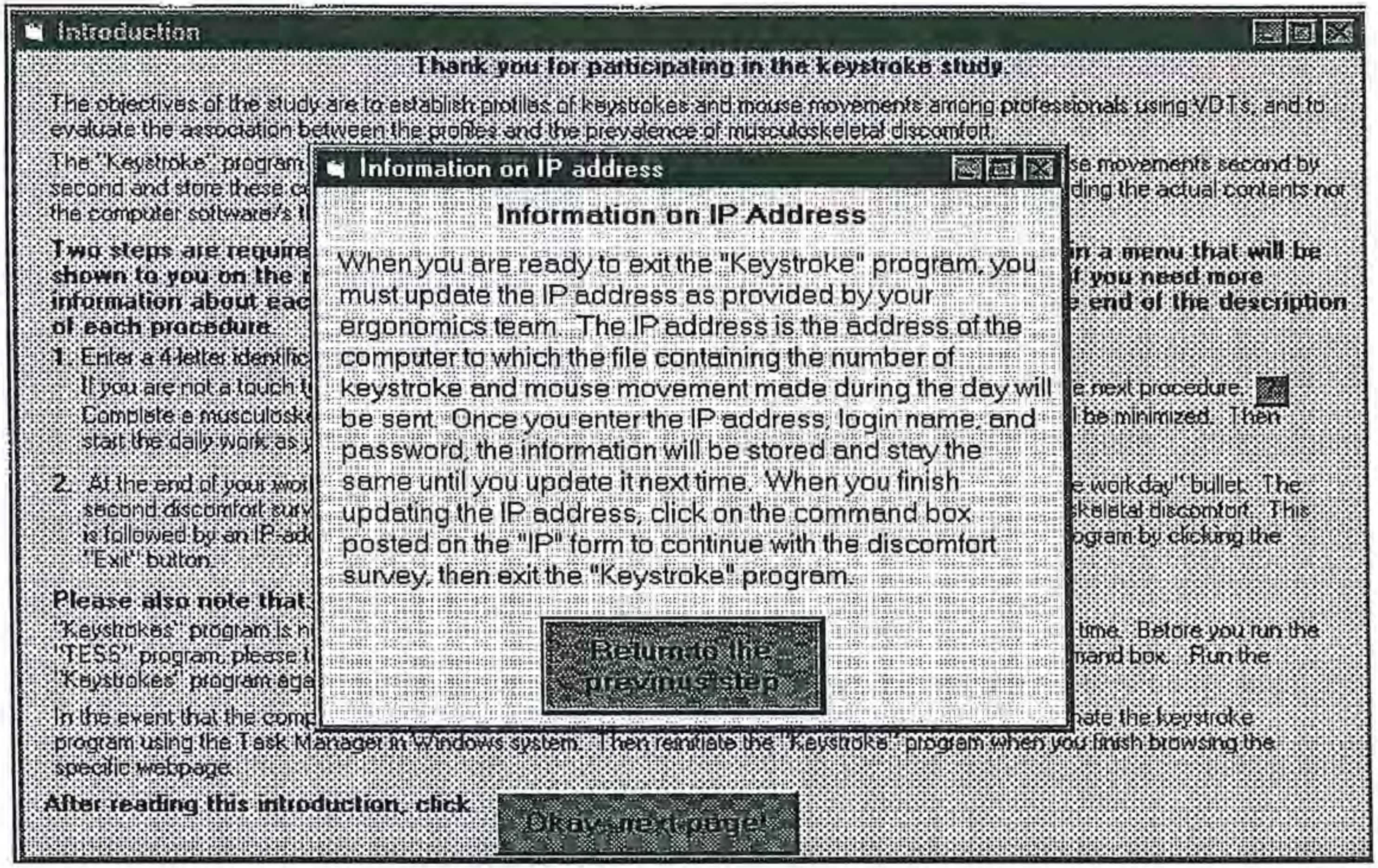


Figure 5. Sample of help message provided in the software-based tool.

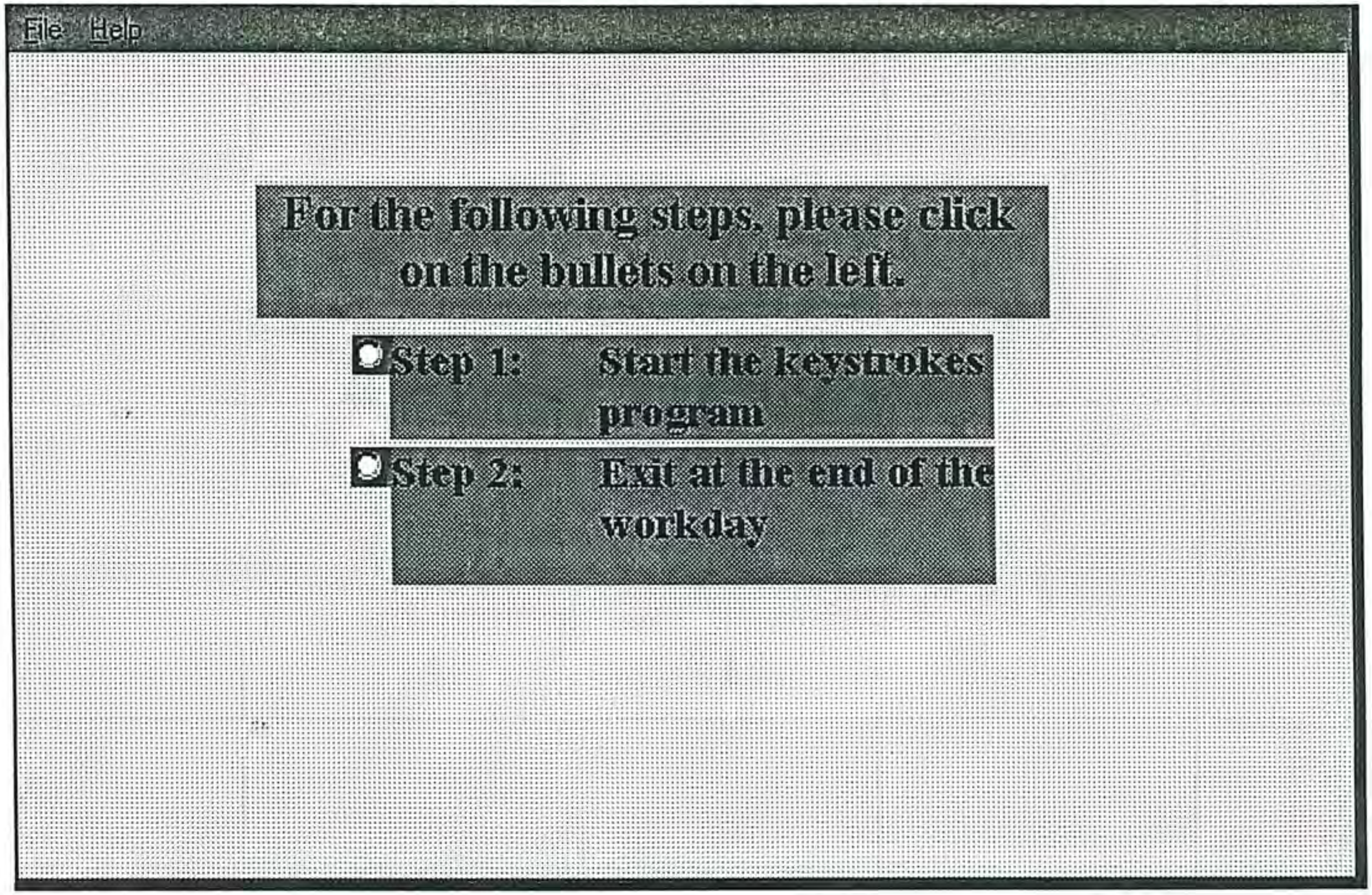


Figure 6. Starting or exiting from the software-based tool.

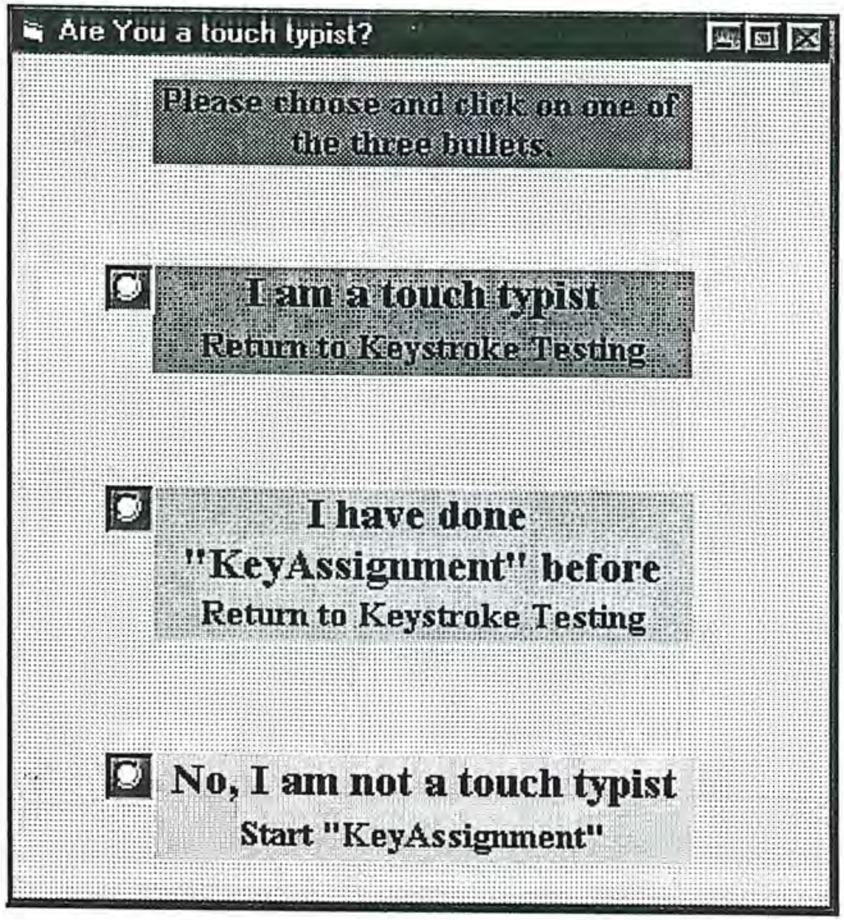


Figure 7. Touch vs. non-touch typist selection screen.

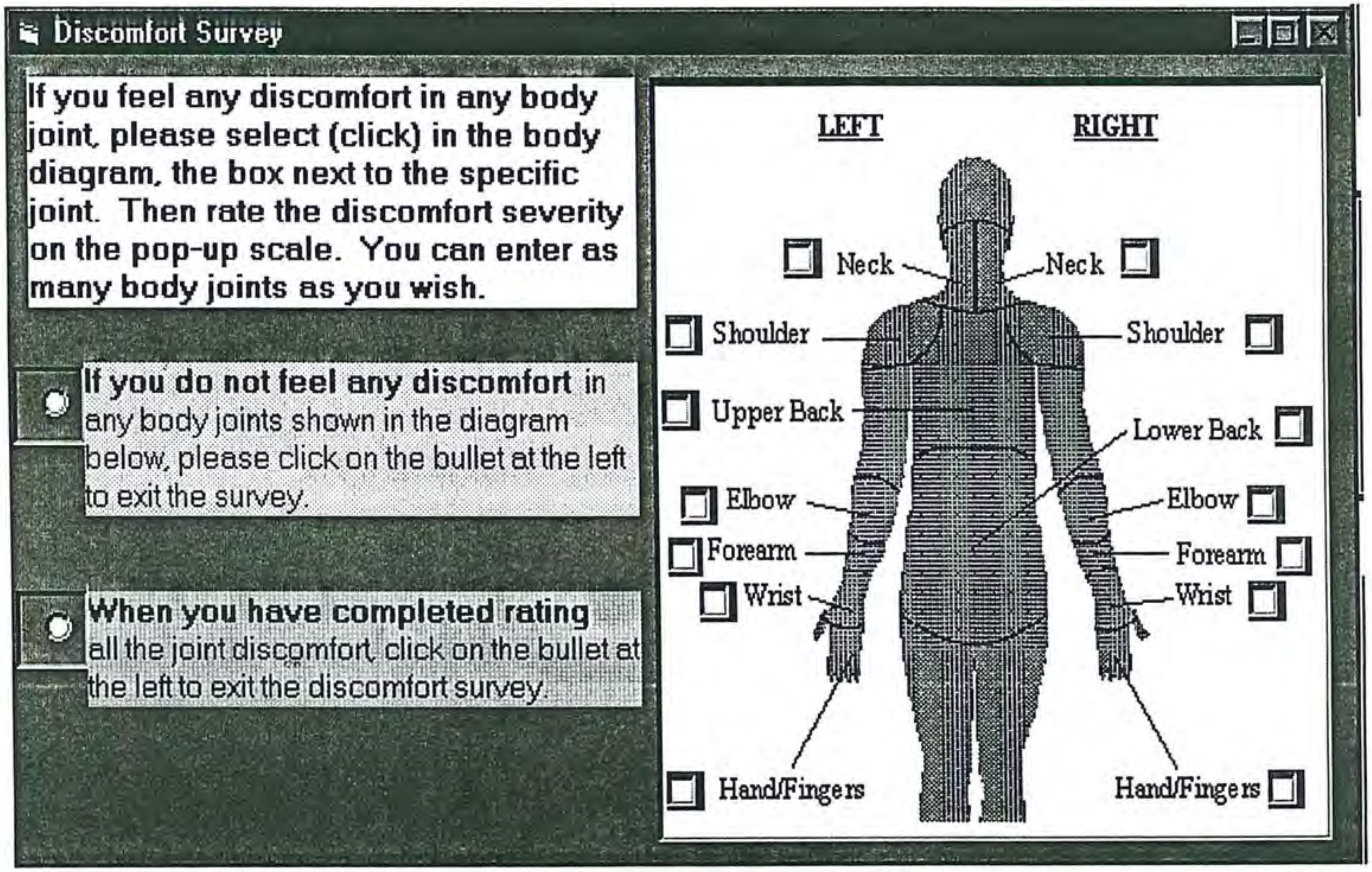


Figure 8. Body diagram for self-perceived musculoskeletal discomfort survey.

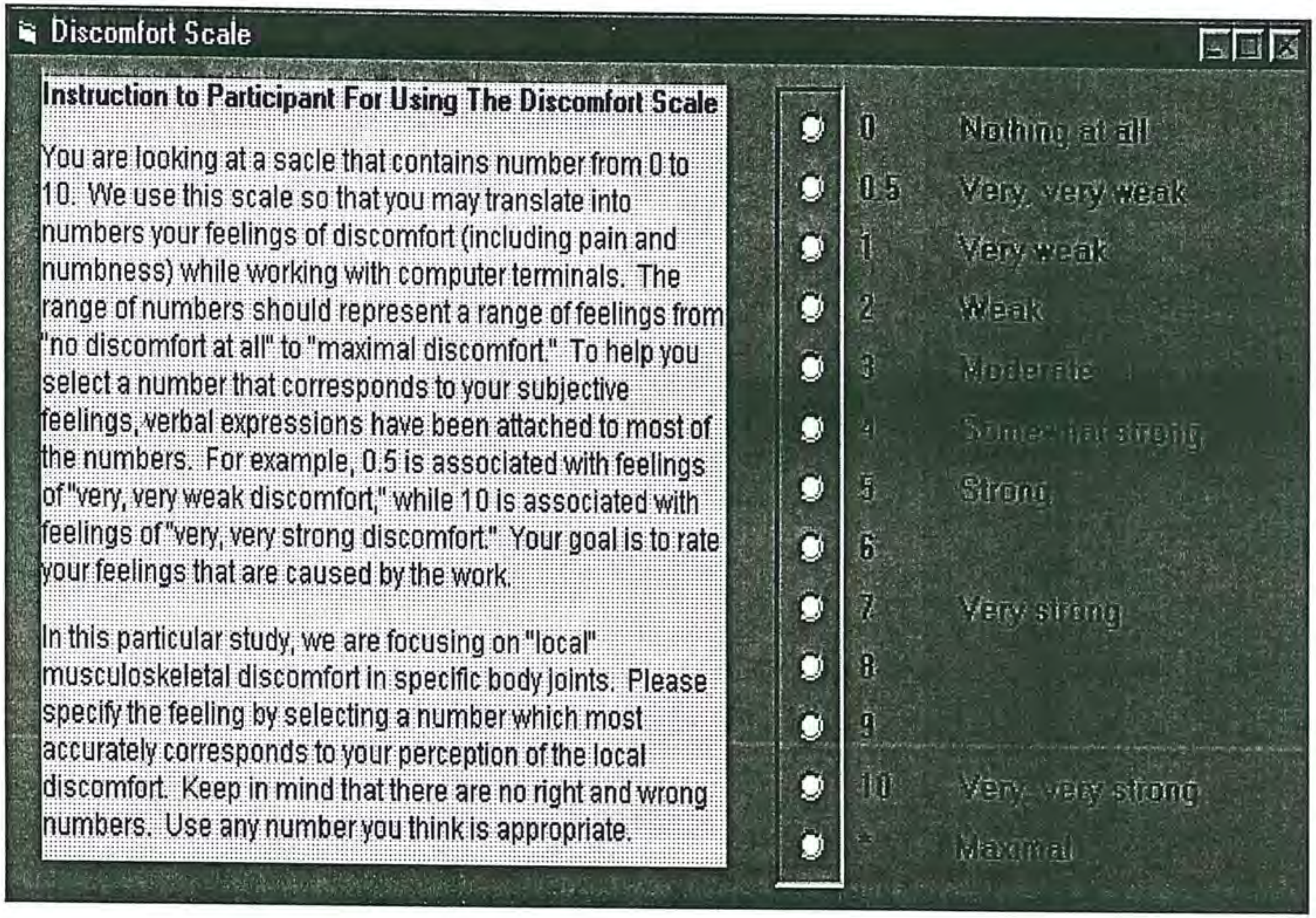


Figure 9. Borg scale used for rating self-perceived musculoskeletal discomfort.

Figure 10. Menu for transferring a file to a data-collection computer on the Intranet.

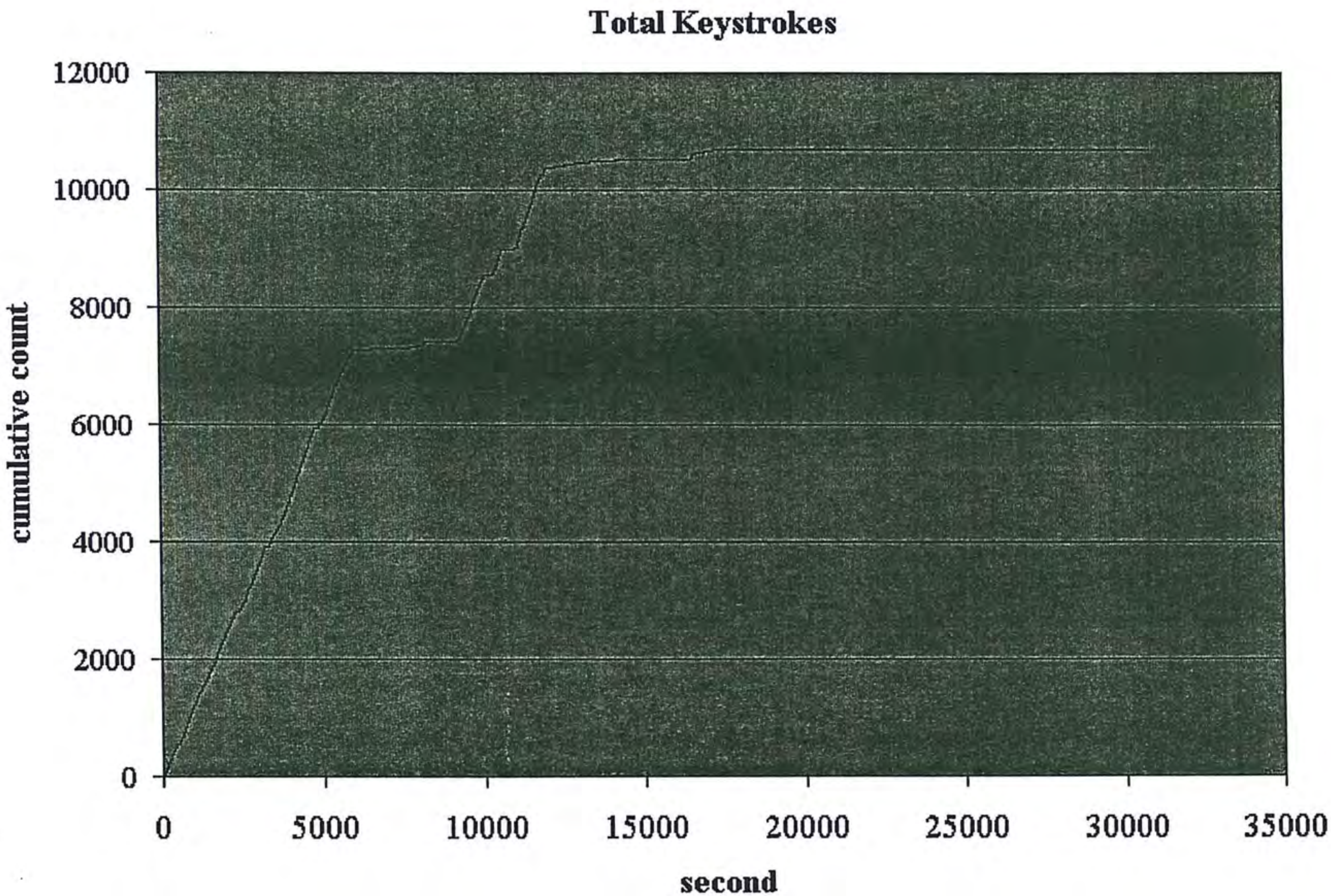


Figure 11. Data sample profiling the use of a keyboard over a period of 8.6 hours.

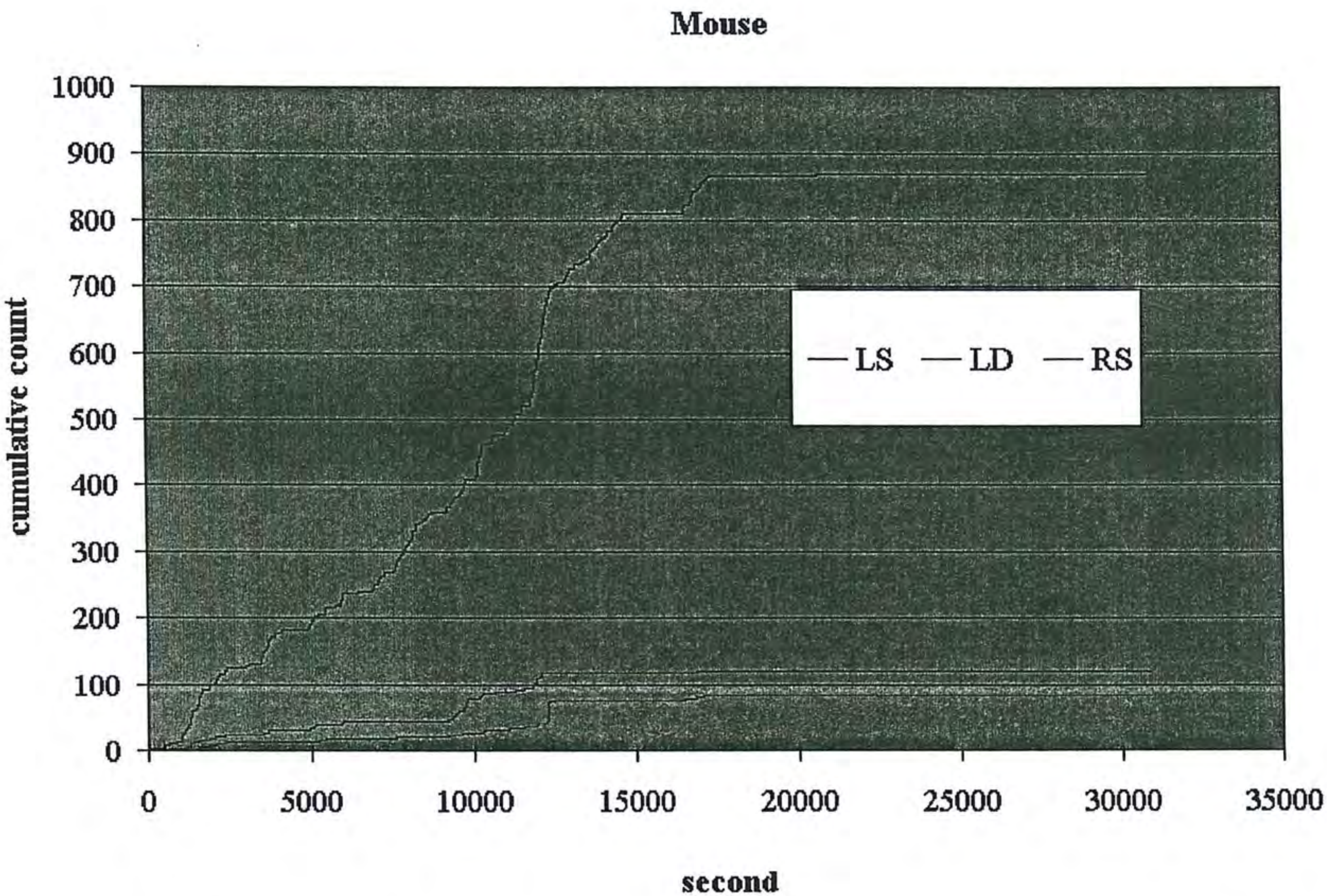


Figure 12. Data sample profiling the use of a mouse over a period of 8.6 hours. (LS: Left mouse button, Single click; LD: Left mouse button, Double click; RS: Right mouse button, Single click.)

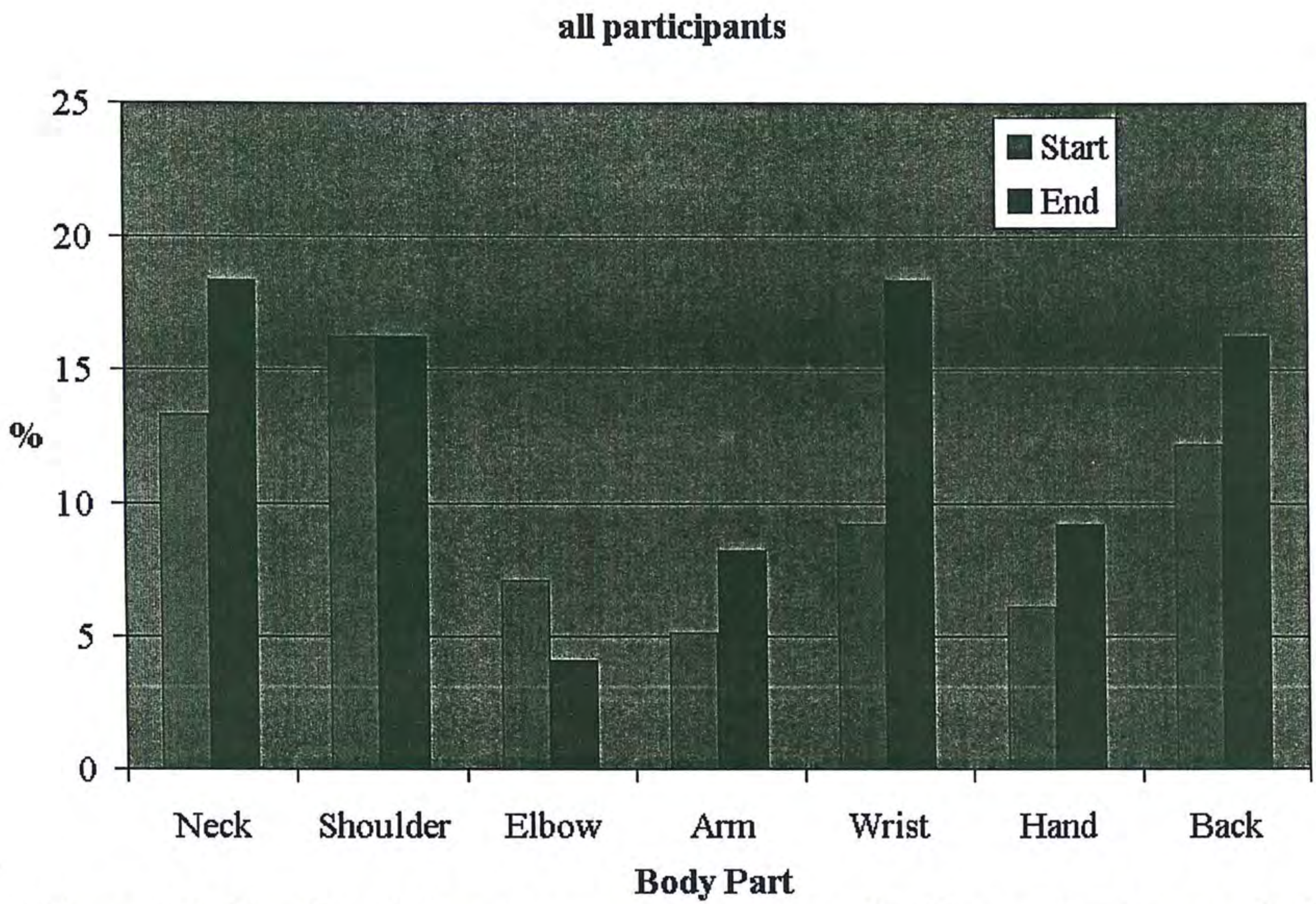


Figure 13. % of participants reported a rating of self-perceived musculoskeletal discomfort greater or equal to 3 on the Borg scale.
(Start: at the beginning of the workday; End: at the end of the workday)

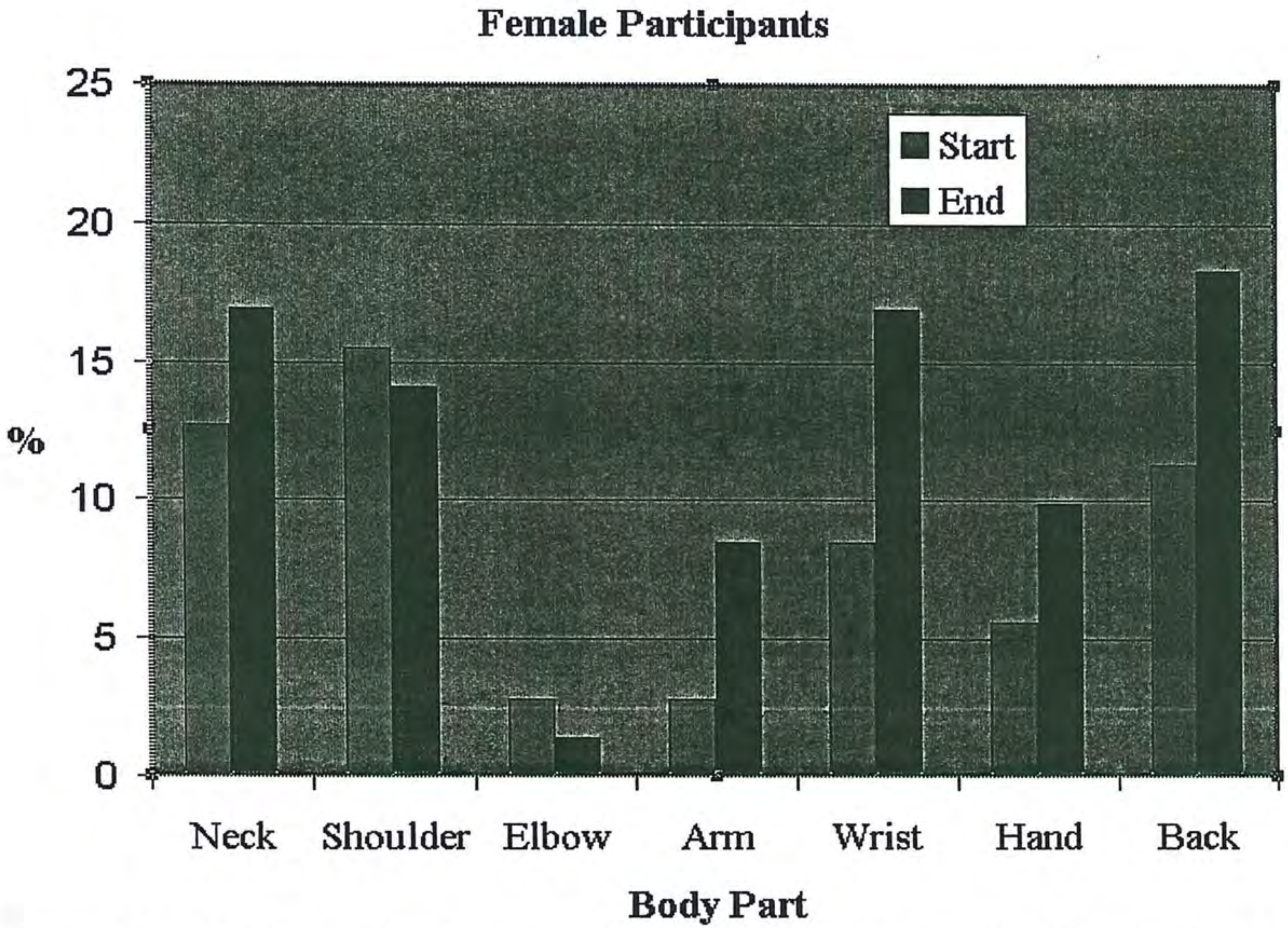


Figure 14. % of female participants reported a rating of self-perceived musculoskeletal discomfort greater or equal to 3 on the Borg scale. (Start: at the beginning of the workday; End: at the end of the workday)

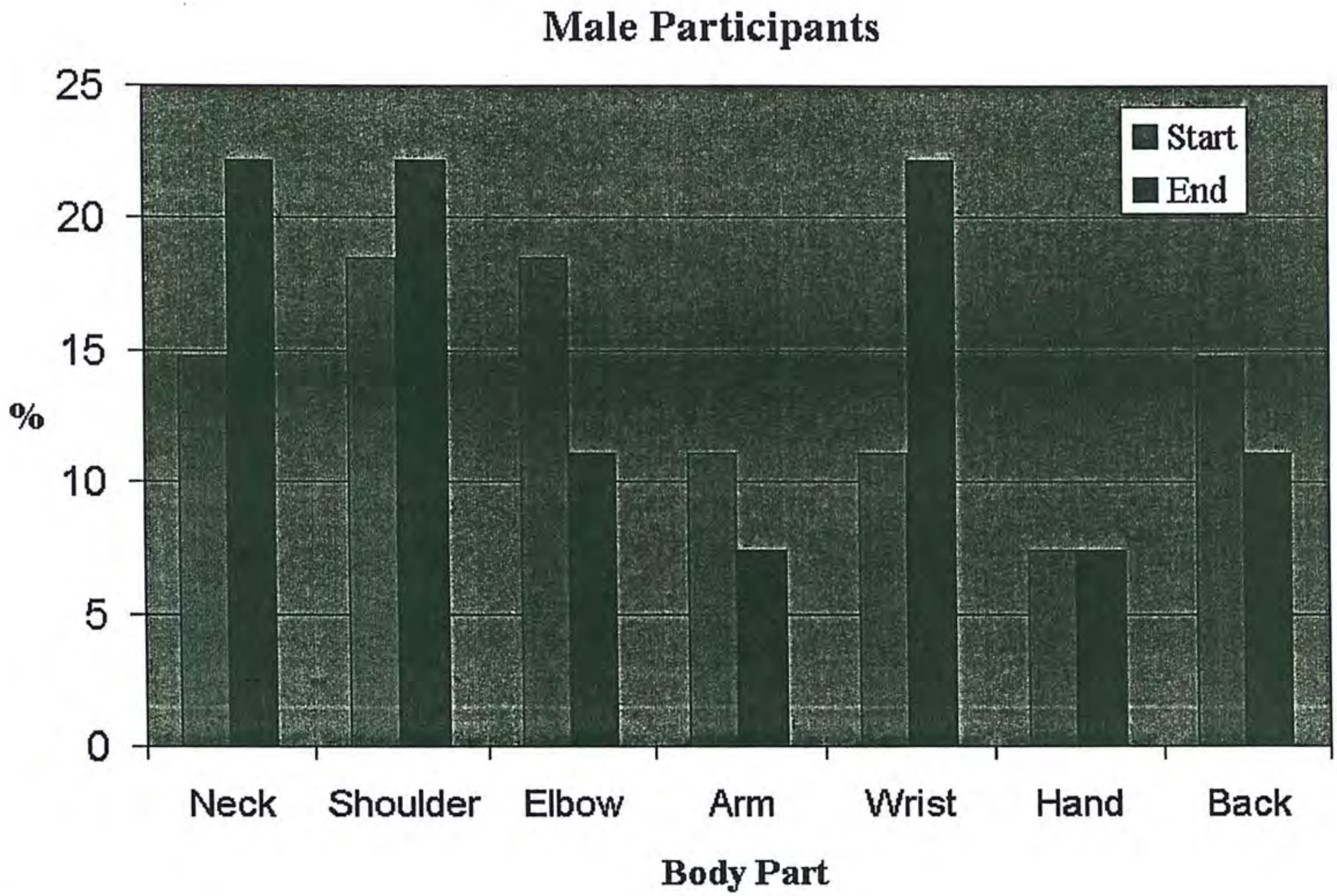


Figure 15. % of male participants reported a rating of self-perceived musculoskeletal discomfort greater or equal to 3 on the Borg scale. (Start: at the beginning of the workday; End: at the end of the workday)

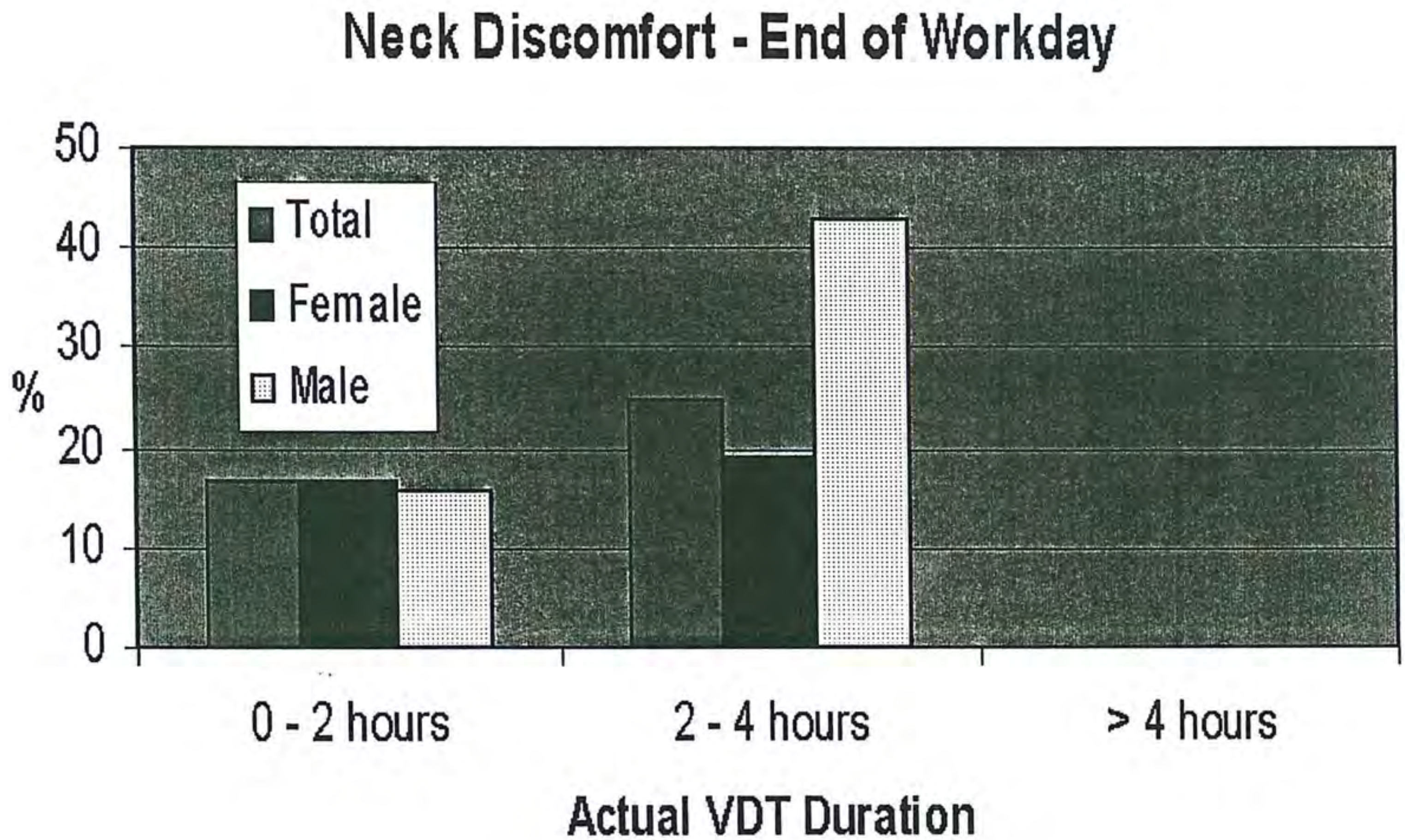


Figure 16. % of participants reported at least "moderate" neck discomfort at the end of the workday vs. actual VDT duration.
χ^2 (total): 0.13, $p > .05$; χ^2 (female): 0.02, $p > .05$; χ^2 (male): 0.70, $p > .05$

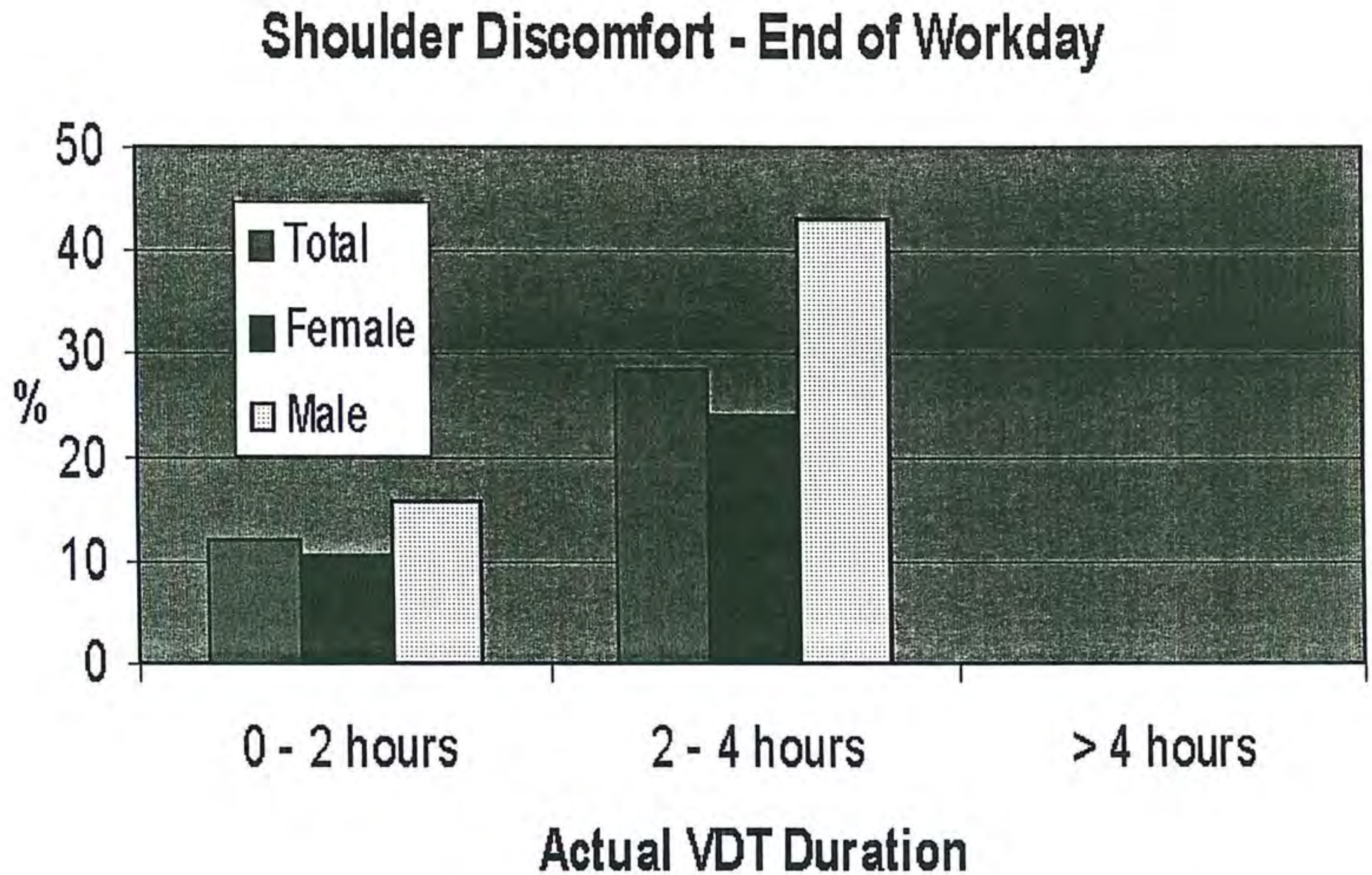


Figure 17. % of participants reported at least "moderate" shoulder discomfort at the end of the workday vs. actual VDT duration.

χ^2 (total): 1.54, $p > .05$; χ^2 (female): 0.88, $p \geq .05$; χ^2 (male): 0.70, $p > .05$

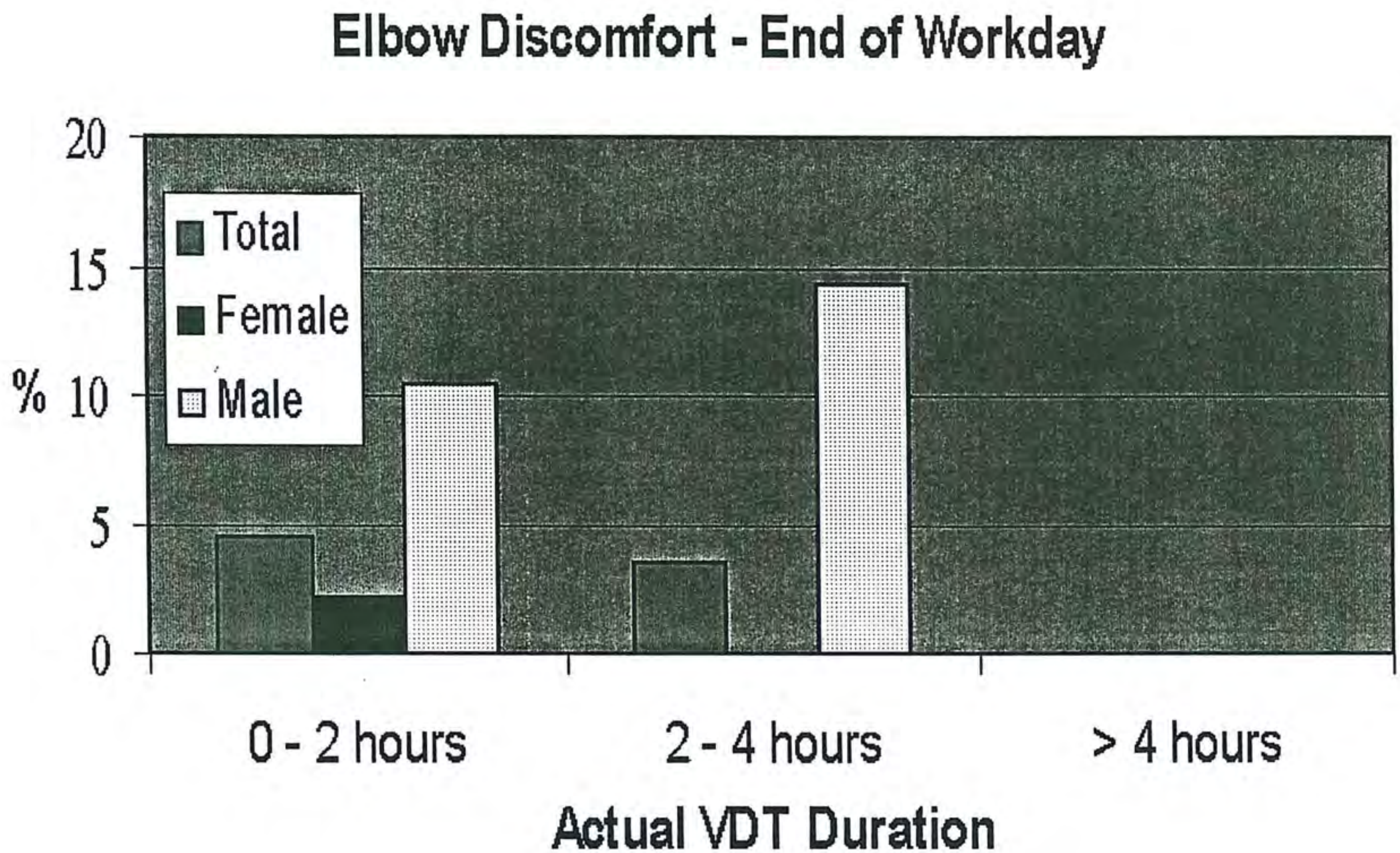


Figure 18. % of participants reported at least "moderate" elbow discomfort at the end of the workday vs. actual VDT duration.
χ^2 (total): 0.14, $p > .05$; χ^2 (female): 0.44, $p > .05$; χ^2 (male): 0.0, $p > .05$

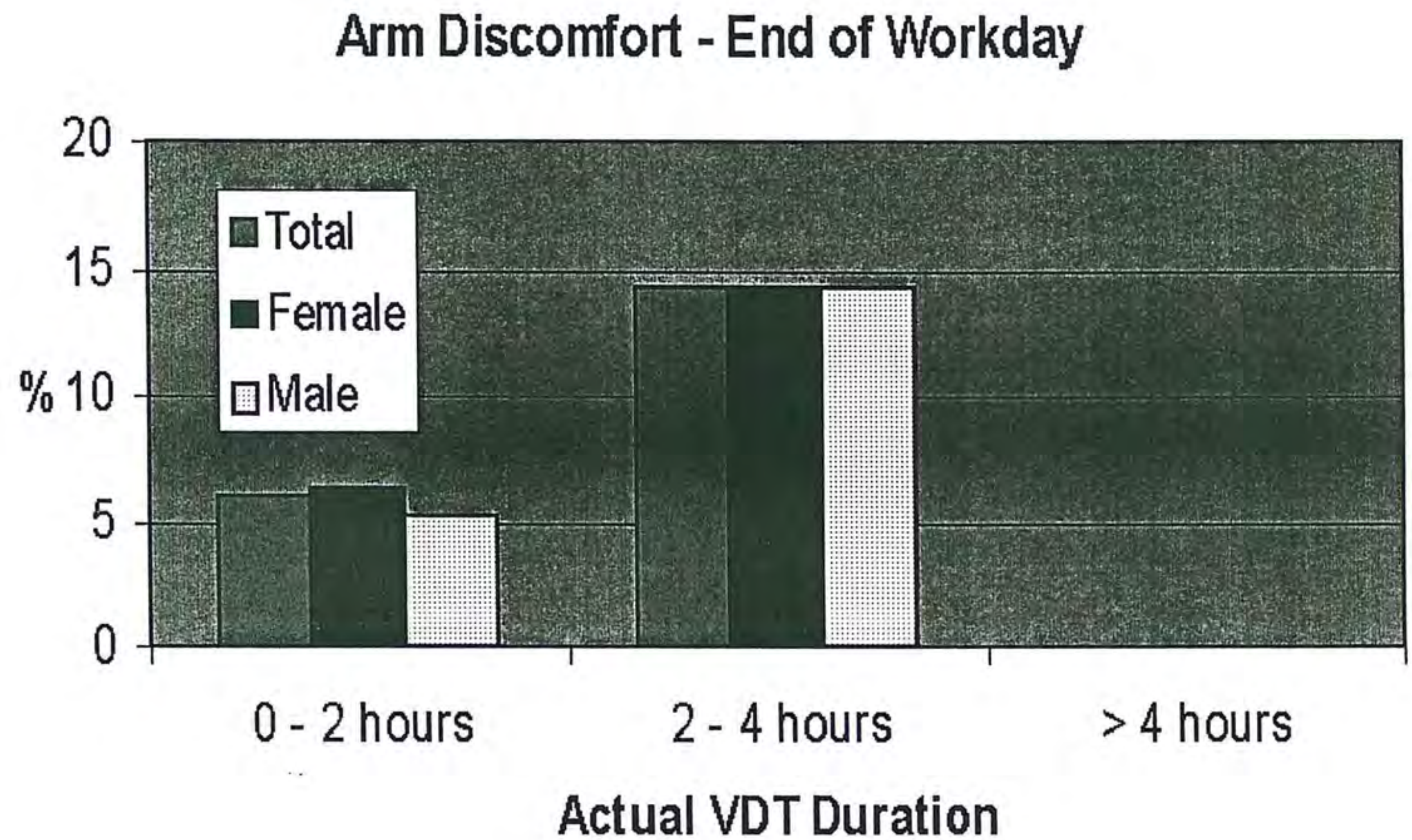


Figure 19. % of participants reported at least "moderate" arm discomfort at the end of the workday vs. actual VDT duration.
χ^2 (total): 0.70, $p > .05$; χ^2 (female): 0.50, $p > .05$; χ^2 (male): 0.20, $p > .05$

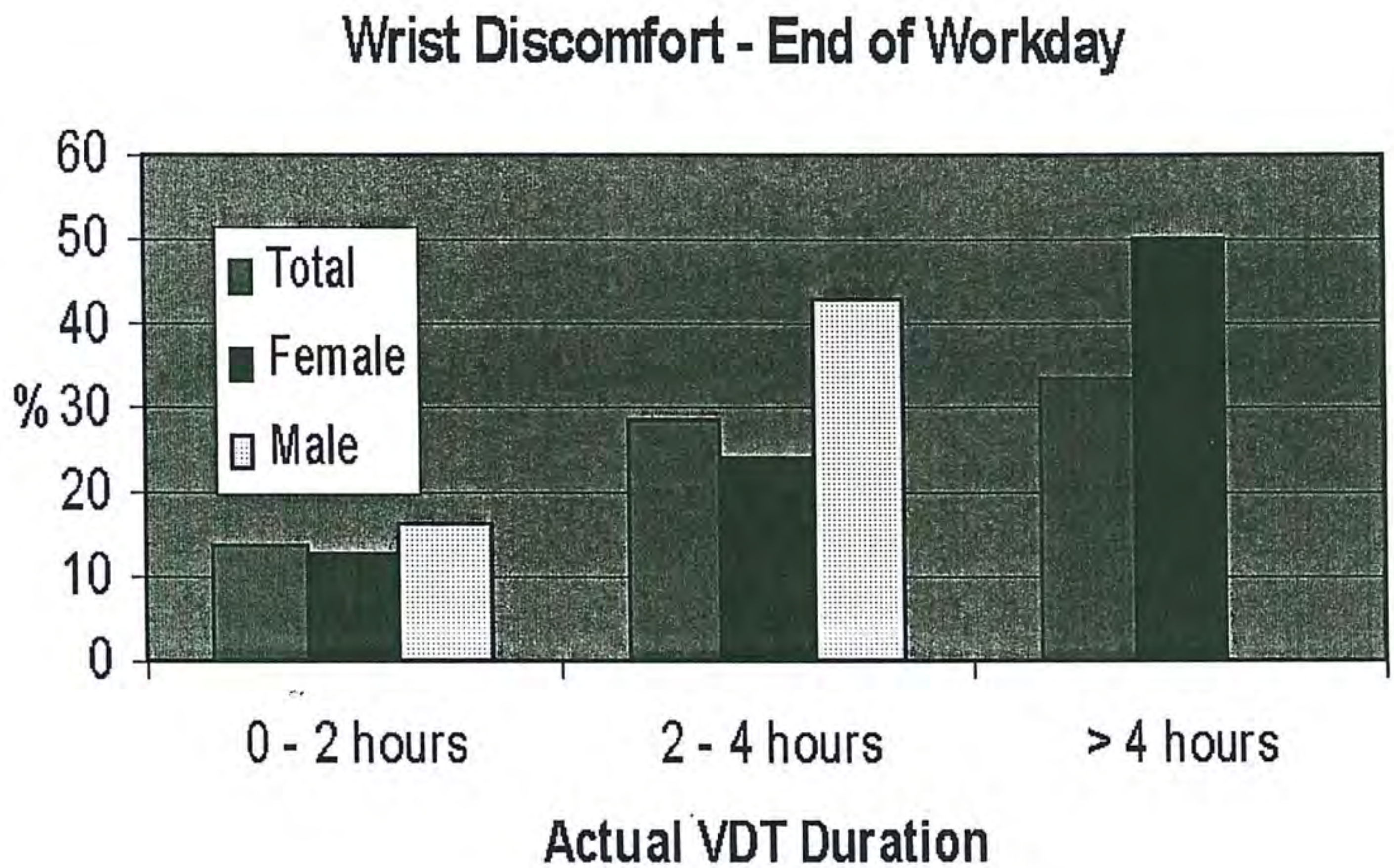


Figure 20. % of participants reported at least "moderate" wrist discomfort at the end of the workday vs. actual VDT duration.
χ^2 (total): 3.30, $p > .05$; χ^2 (female): 2.68, $p > .05$; χ^2 (male): 0.70, $p > .05$

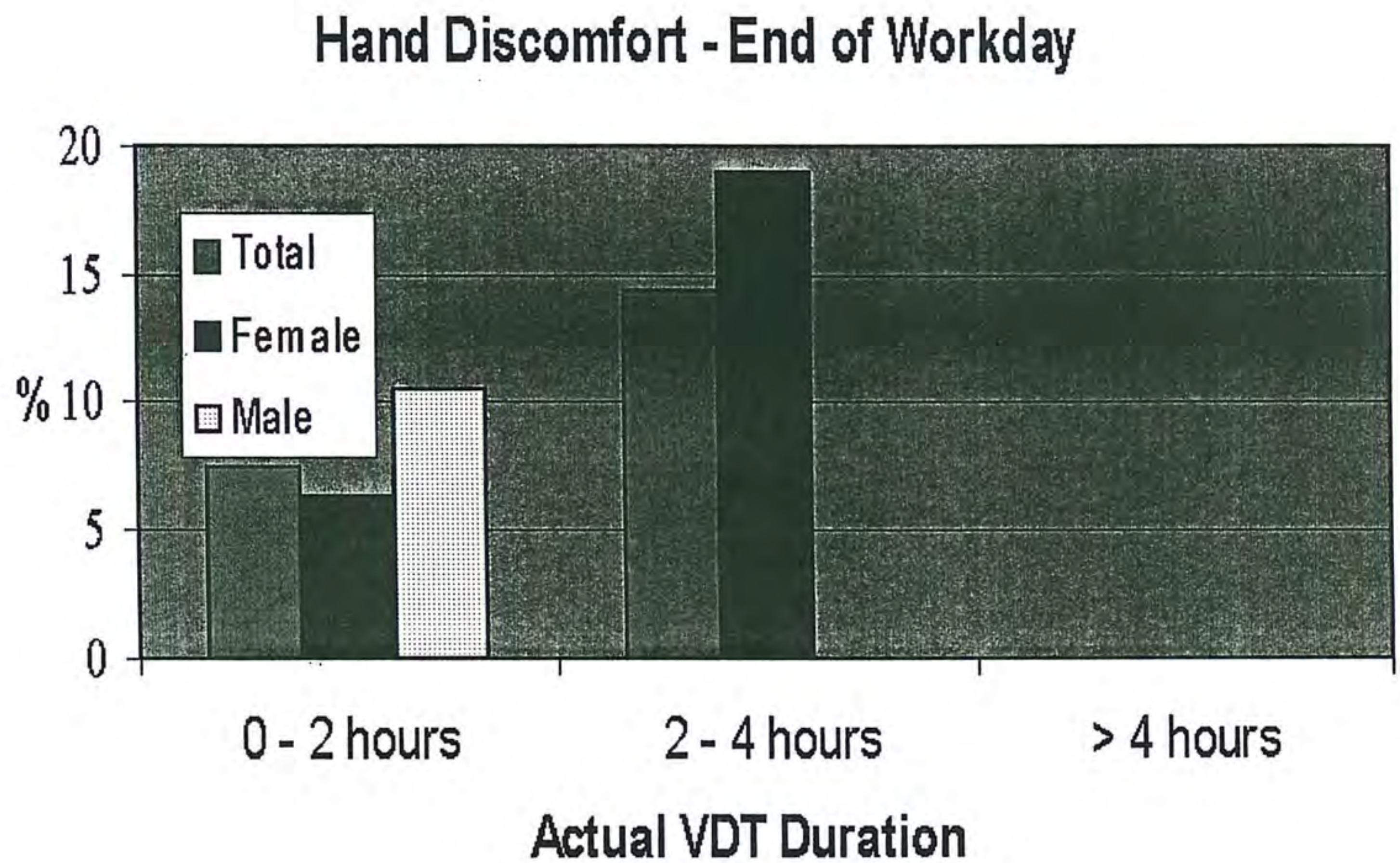


Figure 21. % of participants reported at least "moderate" hand discomfort at the end of the workday vs. actual VDT duration.
χ^2 (total): 0.32, $p > .05$; χ^2 (female): 1.30, $p > .05$; χ^2 (male): 0.78, $p > .05$

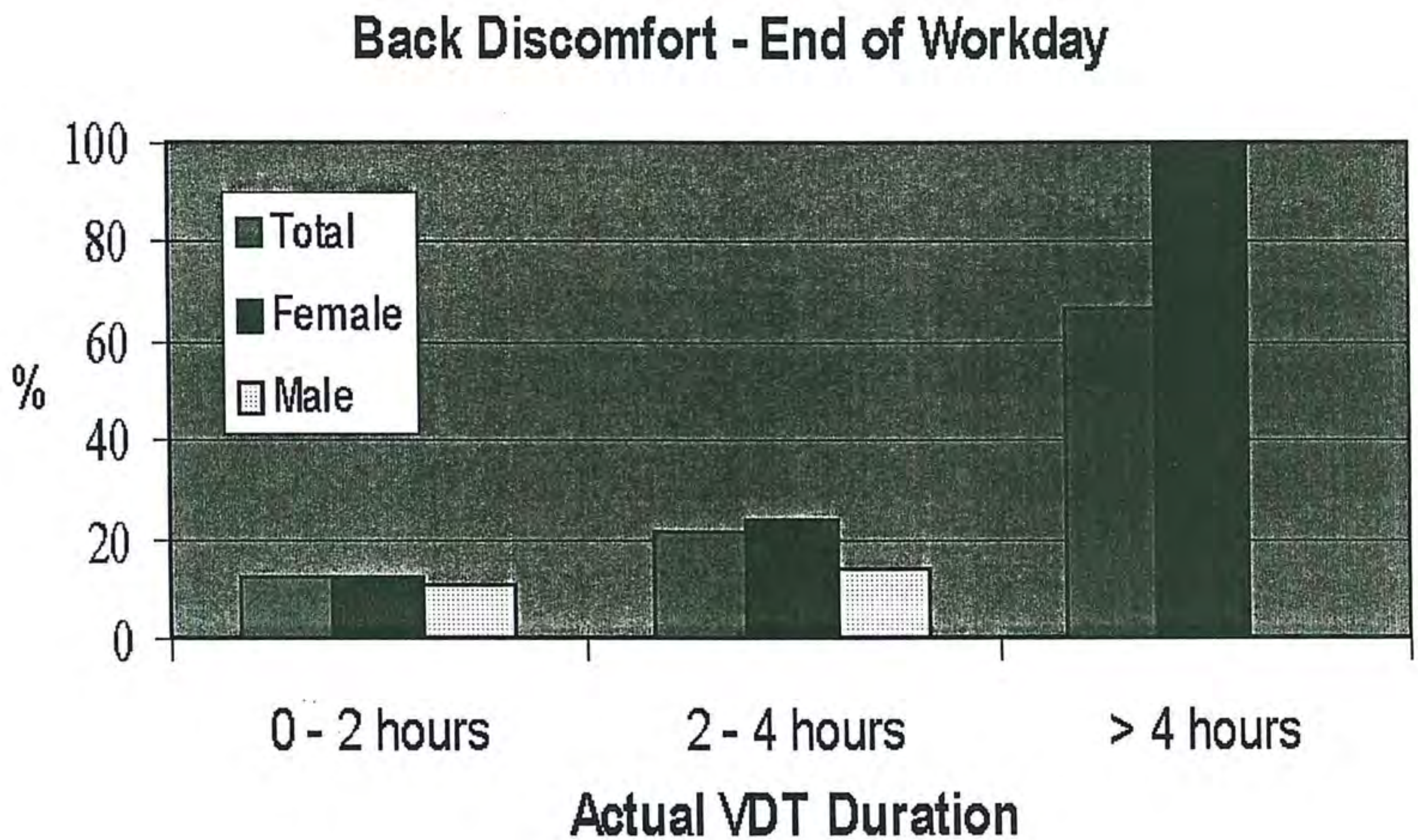


Figure 22. % of participants reported at least "moderate" back discomfort at the end of the workday vs. actual VDT duration.
χ^2 (total): 5.09, $p < .05$; χ^2 (female): 6.38, $p < .05$; χ^2 (male): 0.0, $p > .05$

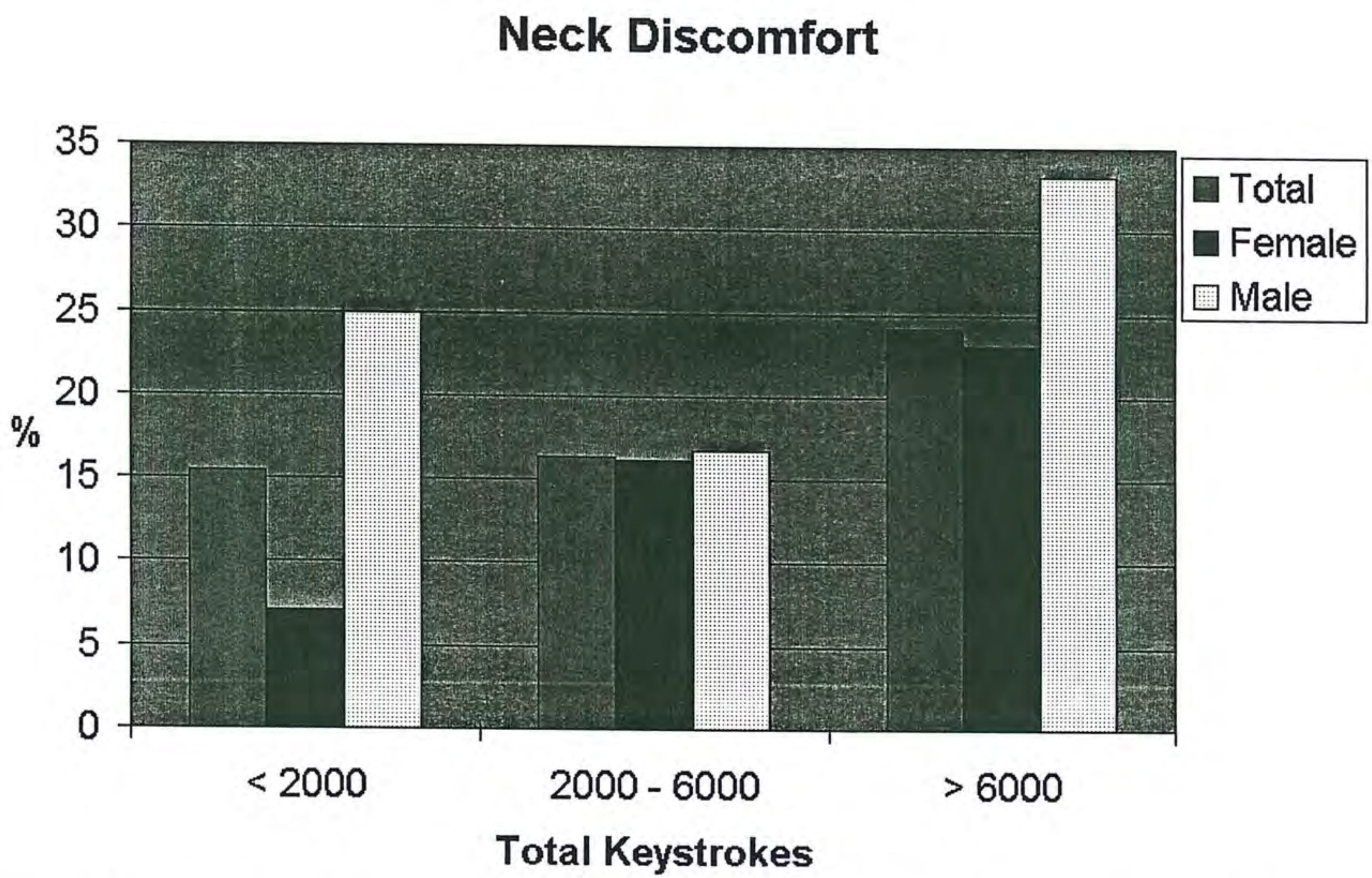


Figure 23. % of participants reported at least "moderate" neck discomfort at the end of the workday vs. total keystrokes.
χ^2 (total): 0.72, $p > .05$; χ^2 (female): 1.63, $p > .05$; χ^2 (male): 0.0, $p > .05$

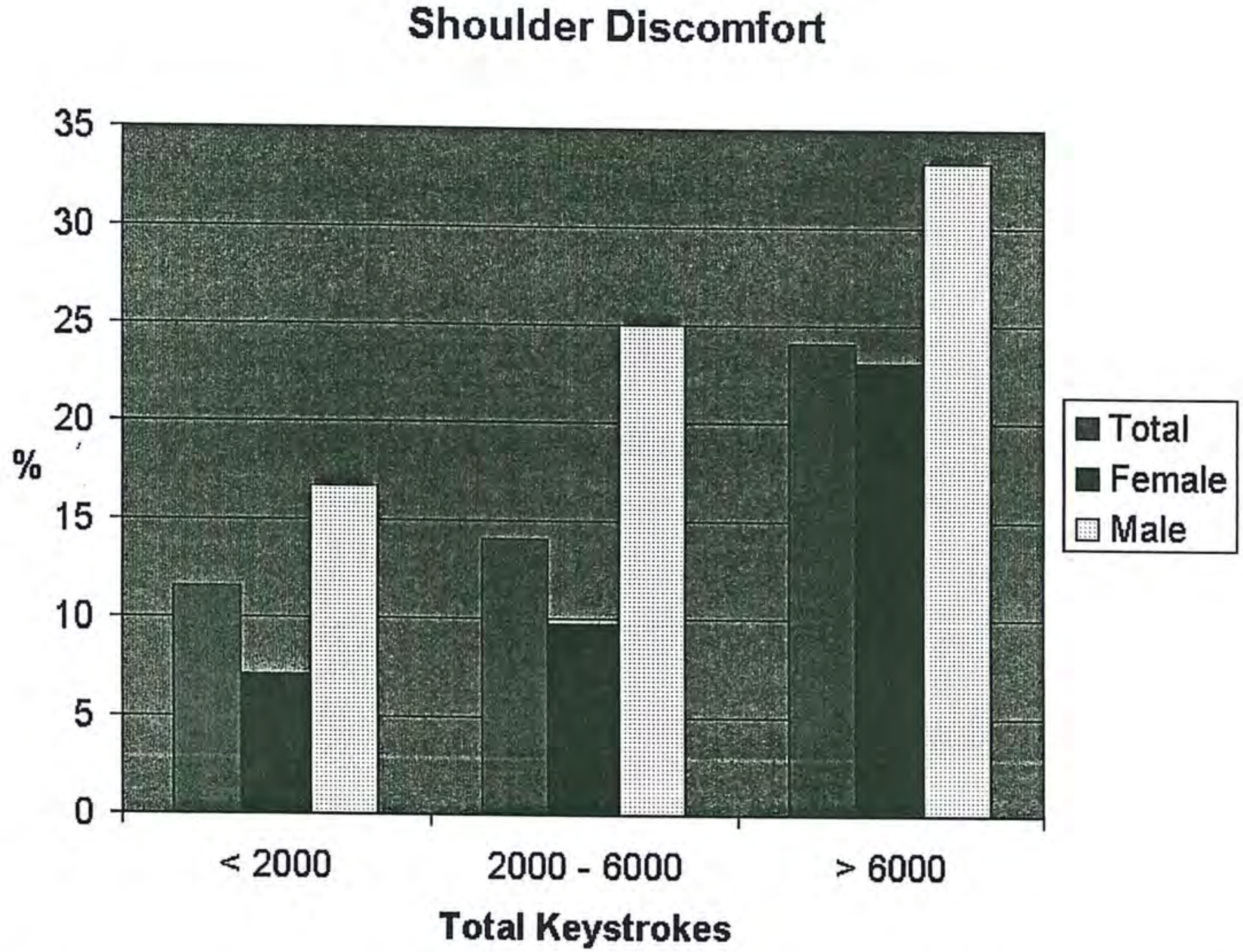


Figure 24. % of participants reported at least "moderate" shoulder discomfort at the end of the workday vs. total keystrokes.

χ^2 (total): 1.63, $p > .05$; χ^2 (female): 2.35, $p > .05$; χ^2 (male): 0.46, $p > .05$

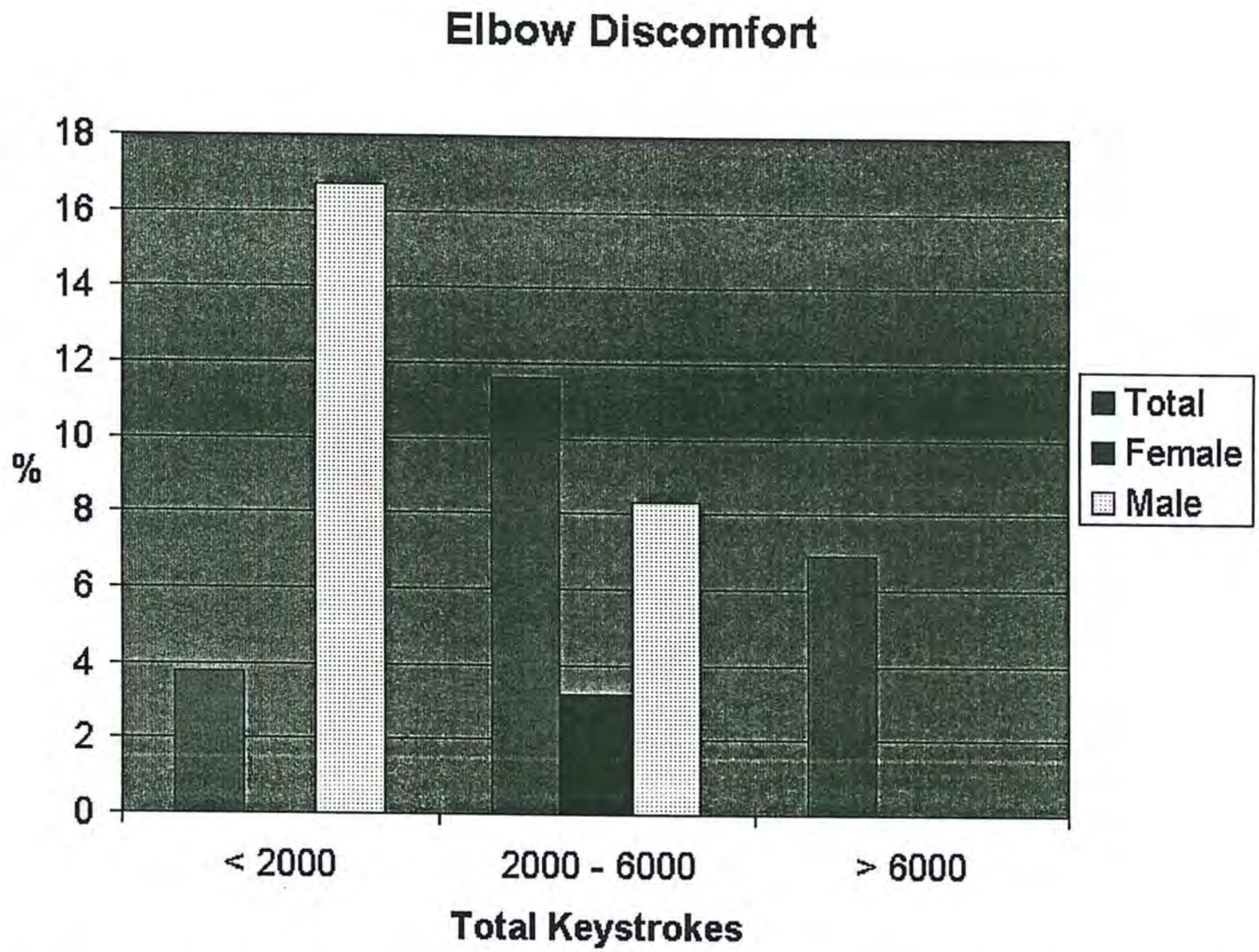


Figure 25. % of participants reported at least "moderate" elbow discomfort at the end of the workday vs. total keystrokes.
χ^2 (total): 2.07, $p > .05$; χ^2 (female): 0.05, $p > .05$; χ^2 (male): 0.81, $p > .05$

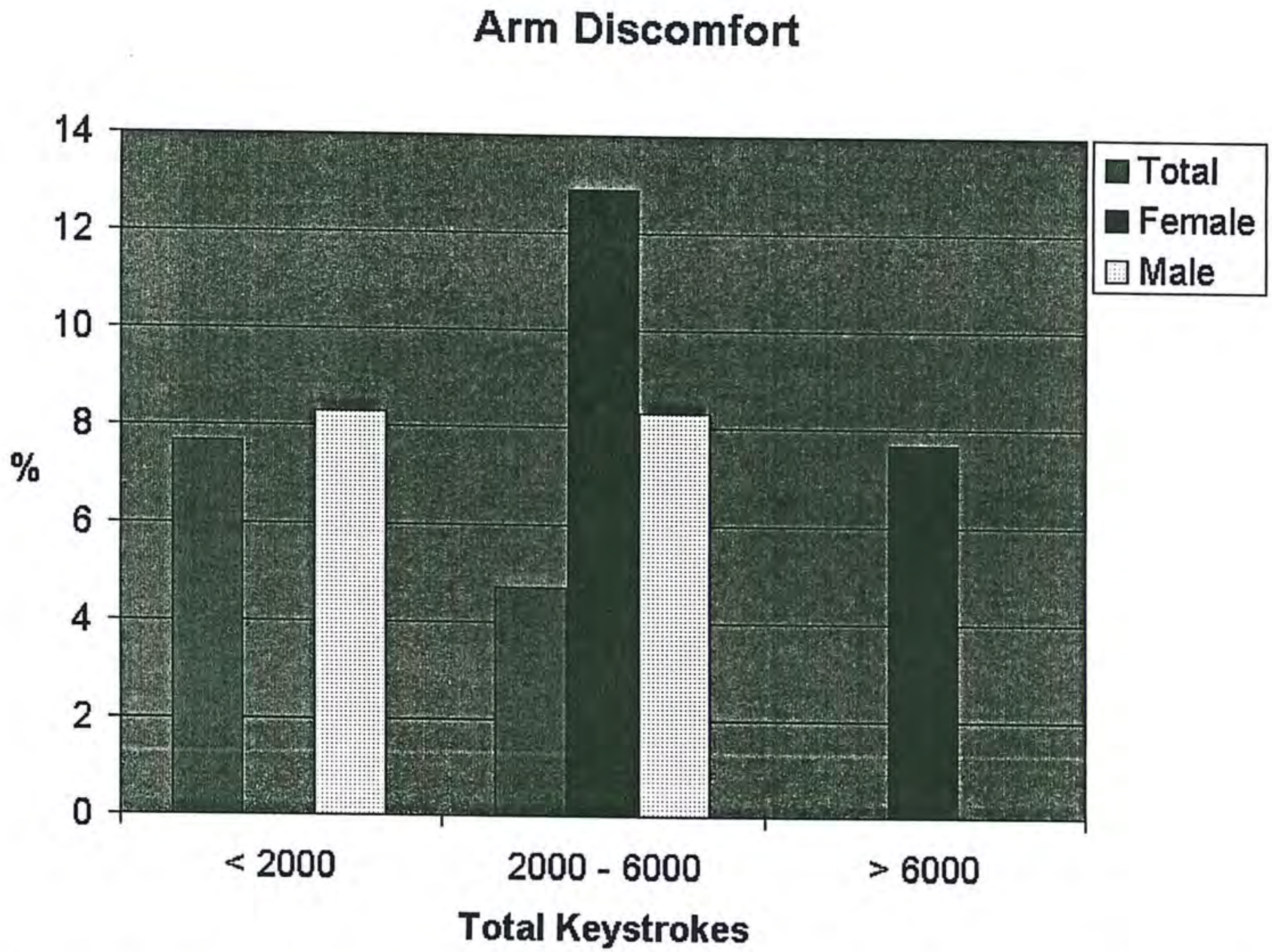


Figure 26. % of participants reported at least "moderate" arm discomfort at the end of the workday vs. total keystrokes.
χ^2 (total): 0.14, $p > .05$; χ^2 (female): 0.33, $p > .05$; χ^2 (male): 0.13, $p > .05$

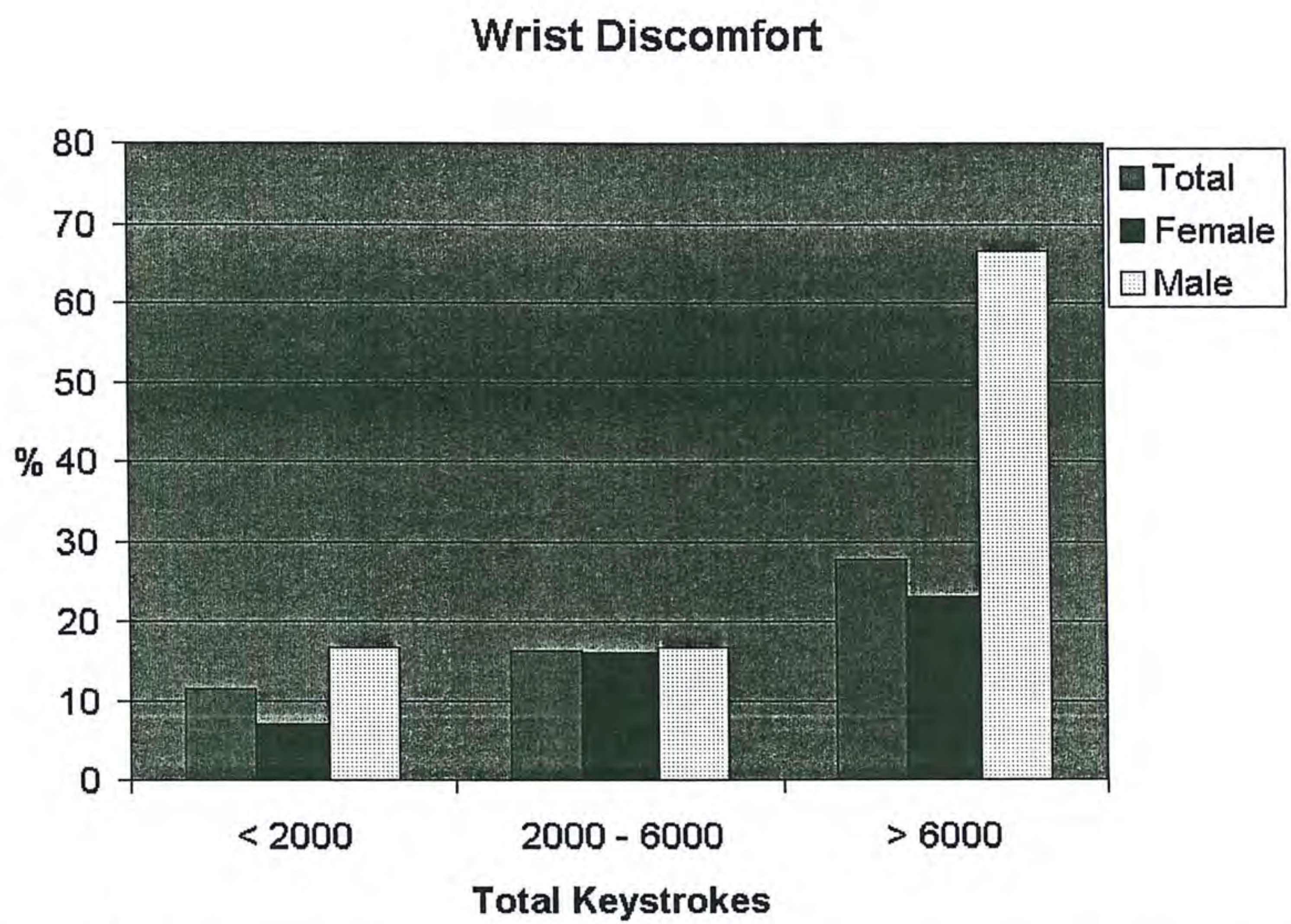


Figure 27. % of participants reported at least "moderate" wrist discomfort at the end of the workday vs. total keystrokes.
χ^2 (total): 2.38, $p > .05$; χ^2 (female): 1.63, $p > .05$; χ^2 (male): 1.86, $p > .05$

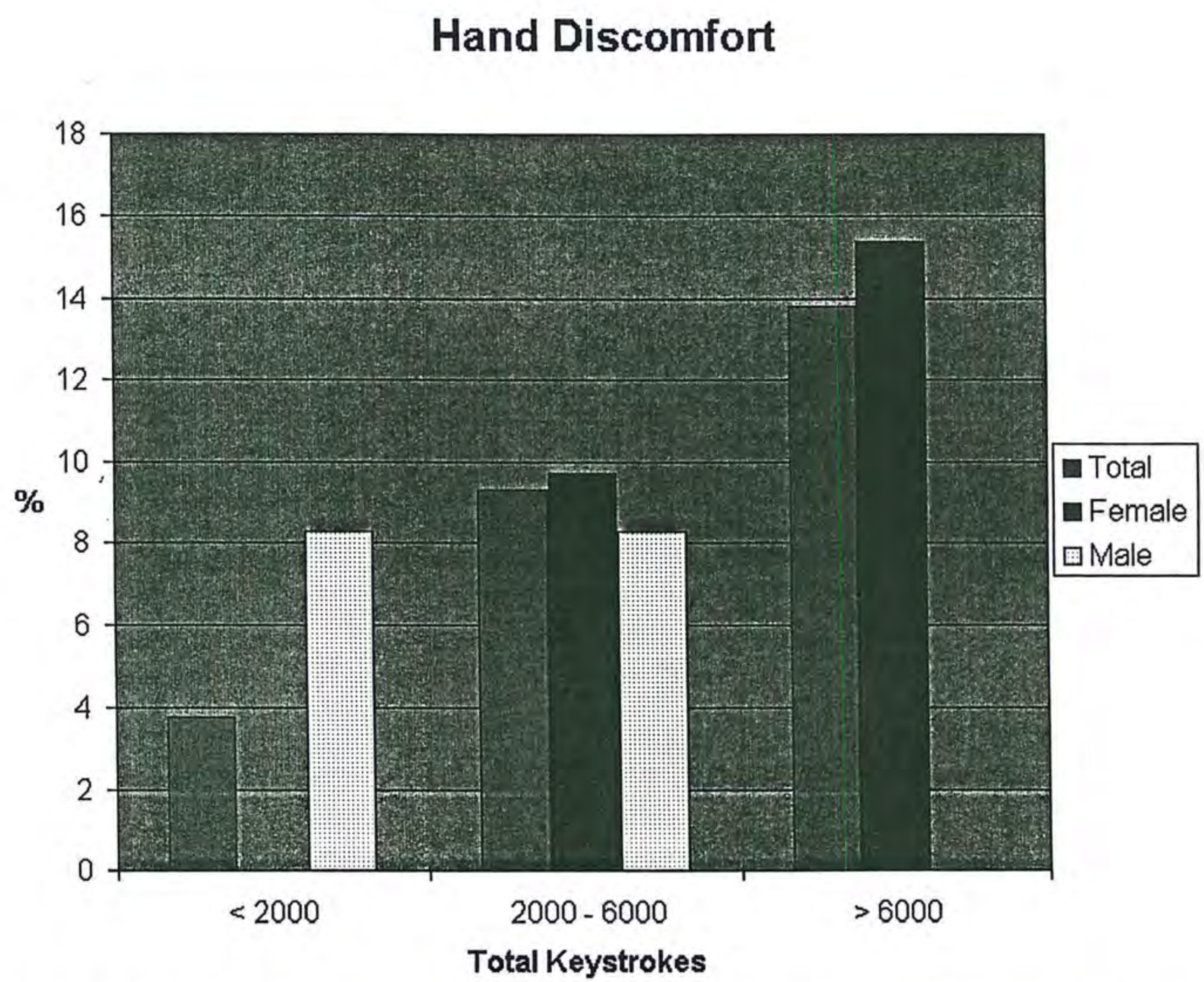


Figure 28. % of participants reported at least "moderate" hand discomfort at the end of the workday vs. total keystrokes.

χ^2 (total): 1.60, $p > .05$; χ^2 (female): 2.32, $p > .05$; χ^2 (male): 0.13, $p > .05$

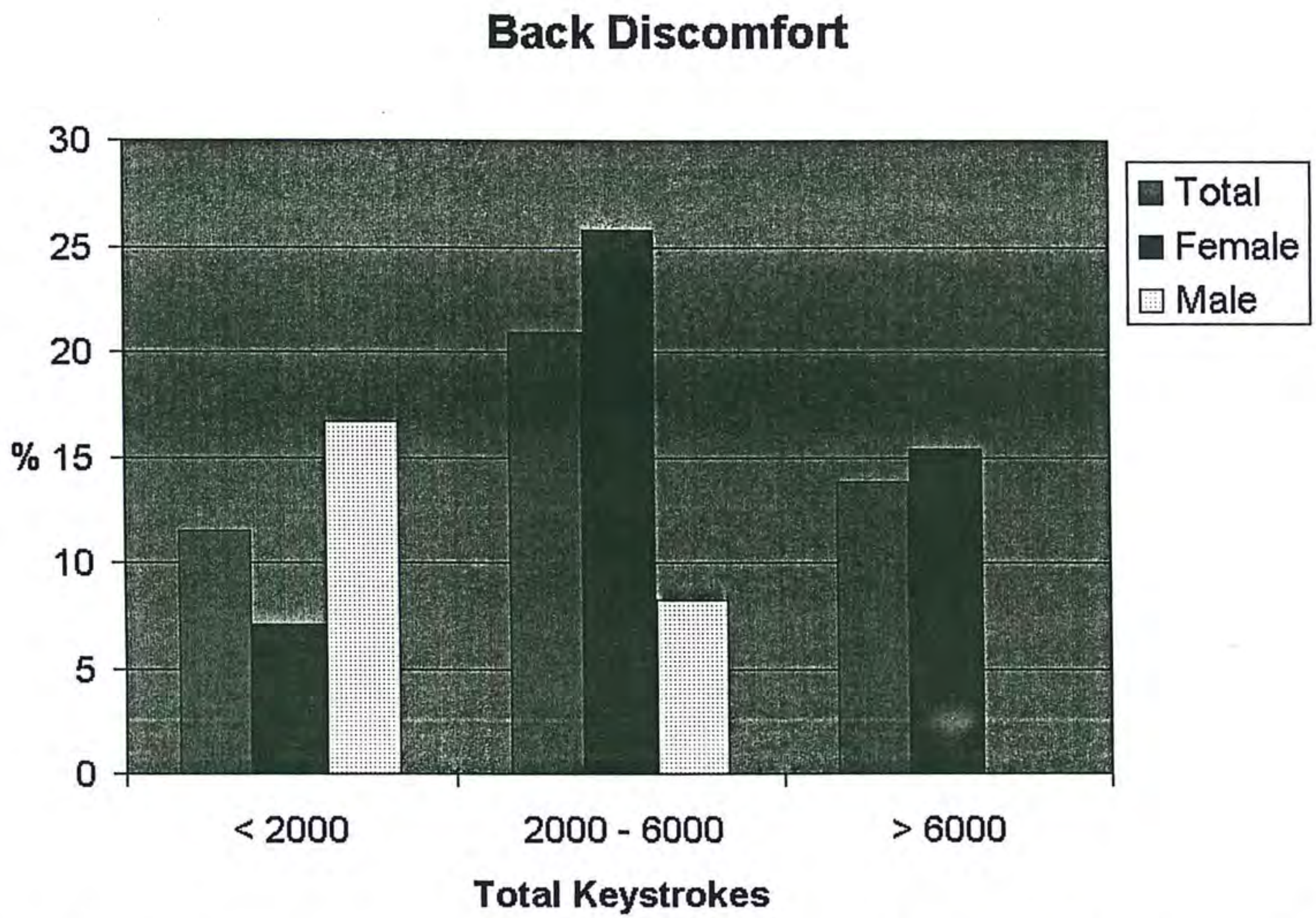


Figure 29. % of participants reported at least "moderate" back discomfort at the end of the workday vs. total keystrokes.

χ^2 (total): 0.03, $p > .05$; χ^2 (female): 0.11, $p > .05$; χ^2 (male): 0.81, $p > .05$

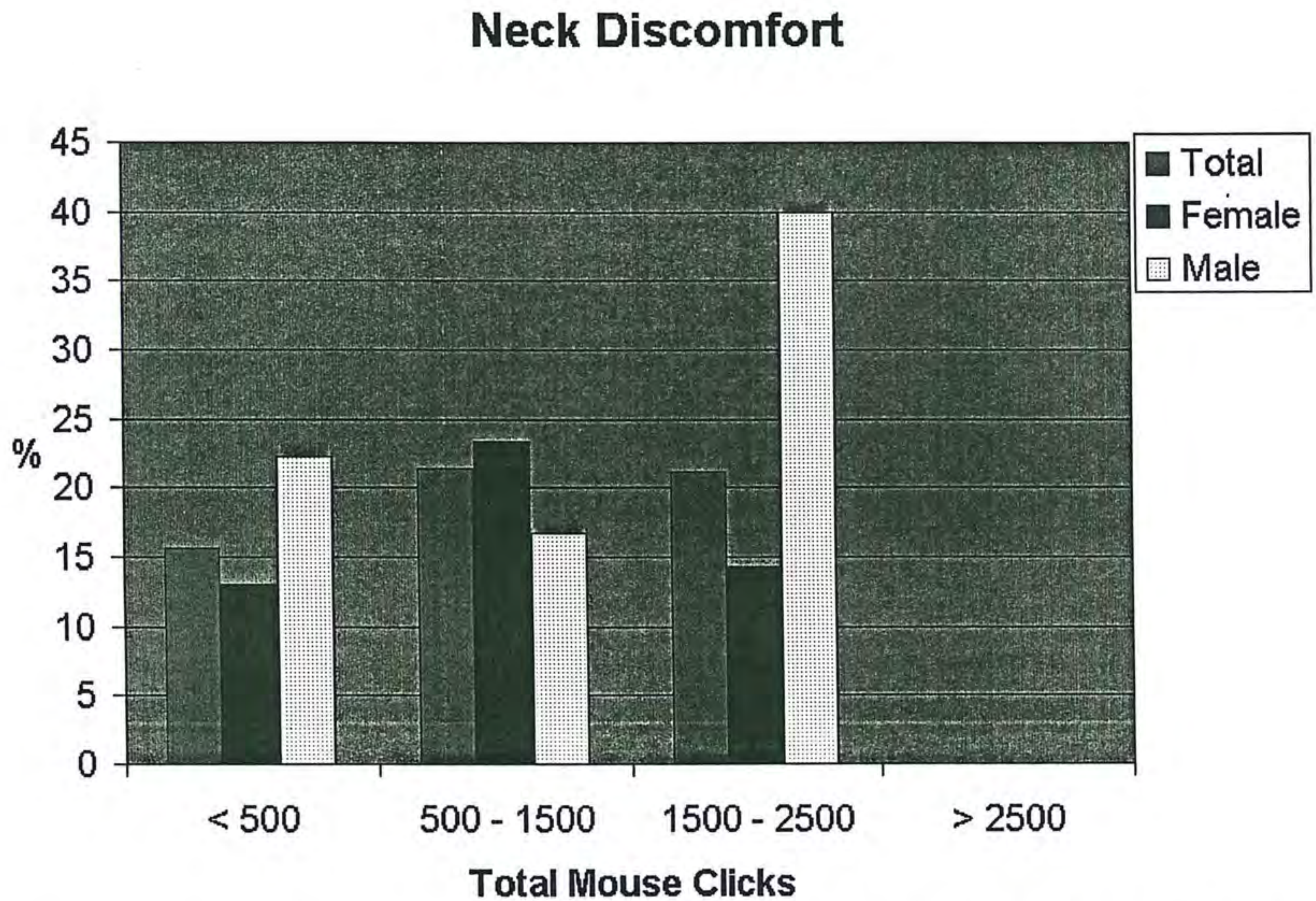


Figure 30. % of participants reported at least "moderate" neck discomfort at the end of the workday vs. total mouse clicks.
χ^2 (total): 0.02, $p > .05$; χ^2 (female): 0.09, $p > .05$; χ^2 (male): 0.06, $p > .05$

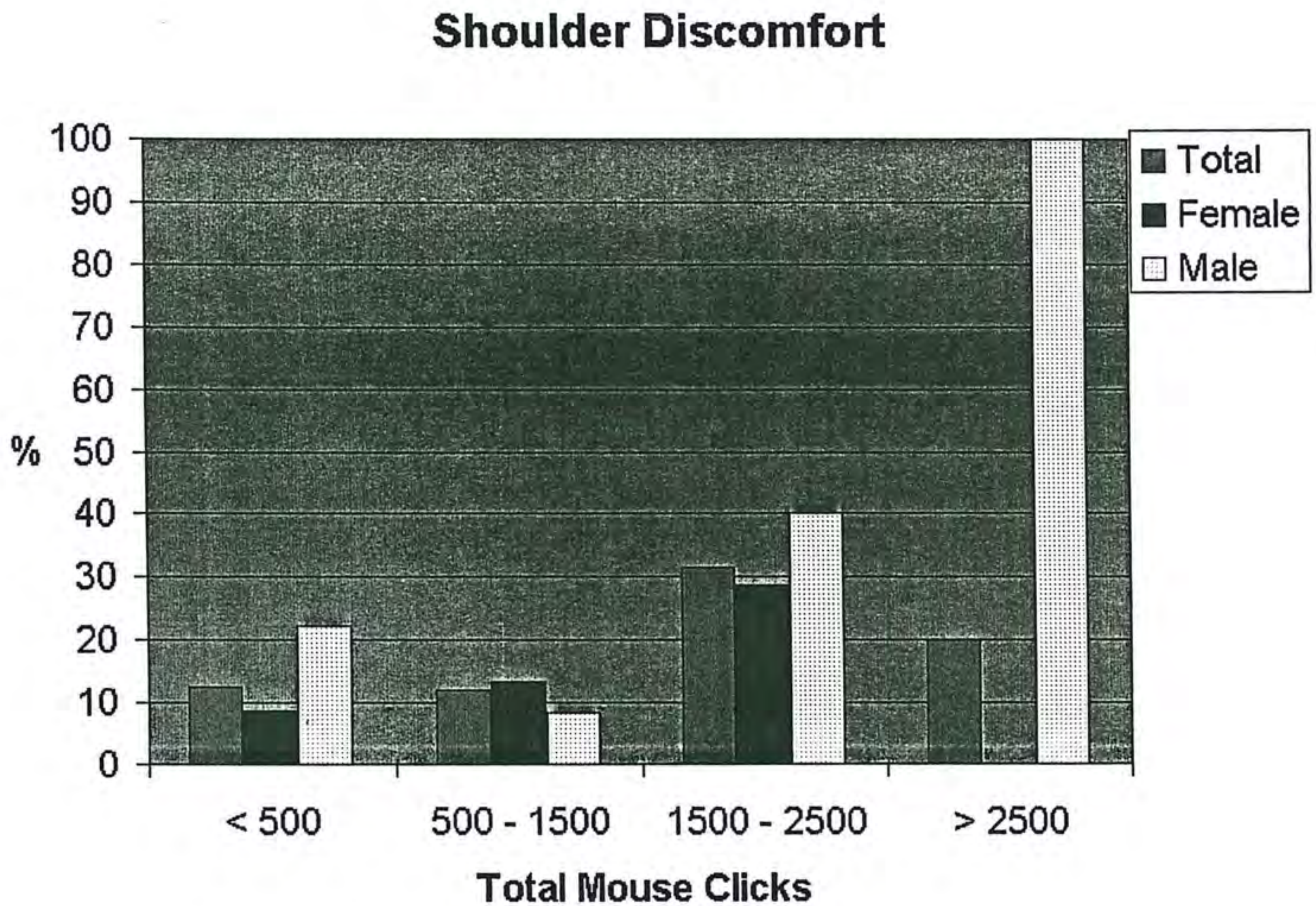


Figure 31. % of participants reported at least "moderate" shoulder discomfort at the end of the workday vs. total mouse clicks.
χ^2 (total): 2.06, $p >.05$; χ^2 (female): 0.71, $p > .05$; χ^2 (male): 1.87, $p > .05$

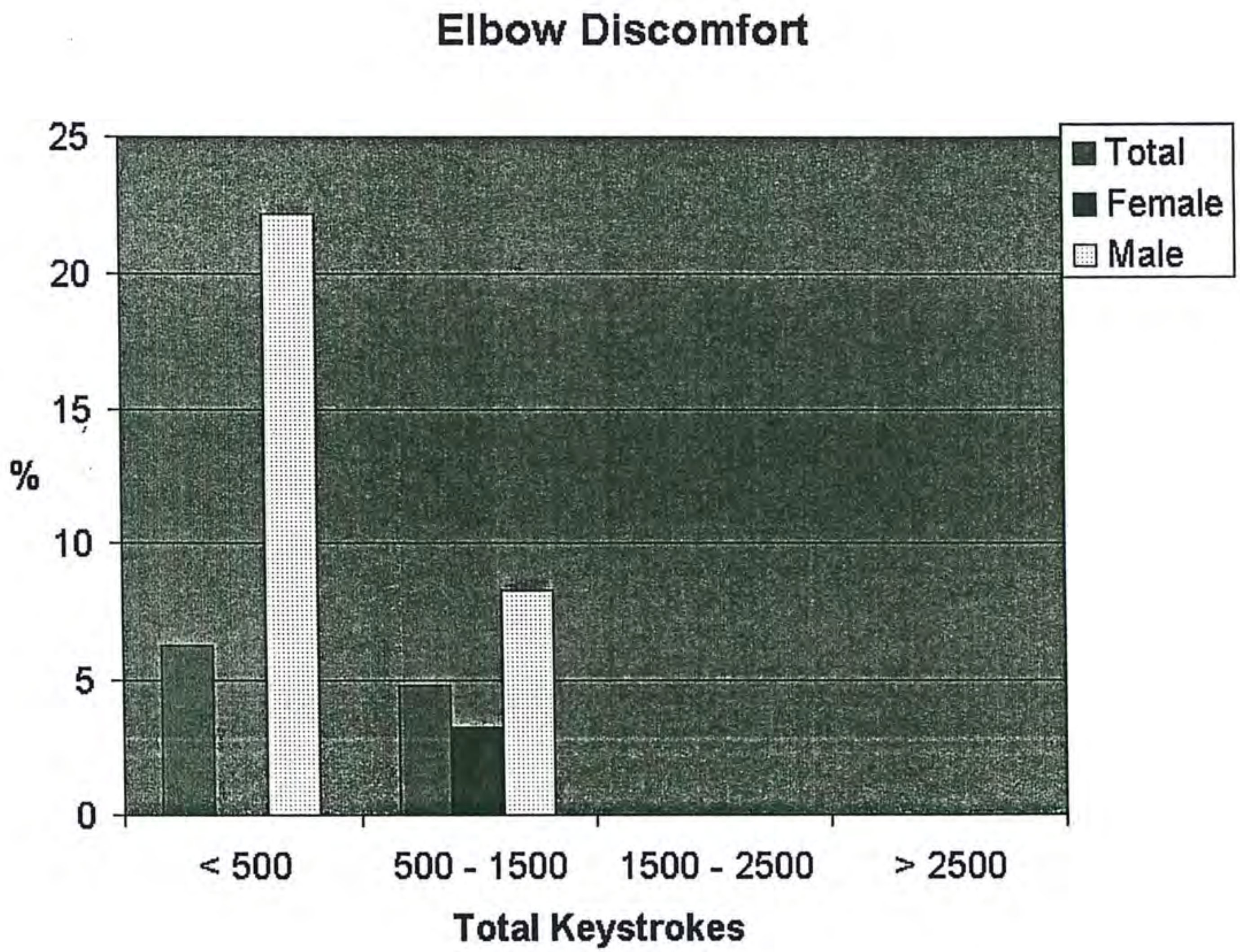


Figure 32. % of participants reported at least "moderate" elbow discomfort at the end of the workday vs. total mouse clicks.

χ^2 (total): 1.26, $p > .05$; χ^2 (female): 0.0, $p > .05$; χ^2 (male): 1.73, $p > .05$

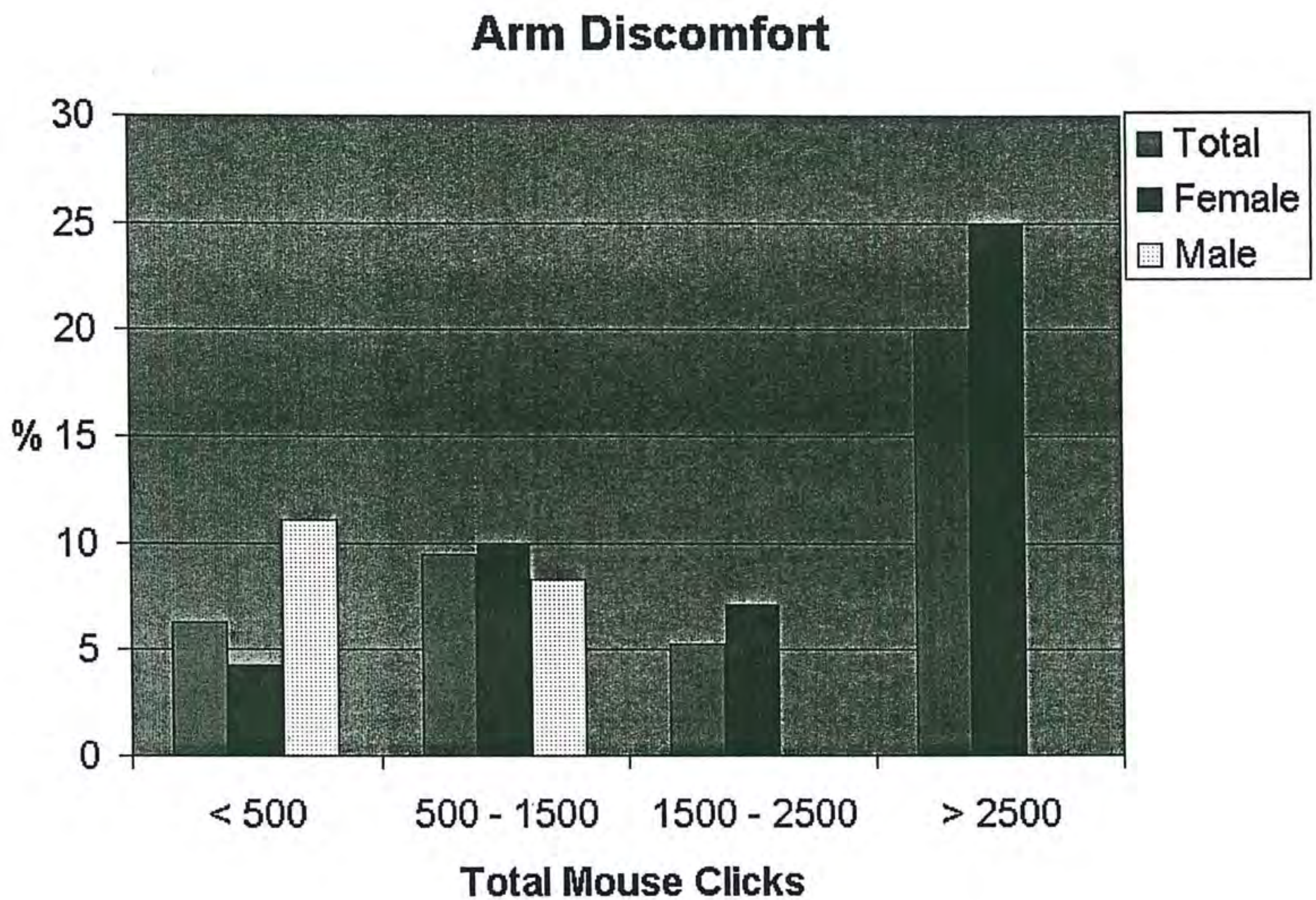


Figure 33. % of participants reported at least "moderate" arm discomfort at the end of the workday vs. total mouse clicks.
χ^2 (total): 0.29, $p > .05$; χ^2 (female): 1.05, $p > .05$; χ^2 (male): 0.57, $p > .05$

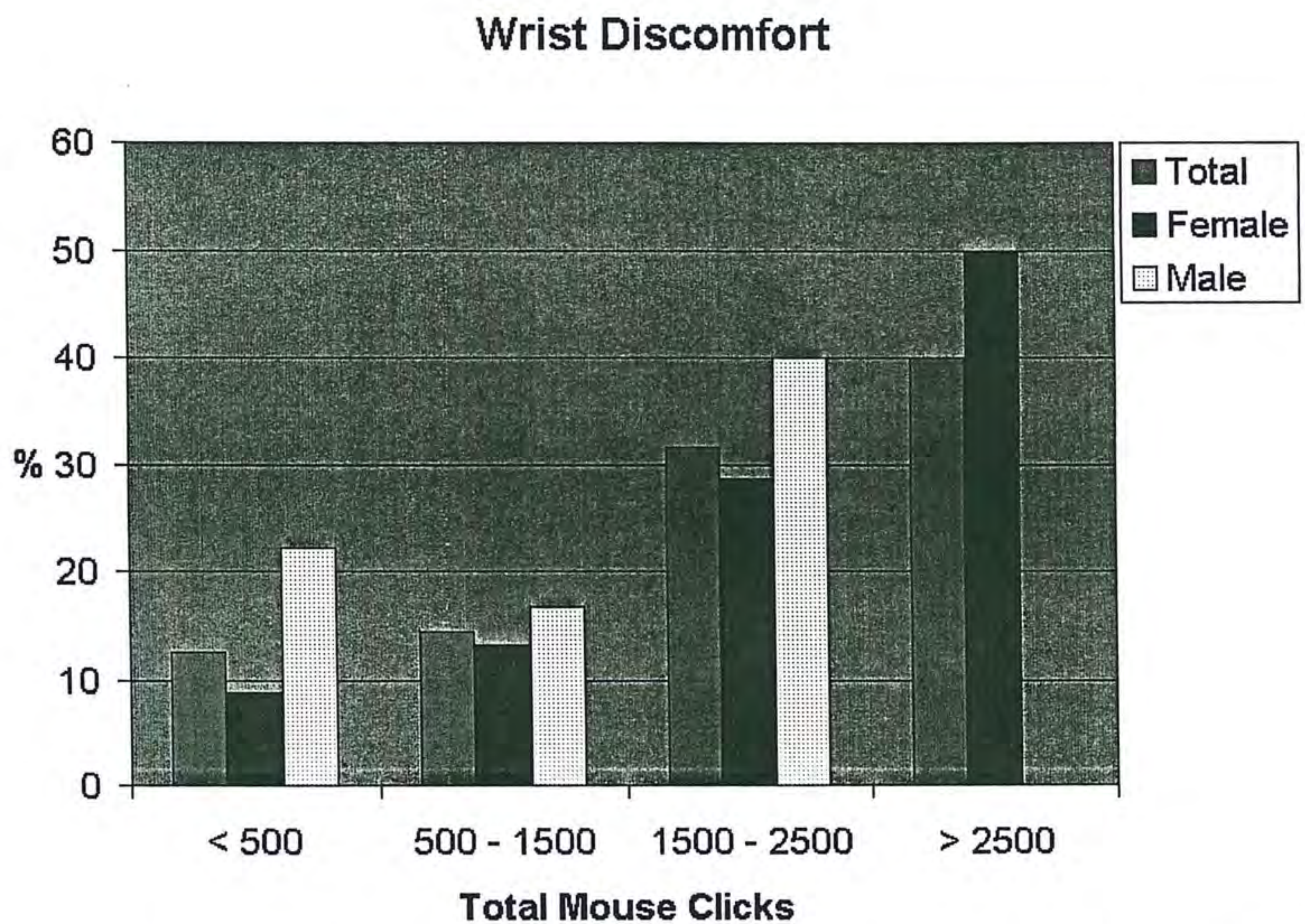


Figure 34. % of participants reported at least "moderate" wrist discomfort at the end of the workday vs. total mouse clicks.
χ^2 (total): 4.0, $p < .05$; χ^2 (female): 5.04, $p < .05$; χ^2 (male): 0.06, $p > .05$

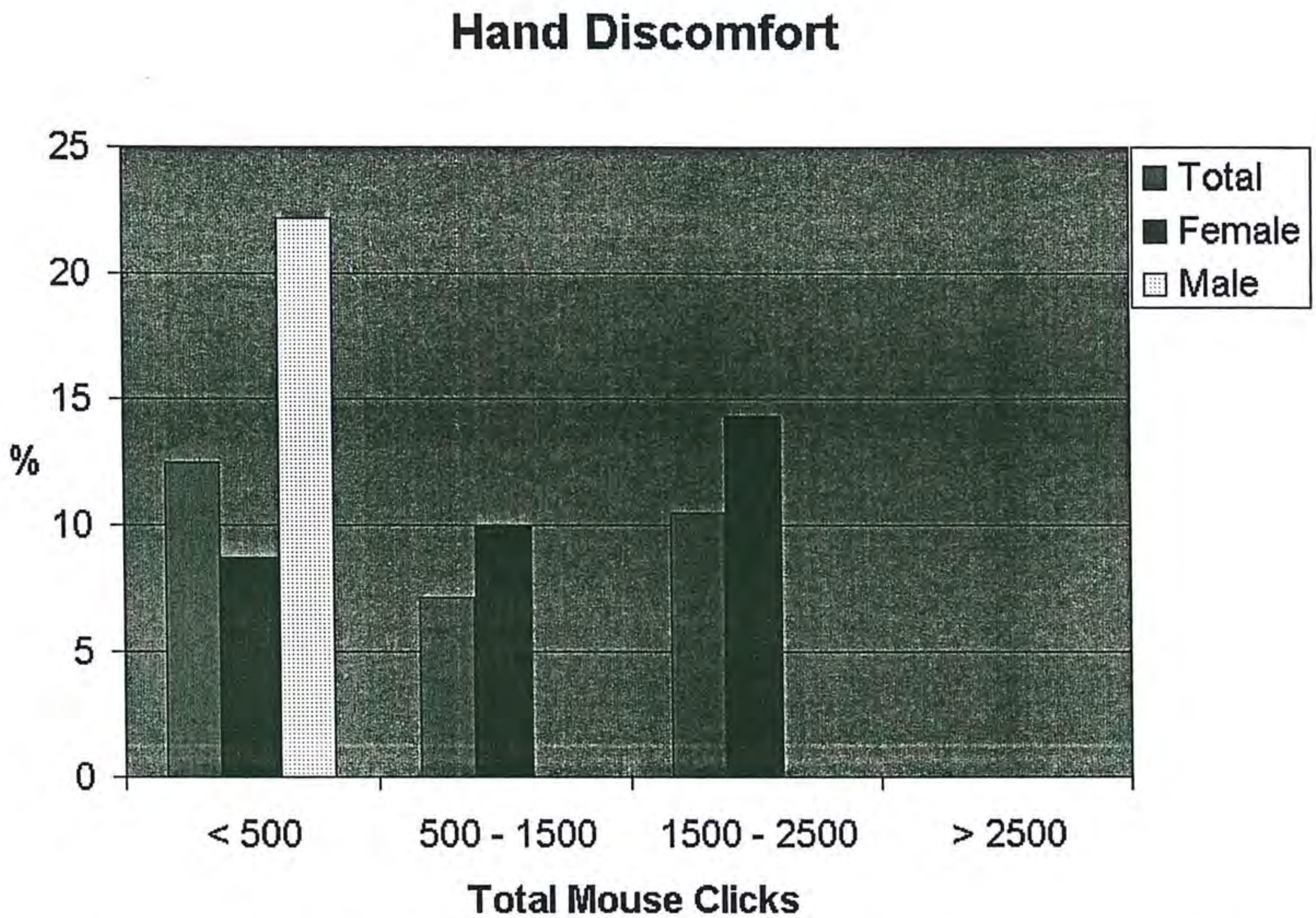


Figure 35. % of participants reported at least "moderate" hand discomfort at the end of the workday vs. total mouse clicks.

χ^2 (total): 0.50, $p > .05$; χ^2 (female): 0.02, $p > .05$; χ^2 (male): 2.70, $p > .05$

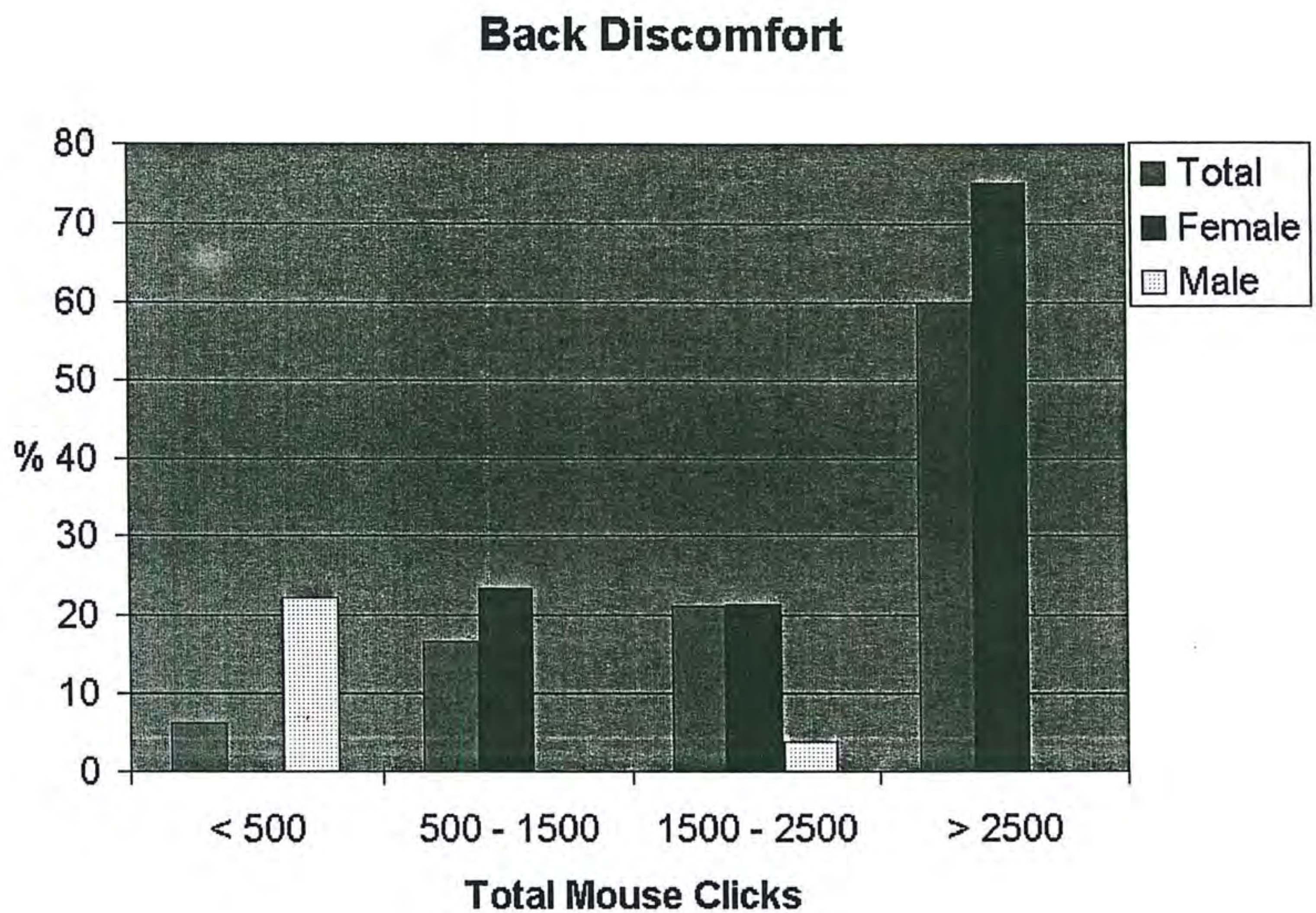


Figure 36. % of participants reported at least "moderate" back discomfort at the end of the workday vs. total mouse clicks.
χ^2 (total): 7.37, p <.05; χ^2 (female): 10.49, p < .05; χ^2 (male): 0.33, p > .05

Table I. Touch-typist keys and finger assignment.

Finger	Keys				
Left Little	Esc	~	!	Tab	Q
	Caps	A	Z		
Left Ring	F1	F2	@	W	S
	X				
Left Middle	F3	#	$	E	D
	C				
Left Index	F4	%	^	R	T
	F	G	V	B	
Thumb	Space	Num 0			
Right Index	F5	F6	&	Y	U
	H	J	N	M	Print Scrn
	Insert	Delete	Arrow Left	Num Lock	Num 7
	Num 4	Num 1			
Right Middle	F7	*	(	I	K
	<	Scroll Lock	Home	End	Arrow Up
	Arrow Down	Num /	Num 8	Num 5	Num 2
Right Ring	F8	)	O	L	>
	Pause	Page Up	Page Down	Arrow Right	Num *
	Num -	Num 9	Num 6	Num 3	Num .
Right Little	F9	F10	F11	F12	_
	+	|	Back Space	P	{
	}	Enter	:	"	?
	Num +	Num Enter			

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service
Centers for Disease Control
and Prevention (CDC)

Memorandum

Date: May 2, 2001

From: Roy M. Fleming, Sc.D., Director, Research Grants Program RMF
Office of Extramural Programs, NIOSH, D30

Subject: Final Report Submitted for Entry into NTIS for Grant 1 R01 OH003785-01.

To: William D. Bennett
Data Systems Team, Information Resources Branch, EID, NIOSH, P03/C18

The attached final report has been received from the principal investigator on the subject NIOSH grant. If this document is forwarded to the National Technical Information Service, please let us know when a document number is known so that we can inform anyone who inquires about this final report.

Any publications that are included with this report are highlighted on the list below.

Attachment
cc: Sherri Diana, EID, P03/C13

List of Publications

Title: Quantifying the Use of Keyboard/Mouse through Intranet
Investigator: Wen Chen V Liu, Ph.D.
Affiliation: University of California
City & State: Los Angeles, CA
Telephone: (310) 794-7687
Award Number: 1 R01 OH003785-01
Start & End Date: 9/30/1998–9/29/2000
Total Project Cost: $62,877
Program Area: Musculoskeletal Disorders: Upper Extremities
Key Words:

Abstract:
A software-based tool was developed in this study to quantify the use of keyboard and mouse through the Intranet. The feasibility and utility of the software-based tool was demonstrated in a field study that profiled 98 non clerical professionals' use of keyboard and mouse during the course of their workday. With the use of the software-based tool, the study quantified for each participant his/her computer on duration, actual duration of keyboard and mouse usage, total number of keystrokes and mouse clicks, and total number of rest breaks from the computer.

The results showed that these technical professionals had their computers on for durations ranging from 115 minutes to 700 minutes during the day of the study. However, the actual duration of VDT usage ranged from 3 minutes to 316 minutes. There was no significant gender difference in the computer-on duration or in the actual VDT usage duration. The total number of keystrokes made by these participants ranges from 203 keys to 18,242 keys (Mean: 5,086; SD: 4,386 keys). The total number of mouse clicks, including left and right, single and double clicks, made during the workday ranged from 27 clicks to 5,749 clicks (Mean: 1,045; SD 940 clicks). There was a significant gender difference in the number of keystrokes made during the workday. Females made more than twice as many keystrokes as males during the workday: 5,957 vs. 2,794 keys, ($p<.01$). There was no statistically significant gender difference in the number of mouse clicks made in the workday. Participants also rated their musculoskeletal discomfort using a 10 point Borg scale. Mantel Haenezel chi square statistic showed that the prevalence of self-perceived wrist and back discomfort was associated with the actual VDT usage duration and with the total number of mouse clicks made in a workday. The results of logistic regression analysis, however, did not show any statistically significant association between the prevalence of self-perceived discomfort and the exposure estimates.

Publications
No publications to date.