Cumulative trauma disorders: A manual for musculoskeletal diseases of the upper limbs

Edited by
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Contents

Abstract

This manual was developed to define cumulative trauma disorders (CTDs) in the workplace, to enable non-medical personnel to recognize them, and to present strategies for preventing their occurrence. Emphasis is placed on CTDs of the upper extremities.

Part I of this manual defines the cumulative trauma category of musculoskeletal disorders. Information is provided on the structures of the hand and arm to help identify the symptoms and location of the disorders. Descriptions of some of the common types of CTDs are also provided along with examples of jobs in which CTDs may occur.

Part II presents methods for determining how many workers at a worksite have CTDs or have some early symptoms of CTDs. Extensive information on conducting an ergonomic job analysis is also provided. Information from such a job analysis is useful for identifying work conditions and tools that may cause or contribute to CTDs.

Part III focuses on two strategies used to control or prevent the occurrence of CTDs: *Instituting Personnel-Focused Practices* and *Redesigning Tools, Work Stations and Jobs*. The merits of each strategy are discussed. Combinations of elements of each strategy are frequently used in workplaces where prevention programs for CTDs have been implemented. Guidelines for ergonomic redesign are also provided along with a list of references for further information on ergonomics.

The Appendices include specialized material designed to supplement information contained in the body of the manual. Appendix A includes a glossary of terms and a series of illustrations to define the positions and movements of the body. Appendix B provides an introduction to the diagnostic process used by the medical profession to identify CTDs and a summary of medical procedures used to treat them. Appendix C defines some common epidemiological terms and describes statistical procedures for evaluating the prevalence, incidence, and severity of CTDs. In addition, a series of case histories are provided to illustrate the frequency and costs associated with CTDs among specific work populations.

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A review of physical exercises recommended for VDT operators

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This paper presents an evaluation of exercises that have been recommended for the prevention of musculoskeletal discomfort among VDT/office workers. 127 individual exercises were analysed for their suitability for performance in VDT workplaces. Additionally, each exercise was judged in terms of its safety and its compliance with principles of physiotherapy. Results showed that, in the majority of cases, the prepared instructions for the exercises were satisfactory and the exercises could be readily performed at the workstation. However, over a third of the exercises were conspicuous and potentially embarrassing to perform, and half would significantly disrupt the work routine. Additionally, a number of the exercises posed potential safety hazards, exacerbated biomechanical stresses common to VDT work, or were contraindicated for persons with certain health problems. These findings suggest a need for greater attention to both the practical and the therapeutic aspects of exercises promoted for VDT users.

Keywords: Exercise; office work; musculoskeletal discomfort

Introduction

Widespread study of video display terminal (VDT) users has raised concerns regarding the potential for musculoskeletal disorders among these individuals. In a review of the literature[1], the World Health Organization found that ". . . musculoskeletal discomfort was commonplace during work with VDTs . . . ," and that "injury from repeated stress to the musculoskeletal system is possible". In addition to the health implications, it is likely that musculoskeletal discomfort in VDT work is associated with performance impairments[2,3].

A review of current literature suggests that the primary emphasis for reducing musculoskeletal strain in VDT work has been on improving the workstation/environment by applying well-established ergonomic principles[4–7]. However, Winkel[8] suggests that ergonomically designed workstations are an incomplete prescription for preventing musculoskeletal discomfort in VDT work because they do not correct for a major contributory factor, namely, constrained postures. Constrained sedentary postures during VDT work may create static loading leading to muscle fatigue, impediment of circulation in the lower extremities, and stresses on joints, chronically stretched muscles and other tissues.

Winkel's contention that ergonomically designed workstations are an incomplete prescription for preventing musculoskeletal discomfort is supported by several studies showing that optimal workstation design does not eliminate the accumulation of musculoskeletal discomfort in VDT work[9,10]. What is needed, according to Winkel, is more dynamic activity to relieve the stresses of sedentary work[8].

This type of thinking no doubt underlies the proliferation of exercise programmes designed to reduce musculoskeletal discomfort arising from VDT work. However, there has been insufficient study of these exercise programmes, in the context of VDT/office work, to ascertain their effectiveness.

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An effective office exercise programme should satisfy two criteria. First, the exercises must be 'usable' (ie, they must be designed to maximize VDT users' ability and motivation to perform them). Second, the exercises must be sound from a physiotherapeutic/safety perspective (ie, they must effectively combat the stresses of VDT work, and performance of the exercises must not pose added safety or health risks). The purpose of this paper is not to advocate the substitution of exercises for job redesign (eg, changes in work routines which result in increased physical activity). Exercises should be regarded as a complement to, not a substitute for, improving the design of jobs to relieve the musculoskeletal stresses of VDT work.

In the present paper, we review exercises proposed for VDT users with regard to the usability and physiotherapeutic/safety criteria. For the usability assessment, it was assumed that exercises which are easy to learn, do not call undue attention to the individual, and can be easily integrated into the work routine, would be most readily utilized by VDT users. Assessments regarding physiotherapeutic value were restricted to judgements regarding potential safety or health risks associated with performance of a particular exercise because, unlike the apparent benefits of these exercises, potential risks have not been addressed.

Ultimately, the suitability of any set of exercises for office workers can be firmly established only through empirical study. The rationale behind the present review is to provide some basis for selection of exercises until empirical data emerge on their effectiveness.

Method

Identification of exercises for review

A total of 14 exercise programmes for VDT users and office workers were identified in the literature:

1 Austin[11]
2 Australian National University[12]
3 Australian Occupational Health and Safety Unit[13]
4 Dahl[14]
5 Emanuel and Glonek[15]
6 Gore and Tasker[16]
7 Joyce and Peterson[17–19]
8 Krames Communication[20,21]
9 Lacey[22]
10 Lee and Humphrey[23]
11 Lee and Waikar[24]
12 *Los Angeles Times*[25]
13 Pragier[26]
14 Sauter *et al*[1]

Two of the programmes[15,23] were designed for microscope operators. Because both microscopy and VDT work involve sedentary work and static postures of the upper extremities and neck/shoulder region, it was presumed that the types of musculoskeletal stresses experienced would be similar.

Of the 14 exercise programmes identified, only 12 were actually evaluated. The exercise programme of Lee and Humphrey[23] was not evaluated since it is identical to that of Emanuel and Glonek[15], except for the duration of the exercises. The exercises of the Australian Occupational Safety and Health Unit[13] were general relaxation exercises which did not target specific muscle groups.

Three sources[16–21] offered multiple exercise programmes. Gore and Tasker[16] offered 45 distinct exercises, organized into five separate exercise programmes (A–E). The programmes were virtually identical in terms of the musculoskeletal structures targeted. Therefore, we selected only programme A for analysis. The Joyce Institute[17–19] has three exercise programmes whose contents overlap. Only the unique exercises in these programmes were reviewed. The same procedure was used for the review of the two programmes by Krames Communications[20,21]. Similarly, because the majority of the Lee and Waikar[24] exercises were identical to those of Emanuel and Glonek[15], only the Lee and Waikar exercises which did not duplicate those of Emanuel and Glonek were included in the analysis.

Exercises which did not target specific musculoskeletal structures (ie, general relaxation exercises or eye exercises) were not included in the analysis. In all, 127 separate exercises were evaluated.

Evaluation procedure Table 1 lists each of the exercises analysed, the source, the exercise instructions, and a listing of the primary muscle groups and structures recruited. (The exercise instructions provided in Table 1 were abbreviated to economize on space. Most instructions included illustrations of a model performing the exercise. The analysis of the exercises was based on the original instructions and illustrations.)

The exercises were classified according to the body part targeted: (1) neck; (2) shoulder; (3) elbow/lower arm; (4) lower back/hip; and (5) knee/lower leg. Many exercises affected muscles from more than one body part. Each of these exercises was categorized under the body part primarily affected.

After classification, each exercise was analysed along a number of dimensions which potentially influenced its usability and physiotherapeutic value. The procedures for these assessments are described below.

Usability assessment

Each exercise was evaluated along five dimensions reflecting the presumed willingness and ability of VDT users to perform them at work. These dimensions were: (1) specificity of instructions; (2) location most suitable for performance; (3) conspicuousness; (4) time requirement/disruption of the work task; and (5) ease of learning/performance. The operational definitions and rating factors used for each of the evaluation end-points are as follows.

Specificity of instructions This dimension refers to the ease with which the instructions can be understood and followed. Three rating categories were utilized: good, fair or poor.

Location most suitable for performance Because the exercises vary in their time and space requirements, not

Table 1. Panel A. Neck Exercises.

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
1	Australian National University	Exercise 2	1) Stand as tall as possible, then 2) relax and go loose like a rag doll. (10 to 20 times).	Lower cervical and thoracic extensors, neck flexors (phase I only)	Upper cervical extensors, anterior ligaments of the lower cervical and upper thoracic spine (phase I), cervical and thoracic extensors, scapular adductors, elevators and upward rotators, posterior ligaments of the cervical and thoracic spine (phase II)	fair	work area	highly	mini	simple	a b c d 1 3
2	Sauter	Head Nods	Nod head (not entire neck) in "yes" motion.		Upper cervical extensor muscles, posterior ligaments of the cervical spine and facet joints	good	chair	somewhat	micro	simple	a b c 1 3
3	Gore and Tasker	The Pigeon	Standing or sitting, keep eyes looking forward. Without dropping head, pull face in to make double chin. Hold for count of 6. Repeat 10 times.	Lower cervical, thoracic and lumbar extensors, neck flexors	Upper cervical extensors, anterior ligaments of the lower cervical and upper thoracic spine	good	chair	no	mini	simple	
4	Krames Comm	Neck Glide	1) Glide head back, as far as it will go, Keeping head and ears level. 2) Now glide head forward. Repeat 3 times.	Phase I: Lower cervical, thoracic and lumbar extensors, neck flexors Phase II: Upper cervical extensors and neck flexors	Phase I: Anterior ligaments of the lower cervical and thoracic spine, upper cervical extensors Phase II: Posterior ligaments of the lower cervical and thoracic spine, lower cervical and thoracic extensors	good	chair	no	micro	simple	
5	LA Times	Dorsal Glides (Turkey)	Sit up straight and pull shoulders back. Slide head straight back on neck, keeping face pointed forward (Turkey Position). Isolate movement to head and neck. Repeat slowly 5 times.	Lower cervical, thoracic and lumbar extensors, scapular adductors, elevators and upward rotators, neck flexors	Anterior ligaments of the lower cervical and thoracic spine, upper cervical extensors	good	chair	no	micro	simple	
6	Joyce & Peterson	Cable Stretch	Sit relaxed, with feet flat on floor. Imagine a cable attached to the top of the head pulling you up. Hold for count of 3; relax. Repeat 3 times.	Lower cervical, thoracic and lumbar extensors, neck flexors	Anterior ligaments of the lower cervical and thoracic spine, upper cervical extensors	good	chair	no	micro	simple	
7	Pragler	Exercise a-1	Tuck the chin in, shoulders back and "sit tall". Hold the position for a count of 3; relax.	Lower cervical, thoracic and lumbar flexors/extensors, scapular adductors, elevators and upward rotators, neck flexors	Anterior ligaments of the lower cervical and thoracic spine, upper cervical extensors	good	chair	no	micro	simple	
8	Emanuel and Glonek	Neck Rotations	Rotate head and neck 3 times clockwise and 3 times counterclockwise.		Anterior and posterior cervical and thoracic rotators, neck upper back extensors and flexors, scapular elevators, anterior, lateral and posterior ligaments of the cervical and thoracic spine	fair	chair	somewhat	micro	simple	a b c 1 3 4

The exercise instructions have been abbreviated to economize on space. Most instructions included illustrations of a model performing the exercise. The analysis of the exercises was based on the original instructions and illustrations.

Key

1 Exercise reproduces physical stresses of VDT work
2 Exercise poses one or more safety hazards
3 Exercise stretches already overstretched structures
4 Exercise places additional loads on lumbar and/or thoracic discs

a Acute neck pain
b Degenerative disc disease
c Moderate to severe osteoporosis
d Acute lower back pain
e Second and third trimesters of pregnancy
f Acute inflammatory or arthritic conditions of the shoulder
i Acute inflammatory or arthritic conditions of the elbow/forearm complex
j Hand/wrist disorders, such as carpal tunnel syndrome
k Acute lateral epicondylitis
l Spinal stenosis
m Arthritic conditions of the hips and/or knees

Table 1. Panel A. Neck Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
9	Australian National University	Exercise 5	Tuck chin in. Circle head in one direction, then in other. Repeat 10-15 times.	Cervical and thoracic flexors, sidebenders, rotators, extensors	Anterior and posterior cervical and thoracic rotators, neck/upper back flexors and extensors, scapular elevators, anterior, lateral and posterior ligaments of the cervical and thoracic spine	fair	chair	somewhat	mini	simple	a b c 1 3 4
10	Dahl	Unnamed	Rotate head to one side, then to the front, and to other side.	Cervical and thoracic rotators, neck flexors	Cervical and thoracic rotators, posterior and lateral ligaments of the cervical and thoracic spine and facet joints	*	chair	somewhat	micro	simple	a b c
11	Sauter	Head Turns	Close eyes and very slowly turn head from shoulder to shoulder (with head positioned upright).	Cervical and thoracic rotators, neck flexors	Cervical and thoracic rotators, posterior and lateral ligaments of the cervical and thoracic spine and facet joints	good	chair	somewhat	micro	simple	a b c
12	Krames Comm.	Head and Neck	Turn head slowly from one side to the other, holding each turn for a count of 3. Repeat 5-10 times.	Cervical and thoracic rotators, neck flexors	Cervical and thoracic rotators, posterior and lateral ligaments of the cervical and thoracic spine and facet joints	good	chair	somewhat	mini	simple	a b c
13	LA Times	Turkey with Rotation	Hold turkey position (see exercise 5) and slowly turn head to point of stretch sensation, first left, then right 3-5 times.	Cervical and thoracic rotators, neck flexors	Cervical and thoracic rotators, posterior and lateral ligaments of the cervical and thoracic spine and facet joints	fair	chair	somewhat	micro	simple	a b c
14	Gore and Tasker	Headrest	Sitting, lock fingers behind head, drop chin to chest. Slowly turn head to right and hold for count of 10. Relax. Repeat to left. Do 3 times on each side.		Upper thoracic and cervical extensors and rotators, posterior and lateral ligaments of thoracic cervical spine and facet joints	good	chair	somewhat	mini	simple	a b c 1 3 4 Alternative exercise to stretch the upper cervical muscles should be chosen that does not produce extreme flexion and rotation of lower cervical and upper thoracic spine.
15	Joyce & Peterson	Neck/Head	Slowly tip head from side to side 3 times. Bring head to upright, then turn it and look over shoulder 3 times to each side. Drop chin to chest, then raise it as far as possible 3 times.	Cervical and thoracic rotators, anterior and posterior cervical and thoracic rotators, neck flexors and extensors	Upper thoracic and cervical extensors, lateral, anterior and posterior ligaments of the thoracic and cervical spine and facet joints, cervical flexors, neck side benders, scapular elevators, anterior and posterior cervical and thoracic rotators	good	chair	somewhat	mini	simple	a b c 1 3 4
16	Austin	Neck	Let head drop slowly to left, then to right. Slowly drop chin to chest, then raise chin as high as possible. Turn head all the way to left, return to normal, then turn all the way right. Return to normal position.	Anterior and posterior cervical and thoracic rotators, neck flexors and extensors	Upper thoracic and cervical extensors, lateral, anterior and posterior ligaments of the thoracic and cervical spine and facet joints, cervical flexors, neck side benders, scapular elevators, anterior and posterior cervical and thoracic rotators	good	chair	somewhat	micro	simple	a b c 1 3 4

*As the Dahl exercises were translated from Danish to English for the authors, the specificity of the instructions was not evaluated

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Table 1. Panel A. Neck Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
17	Australian National University	Exercise 4	Place one hand on opposite shoulder. Pull shoulder down while bending head toward other shoulder. Repeat on other side. Repeat 5-10 times.		Neck side benders, scapular elevators, lateral ligaments of the upper thoracic and cervical spine and facet joints	fair	chair	somewhat	mini	simple	a b c 3 4 Avoid rapid stretching. May produce moderate loading on cervical discs if performed in forward, flexed head posture.
18	Gore and Tasker	Tension Neck	Standing, place left hand on back of neck. Point left elbow to ceiling and keep there. Drop chin on chest and turn head to right without lifting chin. Tilt right ear to right and hold for count of 10. Relax. Repeat with right hand, turning head to left. Do 3 times each side.		Neck side benders, scapular elevators, posterior and lateral ligaments of the upper and cervical spine and facet joints	fair	work area	highly	mini	simple	a b c 3 4 Avoid rapid stretching.
19	LA Times	Upper Trapezius Stretch	Grasp seat or leg of chair with right hand to pull shoulder down slightly. Lean head to left until stretch is felt on right side of neck. Lean body to left to increase stretch. Hold 15 seconds. Repeat on other side.		Neck side benders, scapular elevators	good	chair	somewhat	mini	simple	a b c 4 Avoid rapid stretching.
20	LA Times	Levator Scapulae Stretch	Grasp seat or leg of chair with right hand to pull shoulder down slightly. Move head forward, rotate and lean to left until stretch from neck to top of shoulder blade is felt. Lean body to left to increase stretch. Hold 15 seconds. Repeat on other side.		Neck side benders, scapular elevators, posterior and lateral ligaments of the upper thoracic and cervical spine and facet joints	fair	chair	somewhat	mini	simple	a b c Avoid rapid stretching. May produce moderate loading on cervical discs if performed in forward, flexed head posture.
21	Pragler	Exercise a-3	Keeping shoulders down, bend the head over towards the shoulder to stretch the muscles of the neck. Hold that position for a count of 3, and then bring head slowly back to the center.		Neck side benders, scapular elevators, lateral ligaments of the upper thoracic and cervical spine and facet joints	poor	chair	no	micro	simple	a b c 4 Avoid rapid stretching. May produce moderate loading on cervical discs if performed in forward, flexed head posture. Enhance safety by tucking chin during side bending.
22	Sauter	Nose Drawing	Close eyes and imagine pen attached to nose. Moving head, draw a large circle. Within circle, draw a plus. Go over it several times. Draw a "X" and go over it several times. Try drawing other objects, or writing name.	Neck sidebenders, rotators, flexors and extensors	Neck sidebenders, rotators, flexors and extensors; posterior and lateral ligaments of the cervical and thoracic spine and facet joints	good	chair	somewhat	mini	simple	a b c 1 3 4
23	Dahl	Unnamed	Lift shoulders towards ears in a shrug, then relax and let them fall back.	Scapular upward rotators and adductors	Scapular downward rotators	*	chair	somewhat	micro	simple	
24	Joyce & Peterson	Shoulder Shrug	Sit straight and bring shoulders up toward ears. Hold for count of 3. Relax. Repeat twice.	Scapular upward rotators and adductors	Scapular downward rotators	good	chair	somewhat	micro	simple	
25	Joyce & Peterson	Shoulder Roll	Sit upright. Lower chin. Slowly make 3 circles with shoulders, then gradually tilt head backward. Make 3 slow circles with shoulders. Stretch upward for count of 3, and relax.	Scapular upward rotators and adductors	Scapular downward rotators cervical flexors and extensors	fair	chair	somewhat	mini	simple	a f 1 3

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Table 1. Panel B. Shoulder Exercises

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
26	Krames Comm.	Shoulders	Roll shoulders forward 5 times using wide circular motions. Then roll shoulders backward 5 times. Repeat cycle 5-10 times.	Scapular upward rotators and adductors, scapular downward rotators and shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	good	chair	somewhat	mini	simple	f 1 3
27	Pragier	Exercise a-6	Circle shoulders backward three times, with arms relaxed by sides.	Scapular upward rotators and adductors, scapular downward rotators and shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	good	chair	somewhat	micro	simple	f 1 3
28	Austin	Shoulder Roll	Slowly roll shoulders forward 5 times in circular motion. Then roll back with same circular motion.	Scapular upward rotators and adductors, scapular downward rotators and shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	good	chair	somewhat	micro	simple	f 1 3
29	Australian National University	Exercise 3	Circle shoulders backwards and forwards 10-20 times.	Scapular upward rotators and adductors, scapular downward rotators and shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	fair	chair	somewhat	mini	simple	f 1 3
30	Sauter	Shoulder Circles	With arms at sides, raise shoulders up, and rotate forward in circular motion several times. Repeat several times in backwards direction.	Scapular upward rotators and adductors, scapular downward rotators and shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	good	chair	somewhat	micro	simple	f 1 3
31	Emanuel and Glonek	Shoulder Rotations	Bend elbows and rotate shoulders 4 times forward and 4 times backward.	Scapular upward rotators and adductors, scapular downward rotators and shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	fair	chair	somewhat	micro	simple	f 1 3
32	Austin	Arm Circles	Raise arms to side with elbows straight. Slowly rotate arms in small circles, forward and backward.	Scapular upward rotators, shoulder adductors, scapular downward rotators and abductors, shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	good	chair	highly	mini	simple	f
33	Krames Comm.	Arm Circles	Raise the arms to the sides, elbows straight. Slowly rotate arms in small circles forwards, then backwards. Lower arms, then repeat 3 times.	Scapular upward rotators, shoulder adductors, scapular downward rotators and abductors, shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	good	chair	highly	mini	simple	f
34	Lacey	Upper Arms	Let arms fall to side and rotate hands in circular motion. Put arms up, interlock fingers overhead. Push arms forward, then stretch arms back, pulling ribcage up. Hold arms straight out, rotate them in circular motion. Flex upper arms as in making a muscle.	Wrist flexors, wrist/finger extensors, forearm supinators and pronators, wrist ulnar and radial deviators; shoulder flexors, abductors, external rotators, horizontal abductors and internal rotators	Wrist flexors, wrist/finger extensors, forearm supinators and pronators, wrist ulnar and radial deviators, shoulder extensors, adductors and internal rotators, external rotators and abductors	fair	chair	highly	mini	simple	f j 1 3

[a]As the Dahl exercises were translated from Danish to English for the authors, the specificity of the instructions was not evaluated

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l Spinal stenosis
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Table 1. Panel B. Shoulder Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
35	Dahl	Unnamed	Sit forward in chair. Slump forward, straighten up and arch back, raise arms as high above head as possible, then slump forward again.	Phase II: Cervical, thoracic and lumbar extensors, scapular adductors, elevators and upward rotators, shoulder flexors and external rotators	Phase I: Shoulder extensors and internal rotators, posterior ligaments of the cervical, thoracic and lumbar spine. Phase II: Cervical, thoracic and lumbar flexors, scalpular adductors, elevators and upward rotators	*	chair	highly	micro	simple	a b c d e 1 3
36	Pragier	Exercise b-7	Push one arm up toward ceiling with hand stretched out. Repeat with other arm.	Scapular adductors and upward rotators; shoulder flexors and abductors, thoracic extensors and external rotators	Shoulder extensors and adductors	good	chair	highly	micro	simple	f
37	Krames Comm.	Reaching High	Raise arms over head, stretching as high as possible. Then bring arms back down. Rest a moment. Repeat 2 times.	Scapular adductors and upward rotators, shoulder flexors and abductors, thoracic extensors	Shoulder extensors, adductors and internal rotators	good	chair	highly	micro	simple	f
38	Gore and Tasker	Reach for the Sky	Standing, stretch arms above head and hold for count of 6. Drop arms. Repeat 5 times.	Scapular adductors and upward rotators, shoulder flexors and abductors, thoracic extensors	Shoulder extensors, adductors and internal rotators	good	work area	highly	mini	simple	f
39	Austin	Reach	Slowly raise arms and draw stomach in. Let arms drop. Repeat twice.	Scapular adductors and upward rotators, shoulder flexors and abductors, thoracic extensors, abdominal flexors	Shoulder extensors, adductors and internal rotators	fair	chair	highly	mini	simple	f
40	Sauter	Arm Stretch	Stretch left arm over head, and right arm towards floor. Hold for several moments. Repeat several times, then reverse arms and repeat.	Scapular adductors and downward and upward rotators, shoulder flexors and abductors, thoracic extensors, neck rotators and flexors	Shoulder extensors and adductors, trunk lateral flexors	good	chair	highly	mini	simple	a b c f 1 3 4
41	LA Times	Windmills	Bring head into Turkey Position (see exercise 5), with arms at sides. Point one thumb forward, one thumb back. With arms straight, move them in direction thumbs are pointing. Repeat, moving arms in opposite direction. Do 3-5 times.	Scapular adductors, downward and upward rotators, shoulder flexors, abductors, external rotators, extensors, adductors and internal rotators, elbow extensors, forearm supinators and pronators, thoracic extensors	Scapular downward and upward rotators, shoulder extensors, adductors, internal rotators, flexors, abductors and external rotators, elbow flexors, forearm pronators and supinators	fair	chair	highly	micro	simple	a f 1 3
42	Australian National University	Exercise 1	With arms bent across chest, push elbows back while stretching head up. Repeat 7-15 times.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators		poor	chair	somewhat	mini	simple	

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Table 1. Panel B. Shoulder Exercises (cont.).

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
43	Austin	Shoulder Stretch	Bring right hand to upper back from above. Bring left hand to upper back from below and hook fingers of two hands. Repeat on other side.	Scapular adductors, downward and upward rotators, shoulder flexors, abductors, external rotators, extensors, adductors and internal rotators, elbow flexors, thoracic extensors	Scapular downward and upward rotators, shoulder extensors, adductors, internal rotators, flexors, abductors and external rotators	fair	chair	highly	micro	difficult	f l j 1 3
44	Joyce & Peterson	Arm Rotation	Extend arms straight ahead at shoulder level. Rotate them so the back of the hands face and touch each other. Hold to count of 3. Then rotate hands so palms face upward with sides of hands touching. Hold to count of 3. Repeat 2 more times.	Shoulder external rotators, flexors, shoulder internal rotators, forearm supinators and pronators	Shoulder internal rotators, external rotators, forearm pronators and supinators	fair	chair	highly	micro	simple	f k 1 3 Arm extension may actually increase neck/shoulder strain.
45	Joyce & Peterson	Give Me Five	Hold arms straight out in front. Make fist. Slowly point knuckles to floor. Hold for count of 3. Slowly straighten out fingers. Then point fingers toward ceiling and hold for count of 3. Repeat 3 times.	Shoulder external rotators, flexors and abductors, scapular adductors and upward rotators, thoracic extensors, finger flexors, wrist and finger extensors	Shoulder internal rotators, extensors and adductors, scapular downward rotators, wrist extensors	good	chair	somewhat	mini	simple	f j 1 3 Arm extension may actually increase neck/shoulder strain
46	Gore and Tasker	Fall Back	Sitting up straight, raise arms above head and clasp hands together. Looking forward, let arms and shoulders fall backwards over back of chair. Hold for slow count of 10. Relax. Repeat 3 times.	Shoulder flexors and abductors, scapular adductors and upward rotators	Shoulder extensors and adductors, anterior ligaments of the thoracic spine and facet joints	good	chair	somewhat	mini	simple	b c d e f 2 Potential for chair tipping backwards.
47	Dahl	Unnamed	Sit forward in chair. Raise arms above head and bend backward over back support.	Shoulder flexors and abductors, scapular adductors and upward rotators	Shoulder extensors and adductors, anterior ligaments of the thoracic spine and facet joints, cervical flexors	*	chair	somewhat	micro	simple	b c d e f 2 Potential for chair tipping backwards.
48	Gore and Tasker	Forwards Lean	Standing, push chair against desk. Stand about 1 meter behind chair, place hands on back of chair while keeping elbows straight, drop head forward between arms while keeping back straight. Hold for count of 10. Relax. Repeat 5 times.		Shoulder extensors and adductors, hip extensors/knee flexors (hamstrings), lumbar extensors, posterior ligaments of the lumbar spine and facet joints, cervical extensors	fair	work area	highly	mini	simple	a b c d e 1 2 3 4 Rolling chair potentially dangerous.
49	Krames Comm.	Upper Back Stretch	Raise hands to shoulders. Using the arms push shoulders back. Keep elbows down. Hold for 15 seconds. Repeat 3 times.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	fair	chair	somewhat	mini	simple	f
50	Austin	For your Arms	Bend elbows, keeping arms parallel to floor, fingers in front of chest. Push arms way out to sides with arms straight. Repeat 5 times.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	poor	chair	highly	micro	simple	f

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51	Joyce & Peterson	Trapezius Squeeze	Raise arms up and to the sides, with palms facing out. Squeeze shoulder blades together and hold 3 sec. Relax. Repeat 2 more times.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	good	chair	highly	micro	simple	f
52	LA Times	Shoulder Blade	Bring head into Turkey Position (see exercise 5). Hold arms up, elbows bent, with palms facing forward at shoulder height. Pull hands back as if to touch little fingers together. Repeat 3-5 times.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	fair	chair	somewhat	micro	simple	f
53	Joyce & Peterson	Executive Stretch	Lock hands behind head and bring elbows back. Lean back in chair, stretching and arching spine. Hold to count of 3. Relax. Repeat twice.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators, cervical and thoracic extensors	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	good	chair	somewhat	mini	simple	a d f
54	Pragier	Exercise a-2	Hands behind head, tuck chin in and push the back of the head into the hands. Hold that position for a count of 3; relax.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators, cervical and thoracic extensors	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	fair	chair	somewhat	micro	simple	a f
55	Austin	Pectoral Stretch	Grasp hands behind neck and press elbows as far back as possible. Relax. Repeat.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators, cervical and thoracic extensors	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	good	chair	somewhat	micro	simple	a f
56	Dahl	Unnamed	Interlace fingers, turn palms forward, raise arms above head, lower them behind the neck, then down in front of the body again.	Scapular adductors, upward rotators, shoulder flexors and abductors, arm extensors, cervical and thoracic extensors	Scapular abductors, downward rotators, shoulder internal rotators, horizontal and vertical adductors, extensors and internal rotators, scapular adductors, downward rotators	*	chair	somewhat	micro	simple	f i j 1 3
57	Pragier	Exercise b-2	Rotate both shoulders backwards, keeping arms relaxed by sides.	Scapular upward rotators and adductors	Scapular downward rotators	good	chair	somewhat	micro	simple	
58	Pragier	Exercise b-3	Clap hands in front of body, keeping elbows bent and tucked in by sides.	Shoulder external rotators, scapular adductors, downward rotators	Shoulder internal rotators, scapular upward rotators	good	chair	highly	micro	simple	f
59	Gore and Tasker	Triangle	With arms by sides, turn palms outward and move arms backward as far as possible. Hold for count of 10. Relax. Repeat 3 times.	Shoulder external rotators, scapular adductors, downward rotators, horizontal adductor	Shoulder internal rotators, scapular upward rotators, anterior chestwall	good	chair	somewhat	mini	simple	f 3
60	Pragier	Exercise b-1	Pull shoulders back, arms at sides. Hold for count of 3.	Cervical and thoracic extensors, scapular adductors, elevators and upward rotators	Anterior ligaments of the lower thoracic spine, anterior chestwall	good	chair	no	micro	simple	

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Table 1. Panel B. Shoulder Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
61	Sauter	Upper Arm Relaxer	Slowly open and spread arms to sides as when stretching and yawning. Fold arms back toward body tightly. Repeat a few times.	Shoulder external rotators, scapular adductors, downward rotators, shoulder internal rotators, scapular abductors, horizontal abductors and adductors	Shoulder internal and external rotators, scapular upward rotators	fair	chair	somewhat	micro	simple	f 3
62	Pragier	Exercise a-4	Bring arms over the back of the chair with the hands clasped. Stretch arms down towards the floor. Hold for a count of 3 then relax.	Scapular adductors, downward rotators	Scapular upward rotators	fair	chair	somewhat	micro	moderately difficult	d f
63	Sauter	Shoulder Blade Pinch	Move forward slightly in chair. Place hands on edges of chair behind buttocks and try to touch elbows together behind back. Relax and repeat a few times.	Scapular adductors, downward rotators	Scapular upward rotators and abductors	good	chair	somewhat	micro	simple	d f
64	Pragier	Exercise b-6	Push arm forward at shoulder height with the hand stretched out. Repeat with the other arm.	Scapular adductors and downward rotators, shoulder extensors, elbow flexors, wrist extensors, scapular abductors and upward rotators, shoulder flexors, elbow extensors	Scapular abductors and upward rotators, shoulder flexors, elbow extensors, wrist flexors, scapular adductors and downward rotators, elbow flexors	fair	chair	highly	micro	simple	f 1 3
65	Austin	Upper Back Stretch	Sit with hands on shoulders. Try to cross elbows in front. Relax. Repeat.	Scapular abductors, shoulder horizontal adductors, and external rotators	Scapular adductors, shoulder horizontal abductors and internal rotators	good	chair	highly	micro	simple	f 1 3
66	Austin	Middle-Upper Back Stretch	Hold right arm just above elbow with left hand. Gently pull elbow toward left shoulder. Hold 5 seconds. Repeat other side.	Scapular abductors, shoulder horizontal adductors	Scapular adductors, shoulder horizontal abductors	good	chair	somewhat	micro	simple	f 1 3
67	Austin	Hug Yourself	Cross arms in front of chest and reach fingertips towards shoulder blades.	Scapular abductors, shoulder horizontal adductors	Scapular adductors, shoulder horizontal abductors	fair	chair	highly	micro	simple	f 1 3

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Table 1. Panel C. Elbow/Lower Arm Exercises.

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
68	Gore and Tasker	Eiffel Tower	Straighten fingers and spread apart as far as possible. Bring whole length of fingers together, but keep palms as far apart as possible. Hold for count of 10. Relax. Repeat 3 times.		Finger flexors, anterior ligaments of the MP joints, finger adductors	poor	chair	somewhat	mini	simple	i j
69	Australian National University	Exercise 12	Raise arms above head with palms and heel of hands together. Slowly pull hands down in front of chest with hands together. Repeat 5-10 times.	Shoulder flexors, abductors and external rotators	Finger flexors, anterior ligaments of the finger joints, shoulder extensors, adductors and internal rotators	good	chair	highly	mini	simple	i j
70	Gore and Tasker	Palm Press	Place palms together, point fingers to ceiling. Keeping palms together, try to push heels of hands towards floor and hold for count of 10.		Finger flexors, anterior ligaments of the finger joints	fair	chair	somewhat	micro	simple	i j
71	Dahl	Unnamed	Place palms together and press one hand backwards with the other. Change hands.		Finger flexors, anterior ligaments of the finger joints	*	chair	somewhat	micro	simple	i j
72	Austin	Wrist Flex	Put elbow on table with hand raised. With other hand, hyperextend wrist so that the back of the first hand is aiming to the top of the forearm. Repeat with opposite hand.		Finger flexors, anterior ligaments of the finger joints	fair	chair	somewhat	micro	simple	j
73	Krames Comm.	Wrist Flex	Put your right elbow on a table, hand raised. With your left hand, gently bend your right hand back toward the forearm. Hold 5 seconds. Repeat on the other side.		Finger flexors, anterior ligaments of the finger joints	good	chair	somewhat	micro	simple	i j
74	Dahl	Unnamed	Bend wrist backward. With other hand, grasp tips of fingers and pull hand backward. Repeat with other hand.		Finger flexors, anterior ligaments of the finger joints	*	chair	no	micro	simple	i j
75	Joyce & Peterson	Thumb Stretch	Stretch right hand out. Gently pull the thumb down and back. Hold 5 sec. Relax and repeat 2 times. Repeat with left hand.		Thumb flexors and adductors	fair	chair	somewhat	mini	simple	i j
76	Krames Comm.	Wrist	Hold hands in front of body. Raise and lower hands to stretch muscles in forearm. Repeat several times	Wrist/finger extensors, shoulder flexors	Wrist extensors and flexors	poor	chair	somewhat	micro	simple	f i 1 3 Arm extension may actually increase neck/shoulder strain.
77	Australian National University	Exercise 9	Lift arms forward, slowly clench fists, open and spread fingers. Repeat 10-20 times.	Finger flexors and extensors, shoulder flexors	Finger flexors and extensors	good	chair	somewhat	mini	simple	f i 1 Arm extension may actually increase neck/shoulder strain.
78	Krames Comm.	Finger Fan	Hold hands out in front of body, palms down. Spread fingers apart as far as possible. Hold for 5 seconds, then make a tight fist. Repeat 3 times.	Finger flexors and extensors, finger abductors	Finger flexors and extensors, finger adductors	good	chair	somewhat	micro	simple	i j 1 3

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Table 1. Panel C. Elbow/Lower Arm Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
79	Dahl	Unnamed	Spread and stretch fingers as much as possible, then make a fist.	Finger flexors and extensors, finger abductors	Finger flexors and extensors, finger adductors	*	chair	no	micro	simple	i j 1 3
80	Austin	Fingers	With palms down, spread thumb and fingers as far apart as possible. Hold for count of 5. Relax. Repeat.	Wrist/finger extensors, finger abductors	Finger flexors, finger adductors	good	chair	no	micro	simple	i j
81	Sauter	Palm Push-Ups	Place tops of hands under front edge of worktable. Push up with hands (not arms) for a moment. Then place palms in similar position on top of desk and push down. Drop hands to sides and wiggle hands a bit. Rest in lap for a few seconds.	Finger extensors, wrist extensors		good	chair	no	micro	simple	k
82	Australian National University	Exercise 10	Lift arms forward, circle hands at wrist, then reverse. Drop hands to sides, repeat circling. Raise arms above head, repeat circling. Do 5 times each direction, each position.	Wrist flexors, wrist/finger extensors, forearm supinators/pronators, wrist ulnar and radial deviators, shoulder flexors, abductors and external rotators	Wrist flexors, wrist/finger extensors, forearm supinators/pronators, wrist ulnar and radial deviators, shoulder extensors, adductors and internal rotators	good	chair	highly	mini	simple	f i j k 1 3 May increase joint stress in the wrist. Arm extension may actually increase neck/shoulder strain.
83	LA Times	Forearm Stretch	Bend elbow so palm is facing forward. Make fist. Bend wrist so palm surface points to floor. Turn hand so it points away from body, then straighten forearm and turn arm inward. Hold 15 seconds. Repeat 3-5 times.	Wrist/finger flexors, forearm pronators	Wrist/finger extensors, forearm supinators	fair	chair	somewhat	mini	simple	i j k 1 3
84	Australian National University	Exercise 11	Bend wrist and fingers of one hand towards palm, applying pressure with other hand. Repeat with other hand. Do 5-10 times.		Wrist extensors	fair	chair	no	mini	simple	i j
85	Sauter	Finger Curls	Holding forearms outstretched in front, bend fingers (not hands) downward and curl them into a fist. Open fist and bend fingers up slightly. Repeat once or twice. Return fingers to neutral position and stretch them apart. Drop arms and hands to sides and gently wiggle them about for a moment. Return hands to lap and rest them for a few seconds.	Finger flexors and extensors	Finger flexors and extensors	good	chair	somewhat	micro	simple	i j 1 3

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Table 1. Panel D. Lower Back/Hip Exercises.

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
86	Sauter	Back Arch	Move forward slightly in chair and place hands on edges of chair. Straighten up slowly, raising chest up and out. Hold momentarily. Relax. Repeat a few times.	Upper cervical, thoracic and lumbar extensors, scapular adductors, elevators and upward rotators, neck flexors	Upper cervical extensors Phase II: anterior ligaments of the upper cervical, thoracic and lumbar spine	good	chair	somewhat	micro	simple	a b d f l
87	Austin	Knee Kiss	Sit in chair. Pull one leg to chest, grasp with both hands and hold for count of five. Repeat with opposite leg.	Arm flexors, shoulder extensors	Hip extensors, lower cervical and thoracic extensors and posterior ligaments of the cervical, thoracic and lumbar spine	good	chair	highly	mini	difficult	b c d e f l l m 2 4 Rolling chair potentially hazardous. Difficult to perform in most office attire, or for obese individuals.
88	Krames Comm.	Legs	Grasp shin of one leg and pull slowly toward chest. Hold 5 sec. Repeat several times with both legs.	Arm flexors, shoulder extensors	Hip extensors, lower cervical and thoracic extensors and posterior ligaments of the cervical, thoracic and lumbar spine	good	chair	highly	mini	difficult	b c d e f l l m 2 4 Rolling chair potentially hazardous. Difficult to perform in most office attire, or for obese individuals.
89	Austin	Back Relaxer	Sit on chair. Drop neck, shoulders and arms, then bend down between knees, as far as possible. Return to upright position. Straighten out and relax.		Thoracic and lumbar extensors, posterior ligaments of the thoracic and lumbar spine	good	chair	highly	mini	simple	b c d e 1 2 3 Awkward to perform. Rolling chair potentially hazardous. Difficult to perform in most office attire. Difficult to perform for obese or pregnant individuals.
90	Krames Comm.	Lower Back Stretch	Lower head and slowly roll body as far as possible toward knees. Hold for 10 seconds. Push self up with leg muscles. Repeat 3 times.		Thoracic and lumbar extensors, posterior ligaments of the thoracic and lumbar spine	fair	chair	highly	mini	moderately difficult	b c d e 1 2 3 Awkward to perform. Rolling chair potentially dangerous (as noted in brochure). Difficult to perform for obese or pregnant individuals.
91	Lee and Waikar	Bending	Bend trunk forward as far as possible, letting arms hang loose. Stretch trunk back, placing hands on small of back.		Phase I: Thoracic and lumbar extensors, posterior ligaments of the thoracic and lumbar spine, hip extensors and knee flexors (hamstrings) Phase II: Anterior ligaments of the lumbar spine and hip joints, trunk and hip flexors	good	work area	highly	mini	moderately difficult	b c d e 1 2 3 Awkward and difficult to perform for obese or pregnant individuals.
92	Dahl	Unnamed	Sit forward in chair. 1) Slump forward, 2) straighten up and arch back, then slump forward again.	Neck flexors Phase II: Lower cervical, thoracic and lumbar extensors	Phase I: Lower cervical, thoracic and lumbar extensors, scapular adductors, elevators and upward rotators, posterior ligaments of the cervical, thoracic and lumbar spine Phase II: Upper cervical flexors, anterior ligaments of the lower cervical and thoracic spine	*	chair	no	micro	simple	a b c d e 1 3
93	Joyce & Peterson	Pelvic Tilt	Sit straight in chair. Tighten abdominal muscle. Slowly tilt pelvis by pressing waist into back of chair. Hold 3 sec. Relax. Tilt pelvis in other direction by arching back. Repeat 2 more times.	Phase I: Trunk flexors, hip extensors. Phase II: Trunk extensors and hip flexors	Phase I: Thoracic and lumbar extensors, and posterior ligaments of the lumbar and thoracic spine. Phase II: Hip extensors	good	chair	no	micro	simple	b c d e 4 Avoid strong pelvic tilt contractions as they may increase stress to the lumbar discs.

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	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
94	Sauter	Pelvic Tilt	Imagine you have a tail and are trying to tuck it between your legs by tilting the pelvis up. Hold 1-2 sec. Repeat a few times.	Trunk flexors and hip extensors	Posterior ligaments and extensors of the lumbar spine	good	chair	no	micro	simple	b c d e 4 Avoid strong pelvic tilt contractions as they may increase stress to the lumbar discs.
95	Joyce & Peterson	Glute Clench	Sit straight, tighten both buttock and abdominal muscles, hold for 5 seconds. Relax, then repeat 2 more times.	Trunk flexors and hip extensors		fair	chair	no	micro	simple	b c d e 4 Avoid strong pelvic tilt contractions as they may increase stress to the lumbar discs.
96	Austin	Windmill	Sit in chair. Place feet apart on the floor. Bend over and touch right hand to left foot with left arm extended up. Alternate sides repeatedly.	Anterior and posterior trunk rotators, thoracic, lumbar and hip extensors, trunk side benders	Anterior and posterior trunk rotators, thoracic, lumbar and hip extensors, trunk side benders, posterior and lateral ligaments of the thoracic and lumbar spine	good	chair	highly	mini	difficult	a b c d e f i 1 2 3 4 Avoid rapid stretching. Difficult to perform for obese or pregnant individuals. Rolling chair potentially hazardous. Difficult to perform in most office attire.
97	Austin	Trimming the Waist'	Interlace fingers behind neck. Lift right knee and touch left elbow to right knee. Alternate sides 5 times.	Hip flexors, anterior and posterior trunk extensors and rotators	Anterior and posterior trunk rotators, thoracic, lumbar and hip extensors, trunk side benders, posterior and lateral ligaments of the cervical, thoracic and lumbar spine	good	chair	highly	mini	moderately difficult	a b c d e f 1 2 3 4 Rapid stretching not recommended. Rolling chair potentially hazardous.
98	Dahl	Unnamed	Sit forward in chair. Put hands on seat behind body, extend and raise both legs. Relax.	Hip and trunk flexors, knee extensors	Hip extensors and knee flexors (hamstrings)	*	chair	somewhat	micro	moderately difficult	b c d e f i 1 2 3 4 Hip flexors are often already tight as a result of the sedentary nature of VDT work. Rolling chair potentially hazardous.
99	Joyce & Peterson	Knee Raises	Sit upright in chair. Tighten abdominal muscles and raise knees 2 inches. Hold 3 sec. Relax. Repeat 2 times.	Hip and trunk flexors, trunk anterior and posterior rotators		good	chair	somewhat	mini	moderately difficult	b c d e 1 3 4 Hip flexors are often already tight as a result of the sedentary nature of VDT work. Rolling chair potentially hazardous.
100	Austin	Side Stretch	Interlace fingers. Lift arms over head and press backwards as far as possible. Lean to the left, then to the right.	Trunk side benders, shoulder flexors, abductors and internal rotators, scapular adductors, elevators and upward rotators	Trunk side benders, shoulder extensors, adductors and internal rotators, posterior and lateral ligaments of the thoracic and lumbar spine	good	chair	highly	micro	simple	b c d e f i j 1 3 4
101	Australian National University	Exercise 7	Arms by side, creep hand down thigh toward knees. Repeat on other side. Do 5-10 times.	Trunk side benders	Trunk side benders, lateral ligaments of the thoracic and lumbar spine	fair	work area	highly	mini	simple	b c d e i 1 4 Rapid stretching not recommended.
102	Gore and Tasker	Sideways Bend	Standing with arms at sides, bend sideways so right arm goes down right leg. Return to upright and repeat on left side. Repeat 5 times each side.	Trunk side benders	Trunk side benders, lateral ligaments of the thoracic and lumbar spine	good	work area	highly	mini	simple	b c d e i 1 4 Rapid stretching not recommended.
103	Lee and Walker	Side Bending	Bend to left as far as possible, letting left arm hang loose. Repeat on right side.	Trunk side benders	Trunk side benders, lateral ligaments of the thoracic and lumbar spine	good	work area	highly	mini	simple	b c d e i 1 4 Rapid stretching not recommended.

*As the Dahl exercises were translated from Danish to English for the authors, the specificity of the instructions was not evaluated

Key

1 Exercise reproduces physical stresses of VDT work
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a Acute neck pain
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c Moderate to severe osteoporosis
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m Arthritic conditions of the hips and/or knees

Table 1. Panel D. Lower Back/Hip Exercises (cont.).

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
104	Pragier	Exercise b-4	Bend to left and stretch left arm down side. Repeat to right.	Trunk side benders	Trunk side benders, lateral ligaments of the thoracic and lumbar spine	good	work area	highly	mini	simple	b c d e l 1 4 Rapid stretching not recommended.
105	Sauter	Chair Rock	Place feet squarely on floor with hands at side of chair. Rock slowly to left, looking over right shoulder, then to the right, looking over left shoulder. Do several times.	Anterior and posterior cervical, thoracic, and lumbar rotators	Anterior and posterior cervical and thoracic and lumbar rotators, posterior and lateral ligaments of the cervical, thoracic and lumbar spine	good	chair	highly	micro	simple	a b c d 4 May produce moderate loading on cervical discs if performed with forward head posture.
106	Austin	Trunk Twists	Turn at trunk. Turn head in direction of trunk. Twist 3 times in each direction.	Anterior and posterior trunk rotators, shoulder abductors and external rotators, scapular adductors, elevators and upward rotators, neck rotators	Anterior and posterior trunk rotators, posterior and lateral ligaments of the thoracic and lumbar spine, shoulder internal rotators	good	chair	highly	micro	simple	a b c d e f l 1 3 4 Raised arms (as shown in the brochure) produce additional loading on lumbar and thoracic discs.
107	Emanuel and Glonek	Trunk Rotations	Rotate entire upper body in a clockwise direction 3 times. Repeat counter-clockwise 3 times.	Anterior and posterior trunk rotators, trunk side benders, trunk/hip flexors and extensors	Anterior and posterior trunk rotators, trunk side benders, trunk/hip flexors, anterior and lateral ligaments of the lumbar and thoracic spine and hip joints	fair	work area	highly	micro	simple	b c d e l 1 4
108	Australian National University	Exercise 6	Place palms across the small of back, bend and arch spine. (5-10 times)	Abdominals (eccentric)	Anterior ligaments of the lumbar spine and hips, trunk and hip flexors	poor	work area	somewhat	mini	simple	b d e l
109	Gore and Tasker	Disc Reliever	Standing up straight with feet slightly apart, place hands in hollow of back. Focus eyes on a point straight ahead. Bend backwards over hands without bending knees, then straighten up. Repeat 10 times.	Abdominals (eccentric)	Anterior ligaments of the lumbar spine and hips, trunk and hip flexors	good	work area	somewhat	mini	moderately difficult	b d e l
110	Austin	Derriere Firmer	Place hands on chair, feet flat on floor, lift hips and buttocks up. Tighten buttocks and hold for 5 sec. Sit back and relax. Repeat twice.	Hip adductors/extensors, back extensors, scapular adductors, arm and shoulder extensors	Hip/trunk flexors, shoulder flexors	good	chair	highly	mini	difficult	b c d e f l 2 Arm strength limits ability to perform. Rolling chair potentially hazardous. May be difficult for obese or pregnant individuals to perform.

Key

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Table 1 Panel E. Knee/Lower Leg Exercises.

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
111	Dahl	Unnamed	Standing, extend one leg backwards and upwards. Grab foot and pull upwards. Repeat with other leg.		Knee extensors, anterior ligaments of the hip, hip flexors	*	work area	highly	mini	difficult	b c d e m 2 Support should be provided when performing standing portion of the exercise. Difficult to perform in most office attire, or in high-heeled shoes.
112	Australian National University	Exercise 14	Hands on hips, one foot in front of other, rock forward and backward slowly 10-20 times. Repeat with other leg.	Hip abductors and extensors, knee extensors	Plantar flexors, hip flexors and external rotators, anterior ligaments of the hips	fair	work area	highly	mini	moderately difficult	m
113	Dahl	Unnamed	Standing, take long step forward and bend knee. Keep heel of rear foot on floor. Bend front knee joint further to lower body downward. Repeat with other leg.	Hip abductors and extensors, knee extensors	Plantar flexors, hip flexors and external rotators, anterior ligaments of the hip	*	work area	highly	mini	moderately difficult	m 2 Support should be provided. Difficult to perform in most office attire, or in high-heeled shoes.
114	Gore and Tasker	Calf Lengthener	Stand with one leg behind the other in lunge position, keeping heel of back foot on floor, lean forward onto front leg. Hold for count of 10. Repeat 3 times per leg.	Hip abductors and extensors, knee extensors	Plantar flexors, hip flexors and external rotators, anterior ligaments of the hip	good	work area	highly	mini	moderately difficult	m 2 Support should be provided. May be hazardous for individuals with ankle problems. Difficult to perform in most office attire, or in high-heeled shoes.
115	Australian National University	Exercise 8	With one foot in front of other, lean forward from hip, supporting arm on forward thigh. Circle free arm. Repeat other side. Do 5-10 times.	Hip abductors and extensors, knee extensors	Plantar flexors, hip flexors and external rotators, anterior ligaments of the hip	poor	work area	highly	mini	moderately difficult	m 2 Support should be provided. Difficult to perform in most office attire, and in high-heeled shoes.
116	Australian National University	Exercise 13	Standing with hands on hips, place feet apart and rock from side to side, bending alternate knees 10-20 times.	Hip abductors and extensors, knee extensors		fair	work area	highly	mini	simple	m
117	Prager	Exercise b-5	Walk on the spot, letting shoulders and arms hang loose.	Hip abductors and extensors, knee extensors		good	work area	somewhat	mini	simple	m
118	Dahl	Unnamed	Walk up stairs rather than using the elevator.	Hip abductors and extensors, knee extensors, hip flexors, hamstrings		*	extra-work area	no	major	simple	c d m 4
119	Prager	Exercise b-6	Hop on left foot, then on right foot.	Plantar flexors, knee extensors, hip extensors/abductors		good	work area	highly	micro	moderately difficult	c d e m 4 Exercise creates too much impact through knees, hips and back. Difficult to perform in high-heeled shoes.
120	Emanual and Glonek	Stretching	Stand on tip toes, extend hands as far as possible overhead. Lower arms slowly to side of body, continuing to extend arms as far as possible.	Plantar flexors, knee extensors, scapular adductors and upward rotators, shoulder flexors, abductors, and external rotators, thoracic extensors	Shoulder extensors, adductors and internal rotators, abdominals	fair	work area	highly	mini	simple	f 2 Difficult to perform in high-heeled shoes.

*As the Dahl exercises were translated from Danish to English for the authors, the specificity of the instructions was not evaluated

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Table 1. Panel E. Knee/Lower Leg Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
121	Emanuel and Glonek	Relaxing	Let arms hang loose, try to relax arms, shoulders and knees. Bounce up and down on toes for a few seconds.	Plantar flexors		good	work area	somewhat	mini	simple	2 Difficult to perform in high-heeled shoes.
122	Austin	Strengthen the Quadriceps	Bring legs straight out in front of body in L-shaped position. Hold 5 sec. Relax. Repeat.	Knee extensors, hip flexors, back flexors	Hip extensors and knee flexors (hamstrings)	good	chair	somewhat	micro	difficult	b c d e 1 2 4 Hip flexors already tight as a result of sitting for long periods. Rolling chair potentially hazardous.
123	Dahl	Unnamed	Sitting, extend one leg and flex the foot up and down. Repeat with other leg.	Ankle dorsiflexors, invertors and evertors, knee extensors	Hamstrings	*	work area	somewhat	micro	simple	m
124	Sauter	Leg Reach and Toe Circles	While seated, hold onto chair and raise and extend one leg out in front. Draw a couple of circles in the air with foot, using toe as pointer. Slowly bend knee and bring it about one third of way toward chest. Extend leg again and relax. Repeat exercise with each leg several times.	Ankle dorsiflexors, invertors and evertors, knee extensors	Hamstrings, hip extensors	good	chair	highly	mini	simple	b c d e m 4 May be difficult to perform by obese or pregnant individuals. Difficult to perform in most office attire.
125	Joyce & Peterson	Legs/Ankles/Feet	While sitting, slowly rotate each foot from ankle three times in one direction, then three times in the other. Point toes downward as far as possible. Hold three seconds. Then point toes straight up and hold three seconds. Repeat three times.	Ankle dorsiflexors, invertors and evertors		good	work area	no	mini	simple	
126	Pragler	Exercise a-5	Sitting in chair, lift right leg, hold out straight, then move foot up and down from ankle 10 times. Circle foot to right 10 times, then to left 10 times. Repeat with left leg.	Ankle dorsiflexors, invertors and evertors, knee extensors	Hamstrings	good	chair	no	mini	simple	
127	Sauter	Foot Presses	Sitting erect in chair, press down alternately with ball and heel of right foot several times. Repeat with other foot.	Ankle dorsiflexors, plantar flexors		good	chair	no	micro	simple	

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Table 2. Proportion of exercises, by body part, falling within each of the useability assessment categories.

	Specificity of Instructions			Location			Conspicuousness			Time Requirement			Ease of Performance		
	Good	Fair	Poor	Chair	Work Area	Extra Work Area	No	Some-what	Highly	Micro	Mini	Major	Simple	Mod. Dif-ficult	Difficult
Neck	0.61	0.35	0.04	0.92	0.08	0.00	0.24	0.68	0.08	0.52	0.48	0.00	1.00	0.00	0.00
Shoulder	0.56	0.38	0.05	0.95	0.05	0.00	0.02	0.52	0.45	0.64	0.36	0.00	0.95	0.02	0.02
Elbow/Lower Arm	0.53	0.33	0.13	1.00	0.00	0.00	0.28	0.61	0.11	0.61	0.39	0.00	1.00	0.00	0.00
Lower Back/ Hip	0.78	0.17	0.04	0.68	0.32	0.00	0.16	0.20	0.64	0.40	0.60	0.00	0.60	0.24	0.16
Knee/Lower Leg	0.69	0.23	0.08	0.24	0.71	0.06	0.24	0.24	0.53	0.24	0.71	0.06	0.59	0.29	0.12
All Exercises	0.63	0.31	0.06	0.80	0.19	0.01	0.16	0.46	0.38	0.51	0.48	0.01	0.85	0.09	0.06

all are suitable for performance at the workstation, or even in the workplace. Each exercise was categorized according to the location most suitable for performance. Three categories were utilized: chair, work area and extra-work area.

- *Chair* The exercise can be performed while seated at the workstation.
- *Work area* The exercise can be performed in close proximity to the workstation.
- *Extra-work area* The exercise does not lend itself to performance at the work area due to the required postures, or the inappropriateness of work attire for such an activity.

Conspicuousness This dimension is important because it addresses the issues of modesty and fear of embarrassment. Highly conspicuous exercises may be less likely to be accepted by VDT users, or may not be performed as instructed. Three categories were defined: highly conspicuous, somewhat conspicuous, or not conspicuous.

- *Highly conspicuous* Potentially embarrassing to the user or dramatically different from routine movements.
- *Somewhat conspicuous* Somewhat obvious to others, but socially acceptable and not embarrassing because of the similarity to common movements (eg, spontaneous stretch associated with fatigue).
- *Not conspicuous* Neither obvious nor embarrassing.

Time requirement/disruption of the work process The exercises varied in the amount of time required to perform them, or in the degree to which they could interrupt work. Excessive or repeated disruption of work may interfere with the work rhythm and impair performance, leading to lack of acceptance by employers or individual VDT users. Three categories were defined: microbreaks, minibreaks and major breaks.

- *Microbreak* Very short break required (ie, less than 10–15 s), entailing no significant interruption of work.
- *Minibreak* A break of less than 1–2 min in duration is required; interruption of the work task is usually necessary.
- *Major break* The exercises can be performed only during a formal break from the task/work area lasting several minutes or more.

Ease of learning and performance This dimension refers to the complexity of the exercises, a factor also potentially affecting acceptance and performance of the exercise routine by VDT users. Three rating categories were defined: simple, moderately difficult, or difficult.

Physiotherapeutic assessment

The potential for three types of problems was considered in the analysis of each exercise. The 'Comments' column in Table 1 notes limitations pertinent to these issues (see also Table 3)

Aggravation of pre-existing health conditions Some medical conditions (eg, acute low back pain) may be aggravated by exercise or may limit performance of an

Table 3. Proportion of exercises, by body part, falling within each of the physiotherapeutic assessment categories.

	Reprods physical stresses of VDT work	Stretches over-stretched structures	Places additional loads on discs	Poses one or more safety hazards	Health contra-indications
Neck	0.36	0.44	0.40	0.00	0.72
Shoulder	0.45	0.50	0.05	0.07	0.93
Elbow/Lower Arm	0.39	0.33	0.00	0.00	1.00
Lower Back/Hip	0.60	0.40	0.68	0.36	1.00
Knee/Lower Leg	0.06	0.00	0.23	0.41	0.82
All Exercises	0.40	0.38	0.26	0.15	0.90

exercise. These conditions are noted in the 'Comments' column of Table 1.

Replication/exacerbation of physical stresses associated with the task Some exercises reproduce or exacerbate postural or biomechanical demands of the job. Examples are exercises which stretch spinal muscles and ligaments already overstretched as a result of sitting for long periods in a fixed spinal posture, or wrist hyperextension-flexion exercises which may exacerbate the physical demands of keyboard work.

Safety/therapeutic/performance issues Exercises were also analysed for their potential to create a safety hazard when performed in an office setting (eg, use of mobile office furniture as props), or by certain populations of users (eg, obese or pregnant individuals). Additionally, it was noted when an exercise would be awkward or impossible to perform in typical women's office attire (eg, dress or skirt; high heels).

The usability of physiotherapeutic-safety judgements were arrived at by consensus among the authors. The authors first performed the evaluations individually, then met as a group to resolve any differences. (Each author's area of expertise is as follows: K Lee, biomechanics; N Swanson and S Sauter, office ergonomics; R Wickstrom, biomechanics and physical therapy (RPT); A Waikar, biomechanics; M. Mangum, exercise physiology.)

Results

Nature of the exercises

The exercises were rather unevenly distributed among the classified body parts: neck (n = 25), shoulder (n = 42), elbow/lower arm (n = 18), lower back/hip (n = 25) and knee/lower leg (n = 17). For the most part, the underlying objectives of the evaluated exercises were to relax or stretch chronically tense muscles, to increase flexibility or mobility, and to improve circulation.

Usability and physiotherapeutic assessments

Below is a summary of the usability and physiotherapeutic ratings for the exercises, organized according to targeted body part. The specific rating of each of the 127 exercises on all usability and physiotherapeutic dimensions is presented in Table 1. Tables 2 and 3 give the proportion of exercises receiving each rating within each usability/physiotherapeutic dimension (also organized according to targeted body part).

Implicit in our evaluation is the assumption that those exercises that are least conspicuous, disruptive and most easily performed (preferably at the work station) are most likely to be adopted in a typical office workplace. Our assessment of the utility of these exercises may vary somewhat depending upon employers' willingness to set aside special breaks and places for individual or group exercises by workers. However, even then, some workers may not perform the exercises because of embarrassment or difficulty in performance.

Neck exercises (Table 1, panel A)

Usability assessment There are 25 neck and upper-back exercises designed to offset problems that are very common to VDT operation such as stiffness or soreness associated with long-term shoulder retraction during data entry tasks. All exercises can be performed easily, 61% had good instructions, and all but two (1, 18) can be performed while seated. Approximately half (52%) of the exercises can be performed without significant disruption of the work routine, and most (92%) were judged to be fairly inconspicuous (ie, mimicked natural movements).

Physiotherapeutic assessment Some of the exercises may be somewhat uncomfortable or difficult to perform by individuals with acute neck pain, degenerative disc disease, osteoporosis, etc. Over one third (36%) of the exercises reproduced the physical stresses of VDT work, most further stretching muscles and ligaments which were already overstretched owing to sitting in a flexed spinal posture for long periods of time. Additionally, over one third (40%) of the exercises may place additional loads on already loaded cervical and thoracic discs.

Shoulder exercises (Table 1, panel B)

Usability assessment There are 42 shoulder exercises designed to stretch and relieve tension in the upper back and to enhance the range of motion of the shoulders. Over half (56%) of the exercises have good instructions and all but two exercises (38, 48) can be performed while seated. However, one third (36%) of the exercises are somewhat disruptive of work since they require several minutes to perform, and nearly half (45%) of the exercises were judged to be highly conspicuous. All but two exercises (43, 62) are simple to perform.

Physiotherapeutic assessment Most (88%) of the shoulder exercises may be contraindicated for individuals with acute inflammatory or arthritic conditions of the shoulder (see, for example, Figure 1 (a)). Nearly half (45%) of the exercises reproduce some of the physical stresses of VDT work, primarily in further stretching chronically stretched structures. Three exercises (46–48), all of which require the use of a chair as a prop, pose potential safety hazards because the required exercise movements may cause the chair to roll, or to tip backwards.

Elbow/lower arm exercises (Table 1, panel C)

Usability assessment There are 18 elbow/lower arm exercises, many designed to enhance the flexibility of the fingers and wrists. About half (53%) have good instructions, all can be performed while seated, and many (61%) can be performed without significant disruption of the work routine since they require only a few seconds to perform. Most (89%) of the exercises are inconspicuous or only moderately conspicuous. None are difficult to perform.

Physiotherapeutic assessment Most (83%) of the exercises may be problematic for individuals with hand/wrist disorders owing to the extreme postural angles

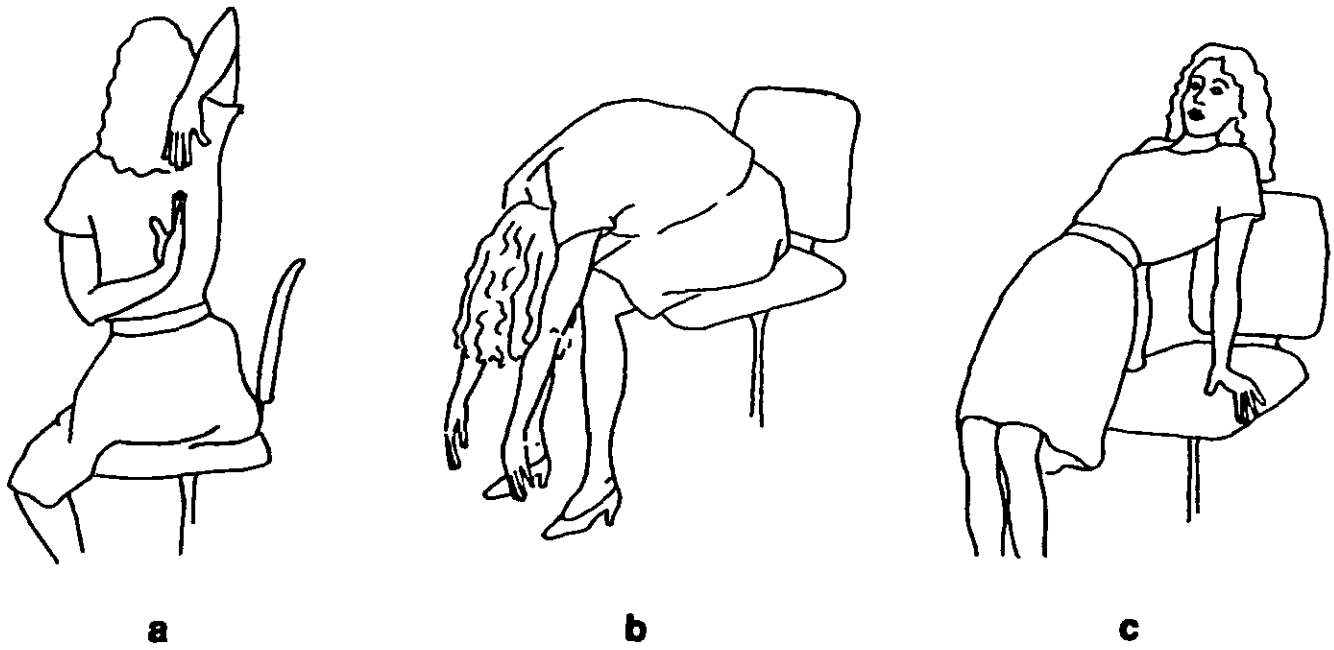

Figure 1 Examples of exercises which (a) had the potential to exacerbate existing health conditions, (b) replicated the stresses of VDT work, or (c) posed potential safety hazards

created in the performance of the exercises. For example, exercises 72–74 require that the wrist of one arm be manually hyperextended with the other hand. Additionally, most of the exercises may be contraindicated for individuals with arthritic conditions of the hands and wrist, and several others (76, 77, 81–83) may be contraindicated for those with lateral epicondylitis or inflammatory conditions of the shoulder. Additionally, three exercises (76, 77, 82) involve static arm extensions of some duration which may actually exacerbate the neck/shoulder strain arising from VDT work.

Lower back/hip exercises (Table 1, panel D)
Usability assessment There are 25 lower back/hip exercises designed mainly to stretch the muscles that act directly on the vertebral column (eg, the erector spinae), and also muscles that act as prime movers elsewhere, but impact on the vertebral column and lower back (eg, the hamstrings). The majority (78%) of the exercises had good instructions. However, many are potentially disruptive owing to time and posture requirements (standing, upper body movement). Nearly two thirds (60%) required a break of several minutes to perform, and 64% were judged to be highly conspicuous. Only four (92–95) were inconspicuous. Over one third (40%) of the exercises are moderately difficult or difficult to perform, especially for obese people, as these exercises involve touching the toes, or lifting the legs to the chest, from a seated position.

Physiotherapeutic assessment All of the exercises may be contraindicated for individuals with low back pain, degenerative disc disease or osteoporosis, or for women in the second or third trimesters of pregnancy, as extreme flexion or extension of the lumbar region is often required. A number of the exercises (60%) reproduce the physical stresses of VDT work, primarily in producing additional loads to the lumbar region (see Figure 1 (b)). Over one third (36%) of the exercises posed safety hazards owing to the potential for an office chair, which is used as a support, to roll while the exercise is being performed (see Figure 1 (c)). Additionally, four exercises (87–89, 96) would be difficult to perform in most women's semi-formal office attire.

Knee/lower leg exercises (Table 1, panel E)
Usability assessment There are 17 knee/lower leg exercises. The primary intent of these exercises is to stretch muscles and to offset poor circulation associated with prolonged sitting and constrained postures. Nearly three quarters (69%) of the exercises had good instructions. However, all would disrupt work to some extent since either minibreaks, a standing posture, or use of both hands is required. Over half of the exercises (53%) are highly conspicuous and 41% are moderately difficult or difficult to perform.

Physiotherapeutic assessment Over half of the exercises (64%) are contraindicated for individuals with arthritic conditions of the hips and/or knees. Additionally, exercises 111 and 113–15 create the potential for a fall if adequate support is not provided during performance, and eight exercises (111, 113–15, 119–121, 124) would be difficult or impossible to perform for individuals wearing high heels or typical women's office attire.

Discussion

In general, the results of this evaluation showed that a considerable number of exercises recommended for VDT users have some features which would facilitate their acceptance and performance in a typical office

workplace. For example, the instructions for the majority of the exercises were clear, and most of the exercises were simple to perform.

The neck and elbow/lower arm exercises had the best overall evaluations on the five usability criteria. Most had clear instructions (58%), could be performed without leaving the chair (95%), were inconspicuous, or mimicked natural body movements (91%), could be performed in a brief period of time (56%), and were simple to perform (100%). On the other hand, the majority of the lower back/hip and knee/lower leg exercises were disruptive because they were highly conspicuous (58%) and/or required interruption of the work task to perform (ie, required standing posture or several minutes to perform). The shoulder exercises were intermediate in that they were judged positively on all the usability criteria except conspicuousness. A large number of the shoulder exercises (45%) were highly conspicuous, primarily because of the arm movements required.

Surprisingly, quite a high proportion (90%) of the exercises may be contraindicated for individuals with one or more acute or chronic musculoskeletal disorders, such as osteoporosis or lower back pain. Individuals with such conditions are advised to seek medical approval before performing these exercises. Of especial concern, however, was the finding that more than a third of the exercises (40%) appeared to reproduce or exacerbate some of the physical or biomechanical demands of VDT work, and that one out of seven exercises posed one or more safety hazards. The majority of these safety hazards were posed by the lower back/hip and knee/lower leg exercises. More than half (60%) of the back/hip exercises, and nearly half (45%) of the shoulder exercises, replicated the physical demands of VDT work, primarily through further stretching of already overstretched muscles of the spine and upper back.

Because the literature shows that musculoskeletal discomfort in VDT/clerical work is particularly acute for the back, neck and shoulder regions[27-29] it is especially important that exercises for these regions satisfy basic design requirements facilitating their performance in the office environment. The present findings are not very promising in this regard. Many of the shoulder and back exercises were highly conspicuous and disruptive of the work process, and thus may meet with resistance by workers. More worrying was the finding that more than a third of the back exercises appeared unsafe to perform, and a sizable number of the neck, shoulder and back exercises (36–60%) appeared to exacerbate, rather than counteract, the physical/biomechanical stresses of VDT work. Apparently, the development of many of these exercises has proceeded without sufficient appreciation for office biomechanical and safety concerns.

While usability and safety criteria should be considered when designing an exercise programme for VDT users, to be fully effective the exercises must additionally combat the full range of musculoskeletal stressors encountered in VDT work. These stressors, and thus the best combination of exercises, will vary to some extent according to the type of task performed. Table 1 was designed to present the results of our analysis in a manner which facilitates the selection of individual exercises for an exercise programme for VDT users. Following an analysis of the task to determine the muscles stressed by task demands, the "muscle groups" and "anatomical structures" columns of Table 1 can be consulted to select exercises to counteract these stressors. For example, Figure 2 illustrates a posture often assumed during VDT work. This posture results in chronically tensed muscles in the shoulders (ie, scapular elevators), forearms (ie, forearm flexors) and chest (ie, anterior thoracic muscles), as well as overstretched muscles of the back (ie, lumbar, thoracic and cervical regions). Table 1 can be consulted to identify exercises which stretch the chronically tensed muscles in the shoulders, forearms and chest, or contract the chronically stretched muscles of the back.

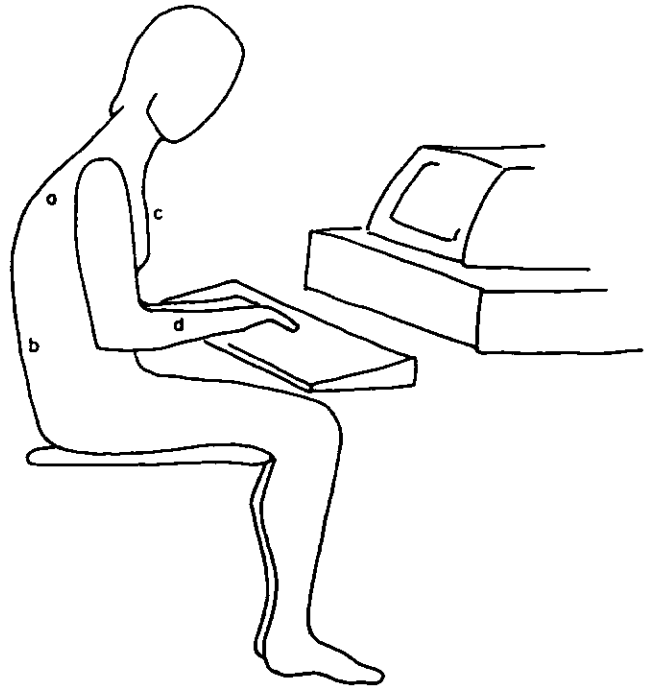

Figure 2 Muscle groups commonly requiring relaxation or activation after periods of continuous VDT work. (a) Chronically tensed scapular elevators require stretching and relaxation. (b) Spinal extensors of the lumbar, thoracic and cervical regions are overstretched and require activation. (c) Muscles of the anterior thoracic region are shortened and require stretching. (d) Forearm flexors are chronically tensed and shortened, and require stretching and relaxation

Regardless of the specific musculoskeletal stressors imposed by a particular VDT task, there are 'generic' stressors common to most VDT work (ie, constrained postures which impart static loads to the neck, back, shoulders and upper extremities, and which impair venous return from the lower extremities). To counteract these generic stressors, any exercise programme for VDT users should include the following components:

1 stretching of chronically shortened and tensed muscles to improve flexibility and circulation, and to reduce muscle fatigue;

2 mobilization of the spine to help relieve stress on the lower back muscles and reduce compressive forces at intervertebral discs;

3 strengthening or contraction of chronically stretched and weakened muscles to increase resistance to fatigue and discomfort, and to promote better posture;

4 improvement of venous return from lower extremities.

The exercise programmes evaluated here focused primarily on the first of these components (stretching/relaxation), and often failed to address the remainder adequately. There is some evidence that strengthening exercises may be more useful than flexibility/relaxation exercises in preventing musculoskeletal discomfort in VDT users[30]. However, such exercises are likely to be far more intrusive and demanding than flexibility or relaxation exercises, and require special employer-designated breaks and exercise areas.

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