Development and evaluation of an office ergonomic risk checklist: ROSA – Rapid office strain assessment

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ARTICLE INFO

ABSTRACT

The Rapid Office Strain Assessment (ROSA) was designed to quickly quantify risks associated with computer work and to establish an action level for change based on reports of worker discomfort. Computer use risk factors were identified in previous research and standards on office design for the chair, monitor, telephone, keyboard and mouse. The risk factors were diagrammed and coded as increasing scores from 1 to 3. ROSA final scores ranged in magnitude from 1 to 10, with each successive score representing an increased presence of risk factors. Total body discomfort and ROSA final scores for 72 office workstations were significantly correlated ($R = 0.384$). ROSA final scores exhibited high inter- and intra-observer reliability (ICCs of 0.88 and 0.91, respectively). Mean discomfort increased with increasing ROSA scores, with a significant difference occurring between scores of 3 and 5 (out of 10). A ROSA final score of 5 might therefore be useful as an action level indicating when immediate change is necessary. ROSA proved to be an effective and reliable method for identifying computer use risk factors related to discomfort.

1. Introduction

The amount of computer work has dramatically increased in the past 20 years. In 2000, 60% of workers were required to use a computer as part of their job duties, with 80% of those workers reporting that they used a computer on a daily basis (Marshall, 2001; Lin and Popovic, 2003). This number is up from 50% in 1994, and 39% in 1989 (Lowe, 1997). This increasing trend in computer usage in the workplace has not come without a cost to the wellbeing of workers. In a review by Wahlström (2005), the prevalence of musculoskeletal disorders was reported to be between 10 and 62% for all computer workers. Furthermore, since the inception of occupational computer use, there has been a similar increase in the number of musculoskeletal disorders reported (Bayeh and Smith, 1999; Wahlström, 2005).

Musculoskeletal disorders associated with occupational computer use are primarily linked to the upper limbs (Gerr et al., 2002), head and neck (Korhonen et al., 2003; Hagberg and Wegman, 1987), and back (Jensen et al., 2002). Repetitive motion of the fingers, hands and wrists, sustained awkward postures of the wrist and forearm, and contact pressures in the wrist have been proposed as possible mechanisms of injury related to the use of the keyboard and mouse (Village et al., 2005). Elevated pressure in the tissues surrounding nerves in the upper extremities has been shown to increase with sustained non-neutral postures, which may lead to further discomfort and injury (Keir et al., 1999). Mechanisms of injury and discomfort for the back while computing include muscle fatigue, which results from increased levels of erector spinae activation when sitting as compared to standing (Callaghan and McGill, 2001), as well as improper sitting posture contributing to a lack of support while sitting (Keegan, 1953; Harrison et al., 1999).

Graphics-based checklists are commonly used to perform ergonomic analyses, specifically in jobs that feature low intensity, repetitive work, or require workers to perform awkward postures (McAtamney and Corlett, 1993; Hignett and McAtamney, 2000; Karhu et al., 1977). The Rapid Upper Limb Assessment (RULA) tool has previously been used to examine worker interactions with a computer in an office environment (McAtamney and Corlett, 1993; Lueder, 1996; Robertson et al., 2009). Hazardous postures, such as wrist extension or radial or ulnar deviation (Serina et al., 1999) can be directly attributable to the use of improper office equipment and equipment setup. However, the direct influence of office equipment (e.g. chair, telephone and monitor) on the worker is not necessarily identified using RULA. The Office Ergonomic Assessment tool (OEA) (Robertson et al., 2009) offers an alternative approach for assessing the office using a checklist format. While the

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OEA is as an excellent method for measuring workstation adjust-ability and worker training outcomes, it doesn't result in outcomes that have been directly correlated with worker discomfort, nor are there scoring or action levels like in RULA that indicate when further intervention is required. Other risk assessment methods have aimed to quantify risk factors related to repetitive upper limb tasks, including the Quick Exposure Checklist (Li and Buckle, 1999) and the Assessment of Repetitive Tasks tool (Health and Safety Executive, 2010). A strength of both of these tools is the estab-lished action levels which direct the user to the urgency and extent of the intervention required to eliminate risk factors for this task. Although neither of these tools feature risk factors that are specific to office work, they have shown good sensitivity and reliability (Li and Buckle, 1999).

Traditional approaches to office ergonomic risk management, training and assessment have come in the following forms: litera-ture, ergonomic redesign, individual assessment and group training (Bohr, 2002). Ideally, an ergonomic redesign of the entire work-space is the most effective method of intervention if the goal is to completely eliminate risk factors in the office environment instead of just control them. However, this approach is very costly and time intensive. With respect to cost, the next best approach is to provide training to workers, and then allow them to actively make adjust-ments to their workspace (Bohr, 2002). However, in certain situa-tions, workers may not be able to make adjustments (due to non-adjustable furniture, space constraints or a lack of equip-ment). Consequently, ergonomic redesign or equipment purchase may be the only option to eliminate hazards from the workstation. Traditional ergonomic assessments may highlight risk factors, and possible solutions, but do not provide a clear picture of how to prioritize the risks and allow for the most effective solutions to be purchased or implemented. This problem is amplified as the number of employees and workstations in a given office environ-ment that would benefit from new products increases. A combined approach of workers receiving adjustable furniture, followed by training to use the furniture, appears to be the most effective method of reducing musculoskeletal disorder symptoms (Amick et al., 2003). In order to prioritize risks in the office to identify who should receive furniture or other equipment first, a quantifi-able method must be used to indicate which problem areas pose the greatest risk, and how urgently these risks need to be addressed.

Therefore, the purpose of this study was to develop and evaluate a new office risk assessment tool, the Rapid Office Strain Assess-ment (ROSA), that can quickly quantify risks associated with each component of a typical office workstation, and provide information to the user regarding the need for change based on reports of discomfort related to office work.

2. Methods

2.1. Tool development

The Rapid Office Strain Assessment (ROSA) was created using postures that were described in the CSA Z412 guidelines for office ergonomics (Canadian Standards Association (CSA), 2000) and on the Canadian Centre for Occupational Health and Safety website (Canadian Centre for Occupational Health and Safety (CCOHS), 2005). The CSA standards were developed by a panel of experts (from both the professional and academic domains) in Canadian ergonomics. This document was thoroughly reviewed until a consensus on proper workstation setup was reached. CSA standard Z412 is based on ISO Standard ENISO9241: Ergonomic requirement for office work with visual display terminals (International Standards Association, 1997). References such as

Ergonomic Design for People at Work (Eastman Kodak Company, 1983) and *Work Related MSD: A Reference Book for Prevention* (Hagberg et al., 1995) served as further guidance for the production of these guidelines. These documents outline information on identifying the unique characteristics of office work, achieving a fit between furniture and the worker, and optimizing the design of the workstations and jobs. All postures that were described as ideal or neutral in the CSA standards were given a score of 1 and became the minimum score for each area within the sub-sections of the tool (see below) (Fig. 1). Deviations from the neutral postures were scored in a linearly increasing manner from values of 1 to 3. Certain factors that could be used concurrently with base risk factors (for example, chair height and chair height adjustability) were given scores of +1. These scores can be added to the base section scores. Risk factors were grouped into the following areas: chair, monitor, telephone, keyboard and mouse. In each of these areas, the maximum score that can reasonably be achieved is tallied and set as the highest possible value on the developed scoring charts (Fig. 1).

The scoring charts were developed by matching two office sub-sections against each other in order to get a complete score for that area. These sub-sections were seat pan height and seat pan depth, backrest and arm supports, monitor and telephone, and keyboard and mouse. The maximum scores from each of the sections were used as the horizontal and vertical axes for the sub-section scores (which were subsequently used to create the ROSA final score). The scores from the monitor and telephone, and keyboard and mouse are then compared in another chart to receive the peripheral score. The ROSA final score is derived by comparing the peripheral chart against the chair score (Section 2.2).

A draft of the completed ROSA tool was given to 5 expert reviewers that worked as professional ergonomists. All of the experts had at minimum, a master's degree in kinesiology with specific focus in ergonomics and biomechanics. Consequently, the experts had specific knowledge regarding ergonomic tool use and development and considerable background in postural assessment and biomechanics. Additionally, all experts had extensive experi-ence in the field of ergonomic consulting, specifically related to office work, and were selected for participation in this study because of their overall expertise related to office work assessment and tool use. The experts were given a training package that out-lined how ROSA was to be used and detailed breakdowns of each of the scoring sections and scoring charts. The experts were told to use the tool and provide feedback on or report any issues with the images selected in the tool, the individual posture scores, or any of the scores within the charts. The feedback from the individual reviewers was then collated, and changes were made to the tool via consensus.

2.2. Creation of scoring charts

The design of the section A, B, C, peripheral and final score charts in ROSA (Fig. 2) is reflective of the increasing values (related to risk level) found within the head/trunk/neck and grand score charts in RULA (McAtamney and Corlett, 1993). The scores used to select values along the axes in these scoring charts are achieved by summing the values associated with the individual risk factors in the specific sub-sections (chair components, monitor, telephone, mouse and keyboard) (Fig. 1). The maximum possible score that can be achieved for the sub-sections is reflective of the presence of all possible risk factors, as well as the maximum duration of use value (Section 2.3.7 below). Within the chair scoring chart and the peripherals scoring chart, the highest possible score that can be achieved is a score of 10. This is also the case in the final score chart. The value of 10 was chosen to provide users with an easy to
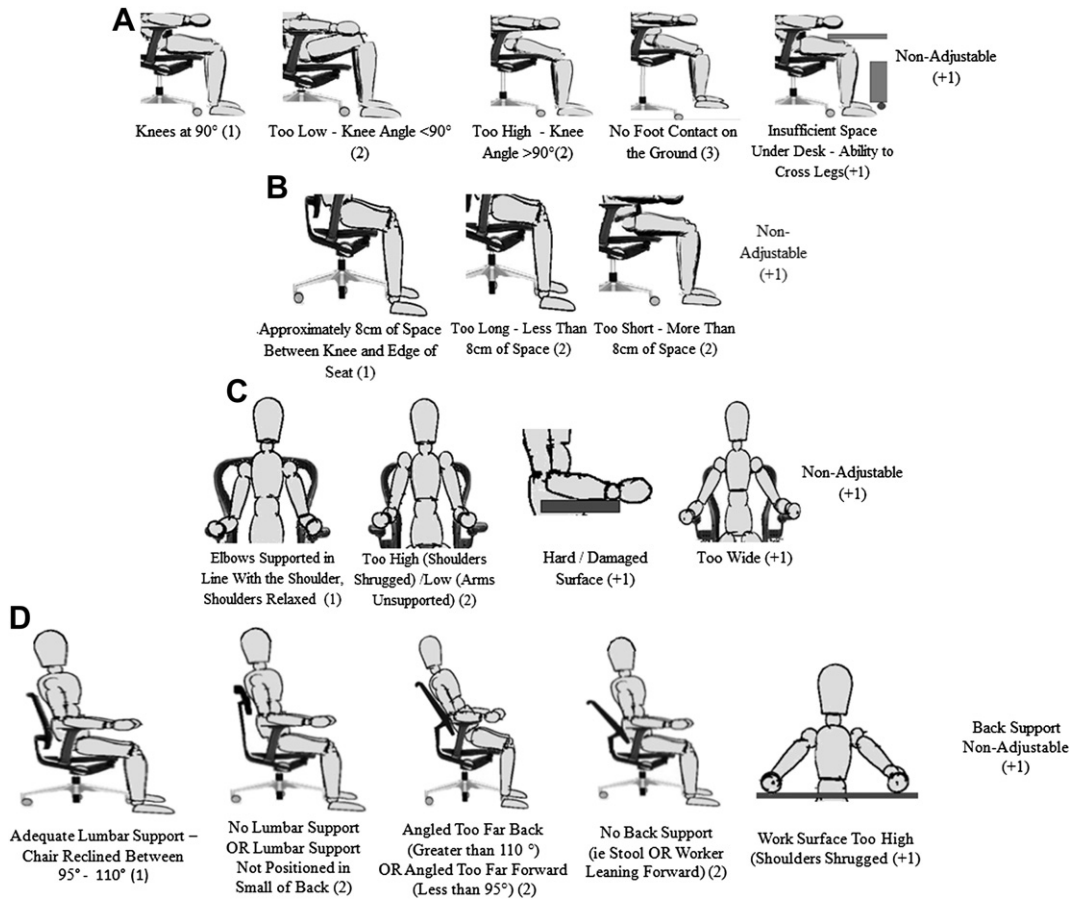
Fig. 1. Scores and diagrams for the risk factors associated with seat pan height (A), seat pan depth (B), armrest (C) and back support (D).

understand 1–10 scoring system that would reflect the amount of risk that was present in the workstation.

2.3. Individual posture and equipment scores

The scores for each risk factor were modelled after deviations from the neutral posture, as cited by the CSA standards on office ergonomics (CSA International, 2000). The deviations are also supported as risk factors for the onset of musculoskeletal disorders based on supporting literature, as well as information contained within the CSA standards.

2.3.1. Office chair scores

As indicated in CSA standard Z412 (CSA International, 2000), the neutral seated posture for an individual is to have the knees bent at approximately 90° with the feet flat on the floor. Risk factors related to the chair being too high include impinged blood vessels in the thigh, which lead to the legs (Tichauer and Gage, 1978), and the worker adopting a posture where they sit on the edge of the chair, increasing lower back muscle activity (Harisinghani et al., 2004). If the chair is too low, there may be excessive pressure under the buttocks, as well as unnecessary spinal lean and pelvic rotation that compromises the lumbar spine curve (Harrison et al., 1999).
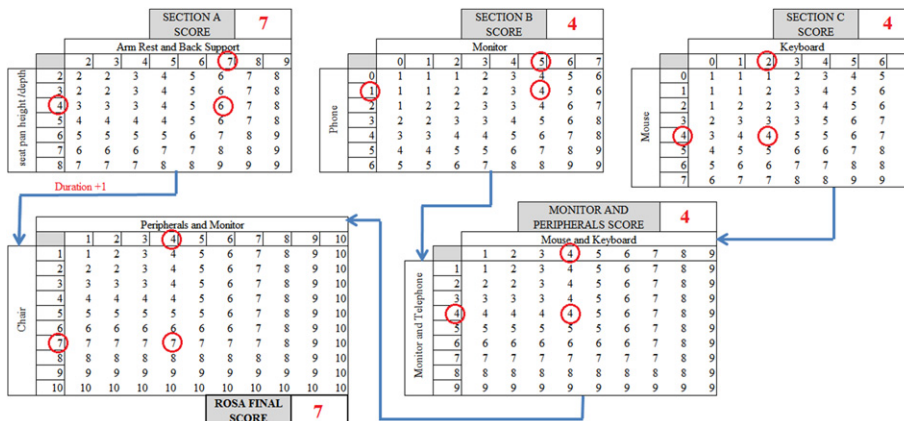

Fig. 2. Scoring charts for sub-sections (A, B and C), monitor and peripherals score, and ROSA final score, as well as a scoring example.

The seat pan should allow for approximately 5 cm–7 cm of space between the back of the knee and the edge of the chair (CSA International, 2000). If the seat depth is too long, the backrest will not support the lower back, and the resulting rearward curvature of the spine may lead to discomfort (CSA International, 2000; Harrison et al., 1999). Additionally, if the seat pan is too short, pressure will be placed on the back of the thigh, compressing blood vessels and nerves (Tichauer and Gage, 1978).

The armrests should be positioned so the elbows are at 90° and the shoulders are in a relaxed position (CSA International, 2000). The presence of armrests on a chair has also been reported to increase comfort in users (Hasegawa and Kumashiro, 1998), and reduce the static loading on the shoulder and arm muscles during mousing (CSA International, 2000; Lueder and Allie, 1997). It is important that the armrest be free of sharp or hard edges, as this may cause pressure points leading to damage to the soft tissues in the forearms (Szabo and Gelberman, 1987).

The lumbar support should be adjusted to fit in the small of the back in order to maintain the natural curve of the lumbar spine (CSA International, 2000). Without proper lumbar support, the lumbar spine loses the natural lordotic curve, increasing the strain on the ligaments, tendons and muscles in the back (Harrison et al., 1999). The worker should be sitting reclined at approximately 95–110° (CSA International, 2000). The incline level of 110° provides a reasonable compromise between the decrease in lumbar muscle activity and a reduction of reaching for office equipment (Harrison et al., 1999).

The chair section was partitioned into 4 smaller sub-sections: the seat pan height, the seat pan depth, the armrest position and the back support position. The risk factors and associated scores and diagrams for each of these sub-sections are outlined in Table 1 and Fig. 1.

2.3.2. Monitor scores

According to the CSA Standards, the monitor should be positioned between 40 cm and 75 cm from the user (CSA International, 2000). The most effective method to determine the proper viewing distance for workers is to instruct them to position the monitor at an arm's length. The user should be able to view the screen while sitting back in the chair. The height of the screen should be positioned at eye level, or just below the worker's seated eye height. The bottom of the screen should be at no greater than 30° below the worker's eye level. Monitor positions lower or higher than this

Table 1
Risk factors (including references) and scores associated with seat pan height, seat pan depth, armrests, and back support. The risk factors and scores correspond to the diagrams in Fig. 2.

Risk factor (reference)	Score
Seat pan height	
• Knees bent to approximately 90° (CSA International, 2000).	(1)
• Seat too low – knee angle less than 90° (CSA International, 2000).	(2)
• Seat too high – knee angle greater than 90° (Tichauer and Gage, 1978).	(2)
• No foot contact with ground (Tichauer and Gage, 1978).	(3)
• Insufficient space for legs beneath the desk surface (CSA International, 2000).	(+1)
• Seat pan height is non-adjustable (CSA International, 2000).	(+1)
Seat pan depth	
• Approximately 7.5 cm of space between the edge of the chair and the back of the knee (CSA International, 2000).	(1)
• Seat pan length too long (less than 7.5 cm of space between the edge of chair and the back of the knee (Tichauer and Gage, 1978; CSA International, 2000).	(2)
• Seat pan too short (more than 7.5 cm of space between the edge of the chair and the back of the knee (Tichauer and Gage, 1978).	(2)
• Seat pan depth is non-adjustable (CSA International, 2000).	(+1)
Armrests	
• Elbows are supported at 90°, shoulders are relaxed (CSA International, 2000)	(1)
• Armrests are too high (shoulders are shrugged) (Lueder and Allie, 1997)	(2)
• Armrests are too low (elbows are not supported) (CSA International, 2000).	(2)
• Armrests are too wide (elbows are not supported, or arms are abducted while using the armrests (Hasegawa and Kumashiro, 1998).	(+1)
• The armrests have a hard or damaged surface – creating a pressure point on the forearm (Szabo and Gelberman, 1987).	(+1)
• Armrests or arm support is non-adjustable (CSA International, 2000).	(+1)
Back support	
• Proper back support – lumbar support and chair is reclined between 95° and 110° (CSA International, 2000)	(1)
• No lumbar support (Harrison et al., 1999).	(2)
• Back support is reclined too far (greater than 110°) (Harrison et al., 1999).	(2)
• No back support (i.e., stool or improper sitting posture) (Harrison et al., 1999).	(2)
• Back support is non-adjustable (CSA International, 2000).	(+1)

Table 2
Risk factors (including references) and scores associated with monitor, telephone, mouse, and keyboard. The risk factors and scores correspond to the diagrams in Fig. 3.

Risk factor (reference)	Score
Monitor	
• Screen at arm's length/screen positioned at eye level (CSA International, 2000)	(1)
• Screen too low (causing neck flexion to view screen) (Burgess-Limerick et al., 1998).	(2)
• Screen too high (causing neck extension to view screen) (Burgess-Limerick et al., 1998).	(3)
• User required to twist neck in order to view screen (Tittiranonda et al., 1999).	(+1)
• Screen too far (outside of arm's length (75 cm)) (CSA International, 2000)	(+1)
• Document holder not present and required (CSA International, 2000).	(+1)
Telephone	
• Headset used/one hand on telephone and neck in a neutral posture, telephone positioned within 300 mm (CSA International, 2000).	(1)
• Telephone positioned outside of 300 mm (Tittiranonda et al., 1999).	(2)
• Neck and shoulder hold used (CSA International, 2000).	(+2)
• No hands free options (CSA International, 2000).	(+1)
Mouse	
• Mouse in line with the shoulder (CSA International, 2000).	(1)
• Reach to mouse/mouse not in line with the shoulder (Cook and Kothiyal, 1998).	(2)
• Pinch grip required to use mouse/mouse too small (CSA International, 2000).	(+1)
• Mouse/keyboard on different surfaces (Cook and Kothiyal, 1998).	(+2)
• Hard palm rest/pressure point while mousing (CSA International, 2000; McMillan, 1999).	(+1)
Keyboard	
• Wrists are straight, shoulders are relaxed (CSA International, 2000).	(1)
• Wrists are extended beyond 15° of extension (Fagarasanu and Kumar, 2003).	(2)
• Wrists are deviated while typing (Gerr et al., 2006; Khan et al., 2009).	(+1)
• Keyboard too high – shoulders are shrugged (Lueder and Allie, 1997).	(+1)
• Keyboard platform is non-adjustable (CSA International, 2000).	(+1)

are associated with increased muscle activity in the neck (Seghers et al., 2003; Turville et al., 1998). The monitor should be positioned directly in front of the worker, as off-centre monitor positions have been show to increase the demands on the neck (Tittiranonda et al., 1999). The risk factors and scores for the monitor are found in Table 2, and the corresponding diagrams associated with the monitor in the ROSA checklist are shown in Fig. 3A.

2.3.3. Telephone scores

The risk factors and scores for the telephone and the corresponding diagrams in ROSA are provided in Table 2 and Fig. 3B, respectively. As shown, the telephone should be positioned within 300 mm of the worker in order to eliminate extensive reaching (CSA International, 2000). Additionally, it is recommended that using a static contraction to hold the telephone headset between the neck and shoulder should be avoided. To accomplish this, it is recommended that the worker use a hands free device, such as speakerphone or a headset.

2.3.4. Mouse scores

The mouse should be positioned so it is in a direct line with the shoulder. The mouse should be positioned on the same level as the keyboard in order to keep the shoulder relaxed. Increasing the amount of reach required to use the mouse is associated with increased muscle activity (Cook and Kothiyal, 1998). It should also not cause the worker to extend or deviate the wrist while moving the mouse, as these wrist postures have been identified as risk factors in other tools used to identify hazards for MSDs in the upper extremities (McAtamney and Corlett, 1993). The mouse itself should accommodate the size of the worker's hand, not creating

a pinch grip or pressure points (CSA International, 2000). Mouse-related risk factors and diagrams are shown in Table 2 and Fig. 3C.

2.3.5. Keyboard scores

The keyboard placement should allow the worker to use the keyboard with the elbows bent at approximately 90° and the shoulders in a relaxed position (CSA International, 2000). The wrists should also be straight. Elevated heights of the keyboard can cause increased upper back and shoulder muscle activity, leading to discomfort (Korhonen et al., 2003; Marcus et al., 2002). The majority of the risk factors associated with keyboard use are a result of the posture of the wrist, which is similar to the wrist-related risk factors of wrist extension (Fagarasanu and Kumar, 2003) and wrist deviation (Serina et al., 1999) found in RULA (McAtamney and Corlett, 1993). Additionally, there should be no hard surfaces that can cause a pressure point on the carpal tunnel, as this may lead to carpal tunnel syndrome (CCOHS, 2005). Table 2 and Fig. 3D depict the risk factors and ROSA checklist diagrams for the keyboard.

2.3.6. Other workstation scores

Other risk factors that did not have their own section were included in specific sub-sections of ROSA based on their mechanical relationships. These were: (1) Reaching to overhead items (+1) was located in the keyboard section (Fig. 3), as it is predominantly an upper limb movement (Tittiranonda et al., 1999); (2) Work surface is too high (+1) was located in the back support section (chair) (Fig. 2) as a work surface that is too high would affect the shoulders and upper back. This risk factor is similar to that of an improper back support that causes a worker to sit forward on the chair. A work surface that is too high may also cause the worker to sit in the chair without back support (Lueder and Allie, 1997).
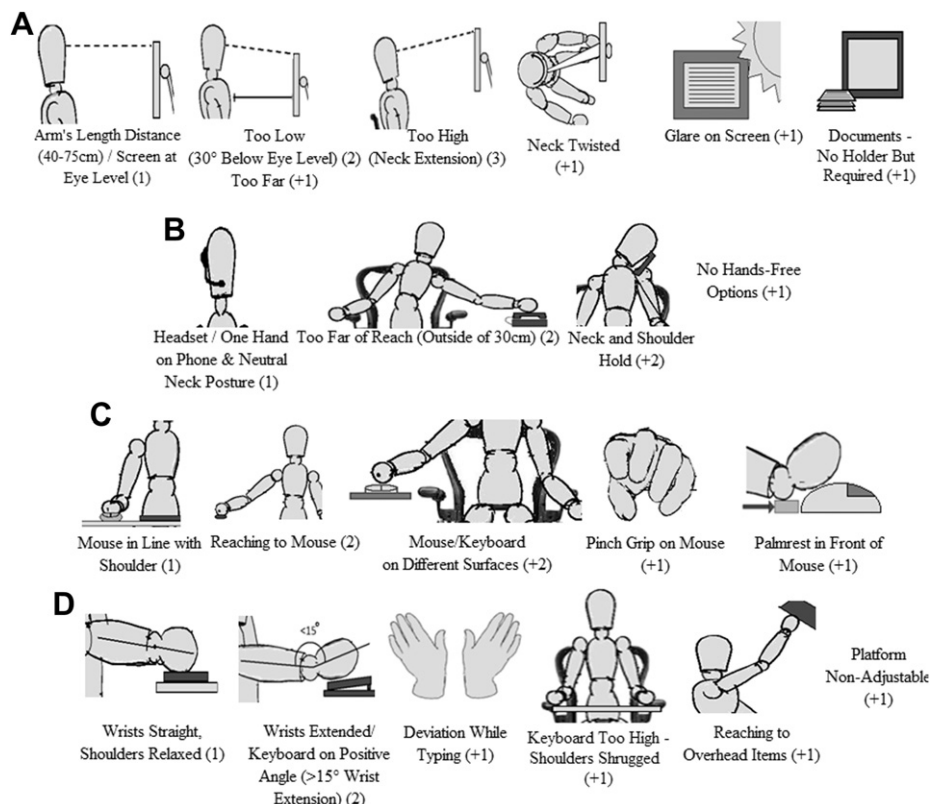

Fig. 3. Scores and diagrams for the risk factors associated with the monitor (A), telephone (B), mouse (C) and keyboard (D).

2.3.7. Duration of use scores

For each section of ROSA, the area score is influenced by a duration score. A significant increase in the prevalence of musculoskeletal disorders in workers that use the computer for greater than 4 h per day has been reported (Blatter and Bongers, 2002). Other studies have indicated that signs of muscle fatigue in the upper extremities may occur within an hour as a result of static contractions under 10% of maximum voluntary contraction (Jorgensen et al., 1988). Office work has been shown to cause workers to exert between 7% and 15% of their maximum voluntary contraction (MVC) in the trapezius muscles (Hagberg and Sundelin, 1986).

After scores are calculated for the chair, monitor, telephone, keyboard and mouse sections, they are modified by a duration score. If a worker uses a piece of equipment for more than 1 h continuously or 4 h per day, the duration score is assigned a value of +1. If the worker uses the equipment for between 30 min and 1 h continuously or between 1 and 4 h per day, then the duration score will be given a value of zero. For less than 30 min of continuous work or 1 h of total work per day, the duration score is given a value of −1.

2.4. Tool use instructions

When using the ROSA, an observer selects the appropriate scores based on the posture of the worker as they are observed at their computer workstation. A brief interview with the worker should also be conducted to understand their work composition. The scores for the seat pan height and pan depth are added together to compose the vertical axis of the "Section A" scoring chart, and the scores for the armrest and back support are combined to compose the horizontal axis of "Scoring Chart A" (Fig. 2). The score from the chair scoring chart is then modified based on the duration score (1, 0, or −1).

The monitor score is achieved by observing the interactions of the user with the monitor and any associated documents. This area score is then modified based on the duration score for monitor use, and the final score for the monitor is used to form the horizontal axis on the "Section B" scoring chart. The telephone interaction score is recorded and modified by the duration value to produce the score along the vertical axis of the "Section B" scoring chart.

Mouse usage is also observed, and the corresponding score recorded based on the user's equipment and work techniques with their cursor control device. The score from the mouse area is also modified based on the duration value for mouse use, and forms the horizontal axis for "Scoring Chart C". Keyboard usage is similarly observed and recorded and modified by the duration value for keyboard use. This score forms the vertical axis for "Scoring Chart C".

The monitor and peripherals scoring chart is used to compare the risk level between the chair and the user's computer input and office peripheral devices. To obtain the monitor and peripherals score, the observer uses the score received in "Section B" as the value for the horizontal axis, and the score received in "Section C" as the value for the vertical axis. This area score is then used as the value on the horizontal axis for the ROSA final score scoring chart (Fig. 2).

To receive the final risk factor score for ROSA, the value from Chart A (the chair) − is used as the vertical axis score on the final score chart, and the value from the monitor and peripherals scoring chart is used as the horizontal axis. This score is a reflection of the overall risk level in the office environment, similar to the grand score presented in RULA (McAtamney and Corlett, 1993). An example of a ROSA assessment can be seen in Table 3, as well as in Fig. 2.

3. Experimental design

3.1. Assessing discomfort relationships in ROSA

Seventy two office ergonomic assessments (7 males, 65 females) were conducted to examine the relationship between the ROSA area and final scores and the workers' reported levels of discomfort. Subjects were recruited from the administrative support staff at a hospital, and fit the inclusion criterion of spending at least 50% of their workday at the computer. Subjects were informed of the experimental procedure (which was approved by the University of Windsor and Hotel-Dieu Grace Hospital Research Ethics Boards), and signed an informed consent form.

In each office assessment, subjects were first asked to complete the Cornell University Discomfort Questionnaire (CUDQ) (Hedge et al., 1999). The CUDQ examines the frequency and intensity of discomfort that a worker experiences and the effects that this discomfort has on workers' productivity. The CUDQ is similar to the Nordic questionnaire (Kuorinka et al., 1987) in the way that discomfort is profiled by body part, and the individual filling out the questionnaire is able to view a diagram of the body as a reference point for identifying their discomfort. This questionnaire has been extensively tested and has been shown to possess high validity and reliability (Erdinç et al., 2008). The frequency of discomfort was coded as − never (0), 1–2 times weekly (1.5), 3–4 times

Table 3
Example of how a ROSA final score is achieved by combining scores from all subsections (also follow flow of scoring charts in Fig. 2).

Risk factors	Score
Chair height	3
• Too high (2)	
• Non-adjustable (+1)	
Chair depth	1
• 75 cm space between back of the knee and the edge of the chair (1)	
Armrests	3
• Armrests too high (2)	
• Non-adjustable (+1)	
Back support	4
• No lumbar support (2)	
• Work surface too high (+1)	
• Non-adjustable (+1)	
Duration	1
• Greater than 4 h per day (+1)	
Section A score	7
Monitor	5
• Too high (3)	
• Documents − no holder and required (+1)	
• Duration − greater than 4 h per day (+1)	
Telephone	1
• Headset/neutral neck posture (1)	
• Duration − between 1 and 4 h per day (0)	
Section B score	4
Mouse	4
• Reaching to mouse (2)	
• Palmrest in front of mouse (+1)	
• Duration − greater than 4 h per day (+1)	
Keyboard	2
• Wrists straight (1)	
• Duration − greater than 4 h per day (+1)	
Section C score	4
Section B − monitor and telephone score	4
Section C − mouse and keyboard score	4
Monitor and peripherals score	4
Section A − chair score	7
Monitor and peripherals score	4
ROSA final score	7

weekly (3.5), once every day (5) and several times daily (10). This score was multiplied by the intensity of the discomfort, which was coded as slightly uncomfortable (1), moderately uncomfortable (2) and severely uncomfortable (3). Finally, the impact on productivity was used as a final multiplier, and was coded as not at all (1), slightly interfered (2), and substantially interfered (3). Therefore, each body part could receive a maximum score of 90. Subjects also reported their age (mean = 45.4 years (SD = 9.1 years)), gender (65 females, 7 males), height (mean = 165 cm (SD = 7.0 cm)), body mass (mean = 71.3 kg (SD = 14.2 kg)), years of experience in their specific job (mean = 8.2 years (SD = 8.3 years)) and years of service to the hospital (mean = 16.6 years (SD = 10.9 years)).

To examine the effects of discomfort on areas that are known to become injured during office work, such as the head and neck (Gerr et al., 2002; Korhonen et al., 2003; Hagberg and Wegman, 1987), shoulder (Borg and Burr, 1997), hands and wrists (Jensen et al., 2002) and lower back (Burdorf et al., 1993; Wilder and Pope, 1996), a discomfort total was created without the leg discomfort scores factored in.

Participants were then allowed to work at their own workstation for approximately 15 min while postures and interactions with equipment were observed. The ROSA scores for the workstation components were recorded on paper, and were later input into a spreadsheet that calculated the ROSA final score. Subjects were asked questions related to how long they would use each piece of equipment continuously and during the entire workday. Assistance was then given to each subject on how to better setup their workstation.

Pearson product moment correlations were calculated to determine the relationship between the various ROSA scores and reported discomfort scores. The cumulative scores for the upper back, shoulders, lower back, thigh and buttocks were correlated independently with the ROSA chair score. The cumulative head/neck and upper back scores were examined in relation to the ROSA monitor and telephone scores. The combined shoulder, upper arm, lower arm and hand/wrist discomfort scores were correlated against the mouse and keyboard ROSA score. Finally, the ROSA final score was correlated against total body discomfort (with and without the leg discomfort included).

3.2. Action levels

Action levels found in the Rapid Upper Limb Assessment (McAtamney and Corlett, 1993) classify the risk associated with a task into one of four categories: posture is acceptable; further investigation is needed and change may be required; investigation and changes are required soon; and investigation and changes are required immediately. To identify which final score values in ROSA are associated with a need to perform immediate change, the mean discomfort scores at each level across the range of ROSA scores were compared using a one-way ANOVA with a Tukey's HSD post-hoc test. Significant increases in discomfort from one ROSA score to another might indicate a change in risk. Such changes in risk could be used as action levels for decision makers based on what office configurations are acceptable and which ones require additional assessment. A sensitivity and specificity analysis was also performed (as per Chu, 1999) to examine positive and negative predictive values with respect to mean discomfort levels at corresponding ROSA final score levels.

3.3. ROSA reliability

To assess inter-observer reliability of ROSA, three trained observers completed evaluations of 14 workstations simultaneously in the participating organization. The observers were all experienced graduate students in ergonomics who had performed office workplace assessments in the past 6 months. Each observer was given a 30 min training presentation that outlined how ROSA was used, and how to identify commonly occurring risk factors. To assess intra-observer reliability, a workstation in a vacant office at the University of Windsor was mocked-up such that each of the three trained observers evaluated it in three different configurations once per week for four weeks. The final scores and the chair, monitor, telephone, mouse and keyboard scores from each observer were examined using the intra-class coefficient (ICC), with two-way random analysis for absolute agreement. Intra-observer reliability was examined using a two-way random analysis ICC for each observer, and average values were reported.

4. Results

4.1. ROSA scores

The mean ROSA final score for the 72 offices analyzed was 4.13 (out of 10). The mean (SD) section scores for the chair, monitor and telephone, and mouse and keyboard were 3.08 (1.02), 2.58 (1.21), 3.65 (1.28) and 4.13 (1.14), respectively.

4.2. Relationships between discomfort and ROSA scores

The body parts reported to have the most significant levels of discomfort were the neck and head (mean 17.7 (SD 24.7)), lower back (mean 11.7 (SD 22.7)) and right shoulder (mean 10.7 (SD 18.8)). The areas with the lowest reported discomfort were the left forearm (mean 1.28 (SD 3.9)), left thigh (mean 1.1 (SD 4.3)) and left upper arm (mean 1.6 (SD 6.13)). The mean discomfort scores for each body part can be found in Table 4.

All correlations between ROSA scores and discomfort were significant ($p < 0.05$), except between chair and chair discomfort, and mouse and keyboard ROSA score and chair discomfort (Table 5). The highest correlation was between total body discomfort (without leg discomfort) and the monitor and phone ROSA score ($R = 0.432$). The total body discomfort (without leg discomfort) and ROSA final score were moderately correlated ($R = 0.384$) (as per Field, 2005).

Mean reported total discomfort scores (without leg discomfort) generally increased between ROSA final scores of 2 and 5. The mean discomfort score at a ROSA final score 5 was significantly more than at a ROSA final score 3, with the largest increase in mean discomfort occurring between levels 4 and 5 of the ROSA final scores (Fig. 4A). A similar trend was seen for the individual areas of chair (Fig. 4B), monitor and telephone (Fig. 4C), and mouse and keyboard (Fig. 4D).

The sensitivity at a ROSA score of 5 was 76%, with specificity measured at 68%. Positive and negative likelihood ratios were measured to be 2.39 (CI: 1.49–3.84) and 0.34 (CI: 0.12–0.93), respectively. The sensitivity increased to 84% at ROSA final score 4,

Table 4
Discomfort profiles for all body parts collected using the Cornell University Discomfort Questionnaire (Hedge et al., 1999).

Mean Discomfort/90 (SD)			
Neck/Head	17.72 (24.46)	Right Hand/Wrist	7.85 (20.12)
Right Shoulder	10.74 (18.68)	Left Hand/Wrist	4.26 (16.18)
Left Shoulder	7.52 (16.64)	Hips/Buttocks	8.83 (21.06)
Upper Back	8.42 (15.62)	Right Thigh	3.15 (13.22)
Right Upper Arm	3.76 (10.28)	Left Thigh	1.13 (4.28)
Left Upper Arm	1.64 (6.13)	Right Knee	5.08 (13.89)
Lower Back	11.70 (22.71)	Left Knee	3.93 (12.99)
Right Forearm	4.09 (12.97)	Right Leg	3.08 (15.53)
Left Forearm	1.28 (3.91)	Left Leg	3.63 (16.47)

Table 5
Correlations between total and area discomfort scores (Cornell University discomfort questionnaire: Hedge et al. (1999)) and ROSA final and area scores.

ROSA Score	Total Discomfort		Area Discomfort		
	With Legs	Without Legs	Chair	Monitor and Telephone	Mouse and Keyboard
Final	0.363*	0.384*	0.341*	0.357*	0.394*
Chair	0.245*	0.281*	0.230	0.300*	0.248*
Monitor and Telephone	0.408*	0.432*	0.247*	0.321*	0.417*
Mouse and Keyboard	0.245*	0.281*	0.228	0.320*	0.366*

*Significant at $p < 0.05$.

however specificity dropped to 45%, and the positive likelihood ratio decreased to 1.56 (CI: 1.14–2.13). The negative likelihood ratio remained was comparable between score 4 and 5 at 0.34 (CI: 0.13–0.88).

4.3. Reliability of ROSA

Inter-observer reliability was found to be strong in general, with ICCs ranging from good (0.74) for the monitor and telephone ROSA score, to excellent (0.83 and 0.91) for the mouse and keyboard ROSA score and the final ROSA score, respectively (Portney and Watkins, 2000). Moderate inter-observer reliability was seen for the chair ROSA score, with an ICC of 0.51. Intra-observer reliability was also found to be excellent with ICCs of 0.80 for the chair, 0.88 for the final score, 0.89 for the mouse and keyboard and 0.95 for the monitor and telephone.

5. Discussion

The goals of developing the Rapid Office Strain Assessment tool were to provide the health and safety professional or ergonomist with a way of quantifying ergonomic risks in the office environment, and provide action levels based on worker discomfort that can serve as screening points between workstations that require further assessment and those that do not. These goals were achieved by establishing significant positive correlations between discomfort and ROSA scores, as well as a proposed action level of 5.

5.1. Relationships between discomfort and ROSA scores

Significant positive correlations were found between the ROSA area and total scores and total discomfort, indicating that increasing ROSA scores are reflective of increasing musculoskeletal discomfort. Correlations between total body pain and increasing RULA scores were also seen in an office environment in a study conducted by Dalkiliniç et al. (2002). Mean discomfort scores were found to generally increase across all levels of the ROSA final score collected, with a significant increase in discomfort scores between level 3 and 5. In other words, a ROSA final score of 5 or greater was found to be associated with a significant increase in worker discomfort, and may indicate an increased potential for injury. The value of 5 as an action level is further supported by balanced sensitivity (77%) and specificity (68%) values when compared to values at ROSA final scores of 4 (85% sensitivity and 46% specificity) and 6 (100% sensitivity and 9.8% specificity). The balance between sensitivity and specificity is important to achieve, as it indicates that the tool will be more effective in distinguishing between false
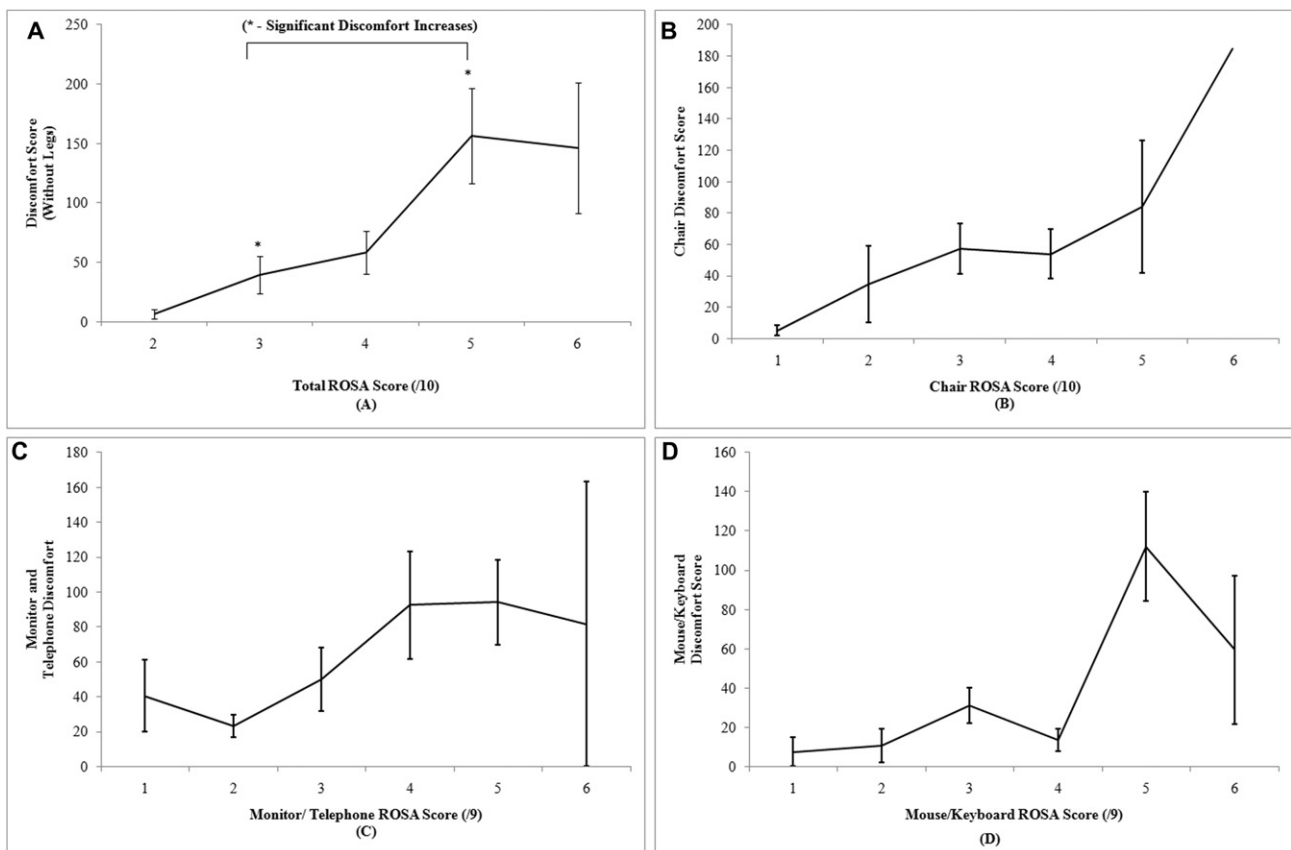

Fig. 4. Localized mean (SE) discomfort scores vs. corresponding ROSA scores: (A) Total discomfort score (without legs) and ROSA final score; (B) Chair discomfort and ROSA score; (C) Monitor/telephone discomfort and Monitor/telephone ROSA score; (D) Mouse/keyboard discomfort and Mouse/keyboard ROSA score.

positives and negatives (Chu, 1999). The likelihood ratio for a score of 5 (2.4) was also higher than at scores of 4 (1.6) and 6 (1.1). A likelihood ratio of greater than 2 has been associated with a significant probability of musculoskeletal discomfort, whereas a ratio of less than 2 is not associated with a significant ability to predict discomfort or outcome (Jaeschke et al., 1994).

Having a discomfort-based action level is important, as it aids in the decision making process for the individual interpreting the ROSA scores. This does not mean that there is no risk associated with scores of less than 5, but that the risk is less. However, if a large scale office intervention is planned, it is recommended that those offices who score 5 or higher be dealt with first. Similar to the action levels found in RULA (McAtamney and Corlett, 1993), the ROSA final score of 5 and greater should be used as the score that indicates an office workstation requires further assessment, and that changes should be considered immediately.

5.2. Reliability of ROSA

Inter-observer reliability was found to be good (ICC > 0.5) for the ROSA final and keyboard scores and excellent (>0.75) (Portney and Watkins, 2000) for the mouse and keyboard scores. Low inter- and intra-observer reliability (ICC < 0.5) was seen for the chair scores, perhaps indicating that a redesign of the images that identified specific postures and equipment conditions should be further investigated. The reliability measures found in the study are similar to those presented for other posture-based tools that have been used to investigate office ergonomic issues (e.g. RULA grand score ICCs between 0.65 and 0.85 (McAtamney and Corlett, 1993); OEA ICCs of 0.91 (Robertson et al., 2009)). The relatively high reliability values found in this study indicate that, with a small amount of training, observers with ergonomic expertise can reliably identify risk factors in the office environment using the ROSA checklist.

5.3. Limitations

5.3.1. ROSA values found during assessment

A full range of ROSA final scores were not observed in this study for several reasons. The low number of scores in the low end of the range (scores 1 and 2) was due primarily to the lack of optimally designed workstations in the workplace evaluated. However, most workstations featured adjustable chairs, and surfaces that varied in height between 66 cm and 81 cm; standard working heights as indicated by CSA standard Z412 (CSA International, 2000). The adjustability of the workstations prevented any ROSA final scores from rising above a level of 7 on the 10-point scale. Although the workstations evaluated in this study did not have enough risk factors present to result in ROSA final scores above 6, scores greater than this are not difficult to obtain. For example, a ROSA final score of 8 would result if the following common conditions were present: chair pan too high so worker could not touch their feet to the ground; there was interference under the desk with the worker's legs; the chair height was non-adjustable; the seat pan length was too long and non-adjustable and the user worked on the computer for 1.5 h consecutively. This scenario is realistic for any worker that is shorter than average and who sits on a non-adjustable chair. Therefore, the limited range of ROSA final scores in this study was directly related to the overall conditions in the particular workplace that was evaluated, and is therefore not a critical limitation of the tool itself.

5.3.2. Reporting of discomfort related to the workstation

Workers were asked to report the discomfort they had while at work over the last week, regardless of what they believed the source to be. This may have led to higher discomfort scores than

were directly associated with the workstation components alone. Furthermore, self-reports of working posture, musculoskeletal discomfort and office work duration have been shown to be over-estimated by workers (Wiktorin et al., 1993; Homan and Armstrong, 2003; Heinrich et al., 2004). While the discomfort scores reported may have been exaggerated, the ease of collecting discomfort data through the use of questionnaires made this method appropriate for this study. Additionally, the practice of using self-reported discomfort questionnaires is consistent with other research conducted in the field of office ergonomics (Hedge et al., 1991; Blatter and Bongers, 2002; Diepenmaat et al., 2004).

5.3.3. Improving the validity of ROSA

While a relationship appears to be evident between worker-reported discomfort and the ROSA final and sub-section scores, discomfort is not the only measure that can be used to establish the validity of the tool. Extensive research has been conducted that has linked increased muscular activity to working postures in the office environment (e.g. Bauer and Wittig, 1998; van Dien et al., 2001; Veiersted et al., 1990; Villaneuva et al., 1998). Future work should include validating ROSA against muscle activation patterns throughout the scoring ranges seen for final and sub-section scores. RULA has been shown to be correlated with discomfort in video display terminal work (McAtamney and Corlett, 1993). To examine ROSA's reliability and validity compared to other tools, future studies could examine the relationship between ROSA scores and RULA scores when examining workstations.

Furthermore, workstations were only assessed by experts with extensive experience conducting office ergonomic evaluations. While research on self-reporting of risk factors related to musculoskeletal disorders has been inconsistent with respect to the tendency of workers to either over or under report risk factors (David, 2005; Heinrich et al., 2004; Homan and Armstrong, 2003), a situation in which workers could self-report ROSA scores would serve as a tremendous screening tool for an office ergonomics program administrator. Other alternative methods of achieving ROSA scores should be examined as well, including the use of photographs and video (compared to observation in person). This could establish how valid and versatile ROSA is in different environmental contexts.

The risk factors that are evaluated using ROSA are those that can be observed by the ergonomist. The relationship between discomfort and ROSA final scores was expressed as a correlation value of $R = 0.363$, which indicates approximately 13% of discomfort is accounted for by increasing ROSA scores. Other research has indicated that there are many other factors at play when examining contributors to reported discomfort, such as job satisfaction, job control and job identity (Kerr et al., 2001). One particular aspect that is not considered by ROSA is the worker's perceived comfort in their chair and office. These factors could account for some of the unexplained variance in the ROSA final score, but they cannot be measured using a purely observational tool, which remains a main goal of this approach.

Other risk factors that will emerge in the modern office environment should be considered in future iterations of ROSA. Items such as the use of dual monitors should be examined for their impact on head and neck discomfort. Seat pan width may also become an issue with the ever increasing obesity of the working population (Hertz and McDonald, 2004), and may also be considered in future research.

6. Conclusions

The Rapid Office Strain Assessment proved to be an effective method of assessing office workstations for risk factors related to

discomfort in the office environment. This initial evaluation has shown high levels of inter- and intra-observer reliability using the ROSA, and a moderate correlation between total body discomfort and ROSA final scores. Further research needs to be conducted with a wider range of ROSA final scores in order to determine if more precise action levels can be established. Determining the relationship between ROSA scores and other outcome measures such as injury incidence may also provide new information that will help establish additional action levels in the tool.

Acknowledgements

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