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Computer workstation ergonomics: Current evidence for evaluation, corrections, and recommendations for remote evaluation



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ABSTRACT

Study Design: Literature Review

Introduction: Computer use in the workplace has increased substantially since the start of the information age in the mid-1980s through 2020. Desktops, laptops, and tablets are essential tools for communication and project management. As a result of the COVID-19 pandemic, many workers have transitioned to work from home (WFH) to sustain public health emergency guidelines, and it is anticipated that many WFH jobs will be maintained post-pandemic. The transition to WFH occurred rapidly without time to establish ideal workstations. Ergonomic assessments that were typically performed in person needed to be performed using virtual technology.

Purpose of the study: The purpose of this review is (1) to describe the components of a computer workstation evaluation; (2) to offer suggestions for identifying computer workstation problems that may be contributing to the client's musculoskeletal (MSK) pain and symptoms; (3) to provide suggestions that may improve the safety and comfort at the computer workstation, and (4) to suggest a method of completing the workstation analysis virtually, without onsite in-person evaluation.

Methods and Results: There is a paucity of peer-reviewed literature regarding computer workstation evaluations to be performed in person, let alone using a virtual method. The components of computer workstation evaluations have been recommended by regulatory agencies that survey injuries in the workplace. Prior to 2020, these evaluations were done in person at the office workstation. Modifications in data collection were needed to transition the analysis to a reliable virtual format. The remote method described provides a consistent approach that engages the client in the process.

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Introduction

Computer use in the workplace continues to increase globally. Home computer use for work and education has also grown during the past decades,¹ as demonstrated by the number of American households with a desktop or laptop computer, which rose from 9%

to 79% between 1984 and 2015.² Prior to the COVID-19 pandemic, only an estimated 10% of the working US population worked from home (WFH).³ WFH was a coveted benefit discouraged by most employers because of cybersecurity concerns,⁴ the cost to set up a home office, and the assumption that optimal job performance required physical presence, until implementation of social distanc-

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Table 1
Risk factors and considerations for office work.^{12,14,15,29,63}

Physical/mechanical	Personal	Psychosocial	Work organizational	Work from home
Abnormal and/or sustained postures	Age	Workplace culture	Workflow	Home distractions
Contact stress	Avocational activities	Employee morale	Lines of command	Individuals and/or pets
Duration of exposure:	Fitness level	Change in work ethics	Decision-making	Environment
Repetition	General health	Work satisfaction	Lines of communication	Less frequent breaks
Long work hours	status	Work stress	Training	Transition time between work and/or home (commute)
Force	Physical attributes			Work and/or home balance
Suboptimal equipment	Mental health			Social interaction
Poor fit of equipment	Status			
Environment: lighting, temperature				

ing caused a sudden and sustained increase in the number of employees WFH since March 2019.⁵ Many US businesses now confirm that, as of Fall 2020, an estimated 75% of their workforce were WFH, and 84% consider this a paradigm shift⁴ that could permanently increase the average number of days WFH from 5% pre-pandemic to as much as 20% post-pandemic.⁶

In both home and corporate settings, the interaction of worker and work method with old, malfunctioning, non-adjustable, or ill-fitting equipment has been associated with some musculoskeletal (MSK) pain and symptoms.^{7–11} The cause of MSK symptoms is multifactorial: medical conditions, physical and biomechanical exposures, work demands and organization, workstation designs, poor postural support, and individual and job-specific psychosocial issues, as listed in Table 1.^{7,9,10,12} COVID-19 has forced a change in work location for many individuals, resulting in additional psychosocial stressors that may interact with physical risk exposure: working with children or a partner at home, reduced opportunity for breaks that would naturally occur in the workplace, and less social interaction. All these factors should be considered to provide a holistic approach to symptom management. However, evidence separating, quantifying, and determining the impact of these issues on MSK pain does not yet exist to the knowledge of the authors at the time this manuscript was submitted, and full discussion of these factors is beyond the scope of the current article. Although some may be outside the domain of hand therapy practice, acknowledgement and discussion of such varied considerations can lead to improved management of work organization, worker equipment interaction, training, and motivation for change,^{13,14} all issues addressed in this review.

The present article focuses on physical risk factors involving computer workstations, remote evaluation of these workstations, possible issues associated with work at the computer, and subsequent solutions. Physical risk factors related to computer workstations that may be linked with MSK symptoms include awkward non-neutral and sustained postures as well as repetitive motions that may increase muscle tension throughout the upper limbs.^{15,16} In an effort to evaluate computer workstations used at home by primary school children in Hong Kong, Szeto et al.¹ utilized a questionnaire about computer use and MSK symptoms with photographs of the workstation to conclude that inappropriate equipment could result in adverse postures in children. The authors provided suggestions about appropriate home computer workstation postures and equipment. While no comparable study of WFH stations for adults is available, it has been suggested that therapists would benefit from more specific information about work-related factors when treating patients with MSK symptoms.¹⁷

Therapists are frequently asked by patients to provide suggestions for the design of computer workstations. They may also be asked to provide industry consultation in corporate or home set-

tings regarding workstation setup, risk factors, and recommendations. In the first situation, the clinician is treating a *patient*. In the second situation, the client may be the employer or the employee requesting evaluation of the workstation and workplace issues and not necessarily the employee seeking specific evaluation and treatment for MSK complaints. In this case, the clinician is dealing with specific needs of a *client*. This distinction is important to ensure that provided services remain within the context of the referral request. For the purposes of this article, the term *client* will be used to denote the person in both a treatment and consultative situations.

As a result of the need to accommodate public health measures, particularly social distancing due to the COVID-19 pandemic, the primary author of this paper developed a virtual process to evaluate computer workstations in a consistent manner by engaging the worker in data collection. The main objectives of this article are to (1) describe the components of a computer workstation evaluation; (2) identify problems related to computer interface that may contribute to the client's MSK pain and symptoms; (3) provide well-reasoned suggestions to improve the computer workstation safety, posture and comfort, and (4) suggest a method of completing the workstation analysis using virtual technology.

Challenges of remote evaluation

Objective data about workstation setup, postures, and performed work tasks are rarely available to clinicians, who may rely primarily on client self-assessment and computer workstation descriptions. Unfortunately, studies^{14,18} have concluded that these methods have low validity, as respondents were not reliably precise about the type of risk exposure and often overestimated risk at computer workstations, particularly if exposure was low relative to duration, force, and severity. COVID-19 social distancing and clinical restrictions limit the clinician's opportunity to perform onsite in-person evaluations, resulting in a greater need to gather reliable, objective data about workstations and work methods by other means in order to provide abatement suggestions to clients.

For example, the Rapid Office Strain Assessment (ROSA) is an effective and reliable tool developed for the use of trained professionals to evaluate computer workstations in the office setting and is based on Canada National Standards for Office Ergonomics and extensive research related to computer and office work.¹⁹ The authors used it to study the validity of employee self-assessment relative to professional evaluation of risk exposure levels,²⁰ finding significant differences between worker ROSA scores and those of trained observers, particularly as related to mouse and keyboard exposure and postures. Liebrechts, Sonne, and Potvin¹⁶ further examined the potential use of the ROSA to de-

Table 2
Data collection sheet: Workstation measurements and requested photographs.

Measurements	Inches
A. Desk Height: from floor to top of desk	
B. Keyboard Support Height: from floor to the top of surface where keyboard sits (may be same as A)	
C. Floor to Elbow Height: from floor to underside of elbow, seated with arm bent 90° (as when keying)	
D. Floor to Eye Height: from floor to eye level, seated	
E. Chair Height: from floor to side of chair seat about halfway between front & back	
F. Monitor Height: from desk surface to top of monitor as shown	
Height adjustable? Yes No	
Armrest Height: (if chair has armrests) from floor to highest point on armrest (do not adjust from normal user position)	
Your Standing Height	
Photographs	
1. In chair, away from desk showing head to feet	
2. In chair, away from desk with elbows bent at 90° showing head to feet	
3. From right or left side, feet to above eyes, hands on keyboard or holding mouse	
4. From behind, showing head and monitors, holding mouse	
5. Over keyboard and mouse, hands on devices	

termine if photograph-based professional assessment was as valid as in-person evaluation. One team of three ergonomists completed in-person ROSA evaluations and took photographs of workstations while the other team completed remote ROSA evaluations using only photographs. Findings indicated that the photograph-based evaluations had potential to provide a valid assessment, but some errors, such as inconsistent photograph angles, could also lead to false positives in final ROSA scores that could result in purchase of unnecessary equipment. The authors suggested that photographs could be standardized and that supplemental information from the client could improve the outcome of photograph-based remote evaluations. The current review seeks, in part, to build upon this suggestion.

A variety of user-friendly computer workstation checklists are available and can be used to systematically augment remote photographic assessment.^{19,20–24} Checklists are typically based on the premise that no single evaluation applies to all situations and body types because of broad variation in stature, ethnicity, gender, anthropometric dimensions, and subtle differences between international standards.²⁵ Despite these inconsistencies, a reliable and tested checklist, such as those suggested in this review, guides a more comprehensive discussion about all parts of the workstation, including setup, overall posture, chair issues, keyboard and mouse position and types, monitor and phone positions, impact of glasses on viewing, placement of documents, footrests, and lighting, thus improving understanding of component-worker interactions, as well as the impact of equipment placement and use on the affected tissue.¹³ More recent checklists^{11,21,22} provide some considerations pertinent to sit-stand issues and OSHA²¹ and CAL OSHA²² Office Ergonomic sections include office-specific checklists. All these resources provide comprehensive information about office workstation components, rationale for evaluation and use, and helpful diagrams that can guide discussion between evaluator and client.

The primary author of this paper has had to modify in-person ergonomic evaluations to remote and/or virtual evaluations because of WFH and COVID-19 restrictions. To improve understanding of the workstation without in-person evaluation, an employee data collection form with specific instructions for measurements and photographs was developed (Table 2). In addition, the authors have completed a review of current evidence for optimal computer postures and equipment options that will assist the evaluating clini-

cian with identifying equipment suggestions that may help to improve client postures.

Performing remote evaluations and collecting data

The primary author has been performing onsite in-person computer workstation evaluations for over 20 years in a variety of industries. In recent years, with contracts for these evaluations at a local college and hospital and referrals from other industries, in-person evaluations have become a significant portion of this private practice. At the two primary institutions, ergonomic workstation evaluations have been offered as a part of the Employee Health and Safety departments to prevent work-related injuries and workers' compensation claims. Employees can request a workstation evaluation directly or through a supervisor. In some cases, onsite in-person evaluations have continued through the COVID-19 pandemic, but at one institution all workstation evaluations have been done remotely.

For in-person evaluation, the referral is provided to the consultant who coordinates a time to meet with the client and travels to the work site to take measurements and photographs. Using a sequence of questions, the consultant and client discuss and examine work tasks, equipment location, and workstation interface, which together guides discussion about equipment options.

For remote evaluations performed by the primary author, the requesting client receives a data collection sheet (Table 2) that includes specific instructions for pertinent measurements and photographs to be gathered by the client. The completed data sheet and photographs, which are returned for review, help the consultant envision the workstation and identify possible areas for corrective action before a scheduled videoconference evaluation, during which the consultant may request any additional data from the client. The collected data is then used to guide discussion with the client about optimal postures at the computer, whether sitting or standing, potential modifications to work method, and suggestions for equipment. This meeting should also educate the client in ideal interaction with and adjustment of equipment and encourage healthy break habits, including stretching and whole-body movements, such as even briefly moving away from the computer and walking. Table 3 provides an outline of issues that can be observed and discussed relating to provided data and photographs. A month after the remote evaluation, the primary author follows up with the client by email, inviting the client to discuss progress as well as any concerns or questions regarding implementation of the modifications.

Collecting and interpreting photographs and data

To proceed from gathering and receiving data to addressing the work setup and methods, interpreting information, and ultimately determining suggestions for equipment and postural improvement, the therapist must understand ideal computer workstation postures and relate symptoms or issues of concern to the interaction of the work components.¹³ Computer workstation components and their positions are highly variable and all may need to be considered (Table 4). The goal of the evaluation and discussion should be to enable and achieve neutral posture for the neck, shoulders, elbows, wrists, and back,^{11,21,22,26,27} which is together described as upright sitting posture in a chair, with elbows, hips, knees, and ankles positioned at approximately 90° angles.^{21,22,26} Woo, White, and Lai²⁵ stated that proper sitting posture is critical to back support and preventing low back pain and suggested that feet should be on the floor while OSHA²¹ indicates on the floor or supported with an appropriate footrest. Generally, the upper arms should be

Table 3

Photograph and data collection issues and discussion points.

Data or photograph	Issues to observe/discuss
Workstation measurements	<ul style="list-style-type: none"> • Desk and/or keyboard support height relative to floor to elbow measurement • Chair height relative to Desk Height Calculator* • Monitor height relative to floor-to-eye height • Standing height: can be used with Desk Height Calculator* to advise proper heights for much of the above
Self-measurement	<ul style="list-style-type: none"> • Floor-to-elbow height relative to measured desk height and armrest height • Floor-to-eye height relative to monitor height
Photographs 1-3: lateral chair view	<ul style="list-style-type: none"> • General fit • Seat depth • Seat angle • Seat height relative to knee and hip angle • Foot support • Employee height relative to desk and/or keyboard height
Photograph 4: from behind	<ul style="list-style-type: none"> • Dual or single monitor • Monitor location relative to employee sitting position and neck rotation • Equipment organization
Photograph 5: superior view	<ul style="list-style-type: none"> • Equipment type: mouse and keyboard • Equipment location • Equipment size • Reach to mouse

* Desk height calculator such as available at: <https://www.ergotron.com/en-us/tools/workspace-planner>.

Table 4

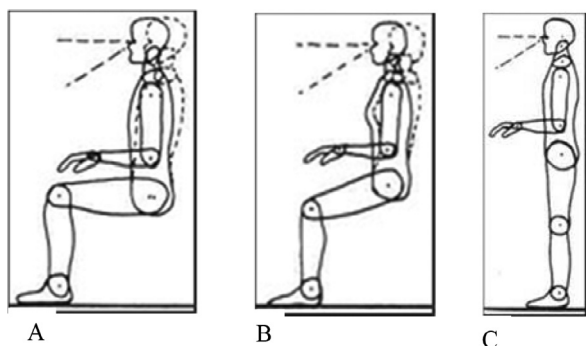
Computer workstation physical components might include.

- CPU: under or on the desk
- Laptop alone or on docking station with external components or separate keyboard, mouse, and monitor
- Single, dual, or multiple monitors (can be as many as 6)
- Full-sized or compact keyboard
- Standard or non-standard mouse device(s) located right, left, or center
- Phone used with standard handset, shoulder rest, headset, speakerphone, or Bluetooth
- Other office equipment: eg card scanner, multi-use device for scanning copying and faxing, small or large calculator, stapler

Table 5

Specific considerations for components and posture.

Chair	Feet on floor or other stable support Hips and knees at approximately 90° Back stable and supported Shoulders relaxed, arms not reaching forward Elbows at 70-90° Wrists neutral without contact stress on table edge or elevated wrist support Adjustable armrests that do not interfere with use of keyboard and mouse
<i>Components and issues for sit-stand workstation</i>	
Keyboard support surface	Sitting: adjustable from 22" to 28.5" Standing: adjustable from 37.5" to 46.5" Wide enough to accommodate keyboard and mouse at the same height
Keyboard and/or mouse	Mouse and keyboard: same height as or just below floor to elbow height Close to torso, minimizing forward reach No number pad if not used, minimize horizontal reach Keyboard flat or slight negative incline Wrist support directly in front of keyboard but not higher than keyboard edge to minimize wrist extension when pausing in keying functions
Monitor:	In line with keyboard and trunk Dual: primary monitor in line with keyboard and trunk Or: if used equally, center point in line with keyboard and trunk Height and/or distance: monitor viewed with neutral neck position Monitor Arm if distance and height should change for specific tasks
Documents	In line with keyboard and monitor
Phone	Hands-free method: headset, earbuds, speakerphone

**Fig. 1.** Computer postures diagram.²¹

close to the body, not reaching forward or to the sides, with elbows flexed 70 to 90°, wrists neutral, and head and neck upright looking forward (Fig. 1A). Photographs taken from the side of and behind the client^{13,28} provide visualization of the client's sitting or standing posture to facilitate discussion. Table 5 summarizes how the equipment used may influence posture and function.

Chair

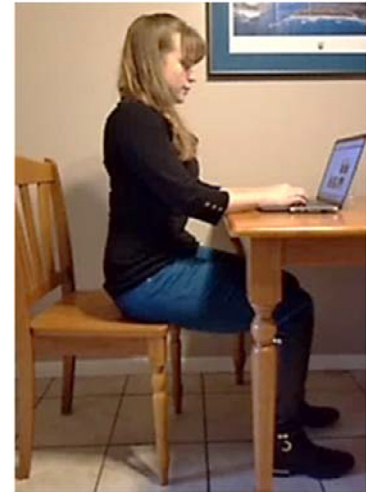
To achieve ideal posture while working on a computer, Van Niekert, Louw, and Hillier⁹ suggested first considering the most



A



B



C

Fig. 2. Home laptop use posture examples.

feasibly modifiable and potentially most impactful component of the workstation: the chair. The chair provides the base of support, specifically for the legs and back and thus the head, and also positions the client for access to keyboard, mouse, and monitor.^{9,28} Rodrigues, Leite, and Lelis²⁹ determined that poor chair fit or adjustment led to increased ROSA scores and user discomfort although, in general, Van Niekert⁹ found limited evidence that a proper chair was directly associated with decreased severity, intensity, and duration of the MSK symptoms associated with prolonged sitting. The authors found that training in proper use and adjustment of the chair was an essential feature of chair interventions for optimal posture and comfort at the computer, and they suggested that clinicians cautiously support chair changes when indicated and ensure that the chair fits the client properly and that the user understands appropriate equipment adjustment.⁹

Proper chair height is important.^{1,9,21,25,30} If the chair is too high, there may be increased pressure on the popliteal space or, if too low, pressure on the low back and ischial tuberosity.²⁵ The lateral sitting photograph will show if hips and knees are flexed at about 90° or if knees are just slightly lower than hips with feet supported which are target postures.²² The chair height measurement can augment this visual: shorter employees will typically need a seat height of 17" to 19" and taller clients may need seat height closer to 20". If a shorter client is sitting with a seat height of 20", it is probable that hips and knees will not be at 90° with feet on the floor, and seat height should be adjusted or foot support provided accordingly. The CAL OSHA Easy Ergonomics for Desktop Computer Users²² provides a systematic assessment of chair issues with suggested interventions that may assist with questioning and resulting suggestions for corrective action.

Seat pan depth is critical for sitting with the back supported. If a chair used either at a corporate office or at home does not fit a client properly, particularly if non-adjustable, too large, too small, or if the client does not know how to adjust these chair components, MSK symptoms may result. A seat pan that is too long may cause clients to sit forward with no lower and middle back support (Fig. 2B and C) and, if seat pan is too short, pressure on the posterior thigh may result in low back muscle strain.^{11,22} Proper seat pan depth generally allows 2" to 4" of space between the front of the chair seat and the client's posterior knee when sitting fully back in the chair.²² One method to determine seat depth

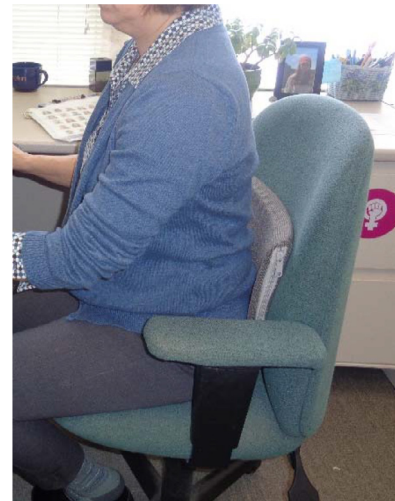


Fig. 3. Pillow insert providing poor back support.

remotely is to ask the client to position four fingers from one hand extended under the distal thigh with the index finger against the posterior knee and the little finger against the front of the chair seat. If the fingers do not fit, the seat may be too long, and if there is a gap between the sides of the fingers in position, the seat may be too short. Caution should be used with pillow inserts intended to compensate for long seat depth as these devices may only push the client forward and not provide sufficient stable back support (Fig. 3).

Seat pan angle can also be adjusted in many ergonomic chairs, though clients are often unaware that the seat may be "pitched" down and may not know how for adjust this. A downward pitch can increase trunk muscle activity and consequent fatigue while sitting and, in most cases, is not ideal.²⁵ A slight downward incline may be used if the perch position is desired, but < 15° forward pitch is generally suggested. This declined or perch position places the client forward on the chair with anterior pelvic tilt and may be used as an occasional sit position to vary posture (Fig. 1B).²¹

Armrests

Armrests are controversial.^{11,25} Some authors²⁵ indicate that use of armrests may decrease muscle load on neck, shoulders, and arms but, if too high or wide, armrests can cause clients to elevate or abduct the shoulders for access. The authors suggest that armrests should be removable or at least adjustable and easily moved out of the way if interfering with neutral position of the arms when using the keyboard and mouse.²⁵ Photographs or measurements can help determine if shoulders are elevated or armrests too high, indicating any need for discussion about lowering or removing armrests.

Desk

The desk should be evaluated for height (sitting and standing if used for both), space for work tasks, and work organization. The suggested height for desks on which keyboards sit is between 22" and 28", depending on client sitting height, and 37.4" to 45.5" for standing height,³¹ with height determined by floor to elbow or hand height when sitting or standing in the optimal posture. This position allows the shoulder to be relaxed and minimizes tension at the elbow and wrist.^{32,33} The height of the standard fixed desk is usually 28.5" to 30", which will be too high for keyboard and mouse use for most women and many men.³¹ Woo²⁵ found that if a desk is as little as 5 to 10 cm (2" to 3") above floor to elbow height with the shoulder relaxed, the client often elevates the shoulders to use the keyboard, leading to fatigue and pain in the thoracic and cervical area.

Keyboard and Mouse

If a desk is too high for keyboard and mouse use, a good solution, particularly if the client has wrist or elbow symptoms, is to provide a fully adjustable keyboard tray that can be flat (not tilted upwards) or positioned with some negative incline.^{22,34} A number of studies^{33,35–37} have found that use of negative tilt keyboard tray position resulted in more neutral wrist and elbow postures, improved comfort, reduced forearm muscle activity, and decreased carpal and cubital tunnel pressures. Rempel, Keir, and Bach³⁶ suggested avoiding wrist extension > 30° to decrease carpal tunnel pressure if typing for long hours, and Woo²⁵ recommended that wrist extension be < 15° to minimize wrist strain, supporting use of a keyboard tray when possible. The keyboard tray should have sufficient space so that both keyboard and the mouse are at the same height to avoid shoulder elevation that may occur if reach for the mouse is above keyboard height or wrist extension that may occur if the mouse is lower on a flip or slide-out extension. This generally requires a space 26" to 30" wide or an opening under the desktop sufficient for a full-sized keyboard tray. The tray should adjust independently for height and angle and/or tilt, and it should have no "under tray" components to hit the client's thighs.

If a keyboard tray is unavailable or cannot be attached to the work surface, the client's chair may be elevated to better position the elbow and wrist. This then requires use of a footrest to support legs and back.^{21,22} Proper footrest height can be estimated by simulating the 90° flexed hip and knee posture, then positioning the ankle as if on the floor and measuring the distance from the volar surface of the foot to the floor. When the client sits too high and is using a footrest, the primary author of this review has observed that it is also harder for the client to use feet on the floor to move into and away from the workstation. As a result, the client may grip the desk edge and push or pull to move into and away from the workstation. This movement pattern may represent risk for high force and awkward wrist and forearm posture and, if often

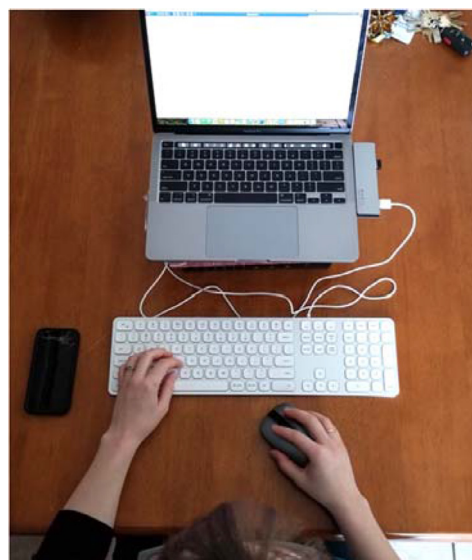


Fig. 4. Photograph above keyboard and mouse.

repeated, could contribute to elbow or wrist symptoms, although a formal study to confirm this observation has not been found. Formal footrests are available but can be too high and unstable. Alternately, reams of paper or unused books can provide a simple and inexpensive 2" to 3" support (Fig. 7A). Lastly, Woo²⁵ advocated for 4" to 10" between desk edge and keyboard to prevent wrist flexion that can occur if wrists hang over the desk edge between keying and mousing functions.

Findings about the comfort and safety of specific keyboard styles are inconclusive.^{13,38} NIOSH³⁹ suggests that the type of keyboard depends on the type of tasks as well as the skill of the operator. Various adjustable, split, and curved keyboards are available on the internet and can be reviewed with the client. Most are designed to moderate forearm pronation or wrist deviation, but there is little evidence that any particular type is best for all applications and users.¹³ Some keyboards do not have a right-sided number pad and, for users who do not use that portion of a traditional keyboard, a keyboard without the number pad will bring the mouse closer, resulting in more neutral right arm position and decreased muscle load to the shoulder.^{11,19,25} It should also be noted that prolonged laptop keyboard use has been associated with increased non-neutral postures of neck, shoulder, elbow and wrist compared to use of a full-sized keyboard.³⁵

Many mouse devices are remarkably different in methods of use and design, such as standard, vertical, trackball or roller styles. As utilization of the mouse was higher than that of the keyboard in 2008⁴⁰ and is likely higher now, mouse type and placement is even more critical. As mentioned above, the mouse should be directly beside the keyboard and on the same surface^{11,21,22,25} to minimize shoulder motion and maintain neutral elbow and wrist posture during use. The photograph taken from above the client allows the evaluator to consider how position of and reach between mouse and keyboard may impact the shoulder or elbow position (Fig. 4). A non-traditional mouse style should be justified by sound clinical reasoning related to MSK symptoms. For example, a trackball mouse will not decrease right thumb discomfort related to holding the mouse or improper mouse to hand size, and a vertical mouse may not decrease wrist motion and extensor muscle tension that could relate to lateral epicondyle symptoms. A better option for these scenarios might be to advise the client to learn to use the mouse on the other side to decrease grip frequency and

wrist motion. This can be more easily achieved by changing the clicker button and suggesting gradual use to build skill and tolerance. Alternately, use of a touch pad or roller bar mouse would also remove pinch grip and may balance use of right and left hands.

Limited evidence shows wrist rests are beneficial for keyboard or mouse use, but if they are at the same level as the keyboard and do not result in contact stress to the volar wrist, then they may be acceptable.¹⁹ Schmid et al.⁴¹ and CCOHS¹¹ found that contact stress on the volar palm and wrist potentially increased carpal tunnel pressure when clients rested too heavily or too frequently on an elevated wrist rest.

Monitor and phone

Improper monitor position can have a direct impact on eye fatigue and cervical, thoracic, and lumbar discomfort. If too high or too low, neck flexion or extension may occur, resulting in muscle fatigue in neck and shoulder stabilizers.^{11,21,25,42,43} This is particularly true for the client using progressive or bifocal glasses or looking between a monitor and paperwork on a desk.³⁵ Neck rotation is associated with increased cervical and thoracic discomfort⁴² and may occur with use of dual monitors, if monitors are not centered with the keyboard and user trunk, and if hard copy documents are on clips or stands beside the monitor.¹³ Repeated or sustained non-neutral neck postures should be minimized by adjusting height and location of monitors to correspond with most frequent use^{11,21,42,43} and by considering the position and type of copy holder. A monitor too far from the user or with very small font may cause trunk flexion to view the screen, with subsequent cervical extension and eye fatigue.²⁵ In general, the authors found that screens should be 63 to 85 cm (24" to 33") from the client. If the client moves between different programs with varying font sizes or if the workstation is shared or has limited space, placing the monitor on an adjustable arm may improve posture for all tasks and users.

An additional concern relative to neck and shoulder MSK pain is lateral neck flexion that occurs when the client holds a phone to the shoulder while looking at data on the computer. A shoulder rest attached to the phone handset does not sufficiently minimize this position, so speakerphone, a headset, or Bluetooth earphones should be encouraged as they allow neutral neck positioning.

Workstation organization

Office work is considered sedentary,⁴⁴ although Springer⁴⁵ and Woo²⁵ stated that sitting at a computer is dynamic because users typically change positions in a chair fairly frequently and, if tasks are varied, they use equipment in varied sequences, positions, and intensities to complete different tasks at the same station. Emerson and Finch¹³ commented that, because of the interaction between user and equipment, changes in one component or work element can potentially affect placement of other components and worker posture. Understanding near, midrange, and far reach (Fig. 5) relative to work task performance can assist with the organization of tools used.^{26,27,30} Photographs taken from behind and above the client can provide insight about client-component interaction. For example, if phone, calculator, scanner, and printer are far to the right, the mouse is to the right, and the keyboard number pad is used to the right, there may be an imbalance of right arm use and the necessity of understanding the interface of components to work method is evident. Discussion about the usage frequency of the various components will help to clarify any need to move and rearrange work tools.



Fig. 5. Near, midrange, and far reach.

Sit-stand workstations

As more research about the deleterious effect of prolonged sitting on overall health has entered the mainstream, interest in sit-stand desks has increased. Research has shown that a sedentary lifestyle and inactive postures at work have been associated with heart disease, type 2 diabetes, low back pain, and other MSK symptoms.^{46,47} A number of studies⁴⁷⁻⁴⁹ have identified that the combination of sedentary leisure time and sedentary work postures was associated with higher risk for heart disease and obesity than sedentary leisure time or work postures alone. According to Sparkman,⁵⁰ standing desks are “the fastest-growing benefits trend” for the office, although an optimal solution for all clients has yet to be identified as research about quantifiable benefits of this intervention is in its infancy.⁵² It is worth noting that there is limited evidence standing is actually healthier than sitting.⁵¹ Primary standing has been associated with a number of health problems including varicose veins, lower extremity edema, cramping, and low back discomfort.^{53,54,55} While standing is frequently requested, Smith et al.⁵³ concluded that primary standing was an often overlooked and minimally studied cardiovascular risk factor in their study of more than 7300 Canadians. Finally, Lin, Barbir, and Dennerlein³² identified three times more low back discomfort after 45 minutes standing than in seated subjects for the same time period. Their study also identified increased wrist extension and forearm muscle activity in subjects who did not have the desk at optimal standing height.

Varying posture, incorporating movement away from the desk, and moving frequently between sitting and standing during the workday should be a goal for many clients.^{13,51} Authors stress that there is no universal pace of movement, but studies^{46,57} concur that we should “sit less and move more.” Karol⁵¹ suggested that standing 60 minutes per day in multiple intervals of 30 minutes or fewer decreased the negative effect of overall sitting. Barbieri, Srinivasan, and Mathiassen⁵⁸ and Robertson, Ciriello, and Garbet⁵⁷ suggested sitting 40% to 80% of the day and standing the remaining 20% to 60%, adding that employees needed to practice and gradually increase standing time to identify an individual’s optimal personal frequency and total duration.⁵⁹ They found that, without training, employees tended to choose only one interval of 40 to 50 minutes standing per day, and Hedge⁵⁶ observed both that employees with only minimal training tended to stand for shorter periods of time and that their time standing rapidly declined after one month. Both standing and sitting equipment must encourage optimal postures if both options are to be utilized effectively.

To achieve sustainable changes in sit-stand behavior, multiple researchers^{7,44,51,57} stressed the importance of educating clients on the benefits of sit-stand and the importance of social and motivational encouragement, including prompts, group reinforcement, and cell phone reminders. Use of electric rather than mechanical height-adjustable desks¹³ and training in proper heights and uses of equipment was associated with better compliance.^{7,32,47,57} The

Table 6
Sit-Stand considerations.

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- Both sitting and standing have unique positive and negative consequences
 - o Is client comfortable standing 15–20 minutes normally?
 - o Will standing impact any present MSK symptoms?
 - Proper height for both sitting and standing is required
 - o Build standing time gradually
 - o Suggested schedule: sit 20–30 minutes; stand 8 minutes; move 2–3 minutes with position changes
 - o Standing limit: 40 minutes at a time, 2–3 hours total per day
 - Fine motor skills: often best when sitting
 - “Desk on desk” considerations:
 - o Most raise sitting keyboard height 1”
 - o Will keyboard and mouse fit on same platform?
 - o Can employee write at standing height if done frequently?
 - o Will monitor be too high for multifocal users or petite individual for sit-stand?
 - o May require wide arm span and forceful lever grip to raise/lower
 - o Requires large desk space, limiting desk space for other functions
 - o May not be optimal for multitasking
 - Electric height-adjustable considerations:
 - o Easiest to adjust for sit-stand
 - o Must go low enough for proper sitting height
 - o Must be set high enough to avoid wrist extension/leaning on wrist
 - o 22”- or 24”- 47” range suggested to accommodate 99% of people
 - Floor mat:
 - o Must move out of the way to allow chair positioning/movement
 - o Should not be needed if varying frequency of standing through day
 - Measurements assist with proper set-up
 - Train client in proper setup and appropriate frequency of position change
 - Alternative to sit-stand: seated work with “micro breaks”
 - o Frequent and varied movement built into the normal workday
 - o Suggested movement: 1–2 minutes every 20–30 minutes
-

type of work performed may also impact sit or stand choices as tasks requiring fine motor skills, such as writing, paper handling, and data analysis were better performed when sitting.⁵²

It has been suggested that the proper setup for standing should resemble sitting posture as regards the shoulder, elbow, and wrist (Fig. 1C).^{21,22} However, in a study of 20 subjects, Lin et al.³² found that, when standing, subjects tended to prefer the monitor 6 cm higher and the keyboard, mouse, and monitor closer to the desk edge than when sitting, and noted that lower desk height relative to elbow height could increase wrist extension. This should be considered in light of any individual with wrist and/or hand symptoms. Their research³² also found that standing was associated with decreased shoulder motion, but increased wrist angle and muscle activity, while sitting was associated with less neutral shoulder, back, and elbow positions. Finally, Robertson⁵⁷ suggested that the type of footwear and floor should be considered to prevent foot, leg, and low back discomfort.

The number of options for sit-stand workstations can be overwhelming and should be carefully evaluated for user fit and function relative to any MSK symptoms. For a client with back or upper quarter limitations or MSK symptoms, electric height-adjustable equipment may best ensure that the client moves between sit and stand without using awkward or forceful postures or levers that require forceful grip to lift or lower the equipment.^{13,60} Adjustable equipment should accommodate the fifth percentile female to the 95th percentile male, and clients should be advised both of optimal heights and that they may have to gradually become accustomed to those heights. Ultimately, whether sitting or standing, neutral postures are desirable, and work function and methods must be considered in conjunction with the client’s physical limitations or discomfort, workstation components, and specific work tasks and methods in order to make appropriate suggestions and decisions

about workstation equipment. Table 6 summarizes considerations for sit-stand dimensions and setup.

The home workstation

The client, with the employer’s permission, may have brought home some corporate office equipment, especially if the employer hesitated to authorize the cost of duplicating equipment, or the home workstation may feature equipment similar to that in the corporate office. However, the home workstation can still present unique challenges. Employees may not have the space for the separate pieces of corporate-office equipment, or the means to move components to and from home. As a result, they may use equipment that does not support optimal postures (Figs. 2A,2B,2C). Employees may not have needed components, and, if no financial assistance is available, may be reluctant to incur the cost associated with the components. Many employers recognize potential problems with home workstations and have provided online suggestions for ergonomic home office components, as well as stretches and additional support services (eg: Chubb 2020, Liberty Mutual 2020, Travelers 2020). Clients should be encouraged to review these documents with the clinician to reinforce improved at-home work postures and to provide a context for discussion with the employer about needed equipment.

Employers have often allowed employees to use laptops outside the corporate environment. While appropriate for short term occasional use, when laptops are used full-time and daily, Yu et al.³⁵ identified significant posture alterations of the neck, elbow, and wrist, and greater shoulder elevation compared to that seen with desktop computer use. If a laptop is the primary computer, an external keyboard, mouse, and monitor should be provided, or at minimum an external keyboard and mouse can be used at a lower height to relax the shoulders, while the laptop is placed at a more optimal height on a desk or table (Fig. 7A). These solutions can be critical to improving postures at the home workstation and should be provided if not previously available.

The workstation at home may be on a high work surface such as the dining table or a kitchen counter.²⁶ If unable to use an adjustable chair from the corporate office, the employee may sit on a non-adjustable wooden upright chair or a bench height stool with poor leg and back support.²⁶ If the work surface is too high, the client might consider using a lap desk to lower the keyboard and mouse, leaving the laptop and/or monitor on a box or stack of books on the work surface (Fig. 6A).²⁶ A lap desk will often not accommodate a full-sized keyboard and mouse on the same height surface, resulting in the need to use a keyboard without a number pad to allow adequate space for the mouse to sit directly beside the keyboard.

There are a wide variety of units that can be placed on existing desks, often called desk-on-desk or desktop converters or risers, which can be raised and lowered to allow sit or stand. While less expensive than electric height-adjusting work surfaces, most of these devices place the keyboard and mouse at least one” above the desk surface even when fully lowered, a potential problem when sitting, particularly if the work surface is already too high. To achieve an at-home standing workstation without purchase of an electric height-adjustable desk unit, a client can use a simple single platform desktop converter in combination with a low-profile lap desk for sitting. To sit, the client moves the keyboard and mouse onto the lap desk while leaving the laptop and/or monitor on the converter or desk surface (Fig. 6A). For standing, the client places the keyboard and mouse on the converter and adjusts the height for standing (Fig. 6B). While this transition is not seamless, it is a less expensive alternative that provides the opportunity to vary posture between sit and stand

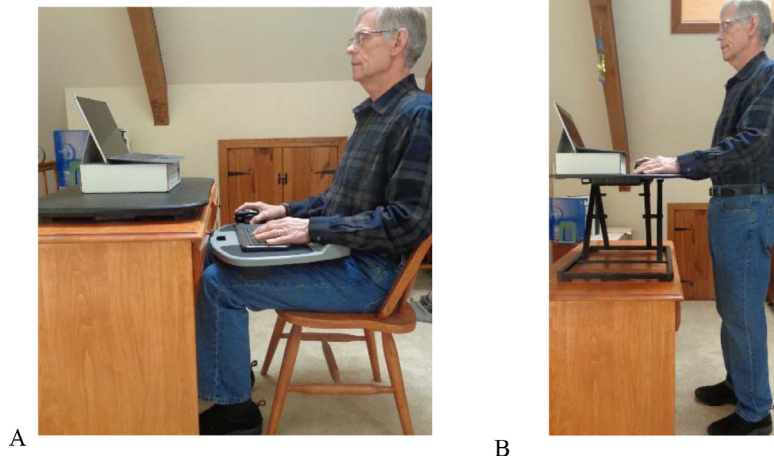


Fig. 6. Lap desk and Desktop Converter for home sit-stand workstation.

while maintaining correct shoulder, elbow, and wrist postures in both positions. If it is anticipated that WFH will continue for a prolonged period even after the pandemic ends, investing in more permanent and convenient equipment may have significant value, although this is not a decision for the clinician to ultimately make.

For all clients working full time at computers, stretching and movement away from the workstation is critical to overall health. Online posters and documents showing movement patterns and motions that move the client out of the postures associated with the work position are readily available and can be reviewed with the client for emphasis.

The therapist's role

No “magic bullet” guarantees prevention of MSK pain.⁶¹ However, to ensure client engagement with the suggestions and long-lasting behavioral changes that will sustain improved work-related health, Darragh, Harrison, and Kenny⁶² found participatory ergonomics and training helpful. Engaging employees in decisions about equipment and reinforcing optimal posture and use of equipment while providing ongoing employee training resulted in better carryover and adaptive change in microscope workers sitting in postures similar to computer workers. Other authors^{25,57} have agreed that training is critical to achieving these benefits, noting that subjects without training were more likely to develop symptoms and to develop them sooner than subjects who had received training. Training reinforced the benefits of movement through the day and encouraged both more control over the work environment and modification in task sequencing, all of which improved health outcome and long-term compliance. Employees who did not receive training and education did not appear to understand the benefits, and notably, standing and posture variation were short lived. A checklist of issues that can be covered in training can be found in Table 7.

In an ergonomic consultation practice, the therapist serving as consultant focuses on answering the referral question from the employer which, for this article, is “does the computer workstation need to be modified.” The therapist-consultant may suspect the need for an upper limb therapy evaluation to address observed movement dysfunction that may contribute to the MSK pain and symptoms reported by the client but, in this situation, it is generally not the role of the consultant to provide evaluation or therapy. This may be suggested for consideration outside of the specific consultative role. Conversely, the therapist who evaluates and manages the upper limb MSK pain of a client in a typical outpa-

Table 7

Training considerations.

- Optimal sit-stand postures
- How to adjust and use equipment properly
- Graduated implementation of posture change
- Gradually implementing use of newly introduced equipment, if needed
- Schedule and/or frequency of posture change, movement, sit-stand
- Stretches at the workstation
- Stretching and movement frequency
- Stress management techniques
- Follow-up discussion and/or address consequent issues
- Encouragement to comply over time

tient clinic setting cannot develop a holistic plan of care without completing a computer workstation evaluation. Due to productivity, patient coverage, and supervision requirements in the outpatient clinic, therapists may not have the ability to perform onsite in-person workstation evaluations. The remote and/or virtual approach described in this paper provides the therapist with a consistent method of data collection and evaluation to provide appropriate recommendations for workstation modifications and patient education to contribute to MSK pain and symptoms resolution.

Case example 1: KJ sought a remote workstation evaluation when she began to do more computer work from home because her music performance career was abruptly interrupted by COVID-19. She had been using her laptop at her kitchen table, on a sofa, or cross legged on the floor and developed low back and/or hip and wrist discomfort. Initial contact was made and KJ completed a remote workstation evaluation form with data about and photographs of the workstation setup, desk height, and floor to elbow height measurements (Fig. 2C). The lateral photographs clearly showed that the table was too high, the chair was not adjustable, seat pan too long, and, using an online sit and/or stand calculator and stated height, the chair was probably too high. This was confirmed upon learning that, when she wore flat shoes and sat back in the chair, her feet were not comfortably on the floor. KJ provided a photograph of the typical sitting posture used because the seat pan was too deep and the chair too high (Fig. 2C). The laptop monitor was also too low and, because of these issues, posture would fatigue, resulting in forward leaning with trunk flexion and weight bearing on the forearms.

Because of limited finances to improve the workstation, the collaborated suggestion was to purchase a fully adjustable chair, adjust chair height to the work surface height, provide foot support, elevate the monitor, and obtain a separate keyboard and mouse



Fig. 7. Follow-up improved workstations.

(Fig. 7A). With these pieces in place, KJ was able to position the chair for proper floor to elbow height relative to the desk height. KJ used two books to support the feet and elevated the monitor on books. KJ purchased a full-size keyboard and had a separate mouse but found that positioning the mouse to the side of the keyboard resulted in uncomfortable reach, so it was positioned in front of the keyboard (Fig. 4). This was not yet optimal as more wrist radial deviation and shoulder flexion and/or extension occurred to move between devices. KJ plans to purchase a keyboard without number pad to address this issue. Overall, KJ feels much better at the workstation, can sit for extended time without symptoms, and is pleased with overall outcome.

Case example 2: SC holds an administrative position at a local college and began WFH in March 2019. The employer allowed the employee to take laptop, full-sized monitor, keyboard, and mouse home, but SC used these devices on a kitchen counter with a bar stool, resulting in sub-optimal posture (Fig. 2A). The client began to experience bilateral wrist pain, low back and peri-cervical fatigue and discomfort, and leg discomfort. Treatment with an occupational therapist was sought and a workstation evaluation was suggested. The evaluator reviewed the collected photographs and measurements and completed the OSHA Computer Workstation Evaluation prior to a virtual workstation evaluation with SC. These data and those gathered during the virtual evaluation directed discussion about the work surface, chair, keyboard, and mouse positions. It was also suspected that the employee leaned on the forearms to support the torso, resulting in progressive posture fatigue, contact stress to the volar wrist, and increased wrist motion when using the mouse. In collaboration with the client, suggestions were made: to bring the office chair home, to request a separate adjustable work surface with keyboard tray, which would decrease stress to the wrists by allowing proper height and reverse incline, to request a keyboard without number pad to bring the mouse closer, and to gradually gain skill in left-hand mouse use to balance use some of the time. When follow-up photographs of new equipment were provided (Fig. 7B) at the request of the evaluator, although SC was not seated at the workstation, the chair was recognized as an older style with limited adjustability. SC was instructed in chair function but could not adjust the chair for optimal fit, so a different chair with more adjustability will be requested. Through discussion, additional concerns related to continued use of the right hand for the mouse prompted a reminder to try to

learn to mouse on the left and to adjust the keyboard tray to -6° incline. Frequency of sit-stand posture variation was reviewed, and movement away from the workstation throughout the day was encouraged. SC will continue to learn to mouse with the left and a follow-up discussion was scheduled for one to two months later.

Summary

This article describes the components of a comprehensive computer workstation evaluation that are based on best practice and recommendations from occupational regulatory agencies. It reviews the primary components of the workstation, namely the desk and chair, type of computer interface used by the client, peripheral devices, and environmental considerations. Based on individual client differences, the unique environment of the home office, and data collected through client measurements and photographs, the therapist-consultant is able to provide well-reasoned suggestive actions to improve sitting or standing postures, keyboard and mouse type and placement, and monitor height and placement. Furthermore, organization of other tools used by the client at the workstation can be modified to adjust reaching parameters or improve balance of tasks across both upper limbs. The case examples demonstrate frequently identified problems with the computer workstation that can be remedied with reasonable modifications to the equipment or organization of the workspace.

Ergonomic consultants and therapists should consider that the MSK pain and symptoms experienced by the client are probably multifactorial. Therapy may be needed for the management of movement dysfunction and postural faults and may or may not be a part of a requested consultation for review of a computer workstation and postures associated with its use. Education may also be required to facilitate healthy work habits to minimize stress associated with personal or work responsibilities and maintaining work-life balance. Equally important is the need to educate clients about the value of frequent breaks away from even the ideal computer workstation to encourage whole body movement and to relax muscle groups that are active during sustained postures.

This article provides a remote method for therapists to perform a comprehensive virtual computer workstation evaluation to complement the therapy services provided in the outpatient clinic. The anticipated permanent growth in WFH office jobs provided

the catalyst to develop the remote format presented. A consistent and systematic virtual method of evaluation will enhance documentation and recommendations. Therapists should be mindful that the differences between incorporating this process into a patient's plan of care versus providing industrial consultation to clients are distinctly different. In both cases, recommendations for proper workstation design and appropriate equipment tailored to the client should be paired with education regarding equipment use and reducing exposure to common risk factors. Further research is needed regarding the reliability and validity of the remote versus the in-person evaluation as well as the feasibility of its use by ergonomic consultants or therapists. Outcomes of the specific recommendations to reduce the incidence of MSK conditions and associated costs, direct or indirect, for workers and their employers must also be studied.

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JHT Read for Credit

Quiz: # 751

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- # 1. The study design is
- RCTs
 - a systematic review of the literature
 - qualitative
 - prospective cohort
- # 2. Prior to the reported method a primary criticism of at home workstation evaluation methods was that often they were
- too expensive to conduct
 - resisted by computer operators
 - resisted by management
 - not valid
- # 3. The described method is designed to detect
- friction between frontline computer operators and management
 - wear and tear on standard work place computers
 - possible causes of musculo-skeletal pain related to computer operation
 - possible causes of psychological stress related to excessive computer operation
- # 4. The authors suggest
- a direct correlation between Dr. Fauci's recommendation and the described method of workstation remote evaluation
 - a direct correlation between the outbreak of COVID-19 and the need for remote workstation evaluation
 - a dramatic return to office work once the COVID restrictions are relaxed
 - mask wearing will diminish workstation efficiency
- # 5. The remote method does not involve the workstation operator
- not true
 - true

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