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Developing an observational instrument to evaluate personal computer keyboarding style

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Abstract

While computer use is considered to be a risk factor for musculoskeletal disorders of the upper extremity (MSD-UE), there is currently little information on how the fingers, hand and thumb are used during keyboarding, and no means to document their postures and motions. A computer keyboarding observational instrument, termed the Personal Computer Keyboarding Style (PeCKS), is being developed to meet this need. The goal of this paper is to describe the process by which the PeCKS was developed. Literature on MSD-UE was reviewed and discussions were held with content experts to develop criterion-based items considered to be potential risk factors for MSD-UE during keyboard use. These items were systematically reviewed and rated by seven experts using the Delphi technique. These ratings were used to determine which items to retain and which to discard, resulting in 19 items to define keyboarding style. The PeCKS, when further psychometric testing is completed, will be useful to document and assess keyboarding to identify those individuals who may be at risk for MSD-UE.

Keywords: VDT evaluation; MSD-UE; Instrument development

1. Introduction

Computer use is considered to be one probable factor for the development of musculoskeletal disorders of the upper extremity (MSD-UE). The incidence of MSD-UE disorders related to computer use has been reported to be around 20% (Gerr et al., 2002). Although the incidence of computer-related MSD-UE appears small compared to other repetitive industrial jobs, the number of people using a computer at work continues to rise, increasing from 45.8% of all workers in 1993 to 53.5% in 2001 (Bureau of Labor Statistics, 2002). In addition, computer use transcends all work categories, and is also used frequently at home; 51% of all households had a computer in 2000 (Newburger, 2001). The ability to assess the effect of keyboarding on the upper extremity is an important issue for clinicians and ergonomists alike.

While numerous studies have focused on the association between MSD-UE/musculoskeletal discomfort and the kinematics of the neck, shoulder, and wrist while keyboarding (Bergqvist et al., 1995; Demure et al., 2000; Faucett and Rempel, 1994; Hales et al., 1994; Marcus et al., 2002), only Pascarelli and Kella (1993) have documented associations between the postures and actions of the fingers and hands and MSD-UE/musculoskeletal discomfort. Little is even known about the kinematics of hand use during keyboarding as only one study has described typical finger and hand use during keyboarding (Sommerich et al., 1996).

Although there are several generic observational methods to evaluate upper extremity work described in

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the literature including the works of James et al. (1997), Lueder (1996), McAtamney and Corlett (1993), Moore and Garg (1995), only two are specific to computer users (James et al., 1997; Lueder, 1996), and none specifically evaluate hand postures and motions. There is a need for a reliable and valid observational instrument that can be used to document and assess parameters of keyboarding, including the postures and actions of the fingers and hands that may be risk factors for MSD-UE.

This paper describes the process used to develop conceptually valid criterion-based items for a new observational instrument, the Personal Computer Keyboarding Style (PeCKS) instrument. The PeCKS documents commonly seen, stereotypical upper extremity postures and coordinated actions associated with computer keyboard use, which we refer to as keyboarding styles. Keyboarding styles, like workstyle (Feuerstein, 1996), are dictated by the context of the computer workstation, but are also related to the worker's individual strengths and limitations. "Risky" keyboarding style has been suggested to be associated MSD-UE (Feuerstein and Fitzgerald, 1992; Kilbom and Persson, 1987; Pascarelli and Kella, 1993), although it is not an area that has been studied in great depth. An observational instrument which can be used in the field by clinicians and researchers to quickly document and assess keyboarding style would facilitate the understanding of the association between MSD-UE, musculoskeletal discomfort and keyboard use.

2. Methods

To develop the items used for the PeCKS, we identified aspects of keyboarding style that were most likely to be associated with MSD-UE from the literature on the pathomechanisms of MSD-UE. After items were identified and operationalized, experts in MSD-UE and biomechanics assessed the extent to which they felt items were risk factors for MSD-UE.

The following two sections gives a brief overview of the literature used to develop the initial set of PeCKS items and the Delphi techniques used to finalize the items.

2.1. Rationale for PeCKS item development from literature

Repetition: Repetition has consistently been associated with an increased incidence of musculoskeletal discomfort. High repetition has been associated with viscoelastic creep (Goldstein et al., 1987), and systemic inflammation response (Barr and Barbe, 2002). A skilled data processor can have keying rates of 15,950 keystrokes per hour (Hales et al., 1994), although this rate varies tremendously by skill and job type. High typing speeds have been associated with high carpal tunnel pressure (Sommerich, 1994), and touch typing, a method that often involves high-speed typing, has been associated with MSD-UE (Hedge et al., 2002). Most studies on keyboarding examined repetition as it related to duration of keyboard use. There is a consistent association between keyboarding more than 4 h a day and MSD-UE (Bergqvist et al., 1995; Demure et al., 2000; Faucett and Rempel, 1994; Marcus et al., 2002; Matias et al., 1998).

The PeCKS will be designed to be an observational instrument that examines short periods of typing (approximately 10 min), so it will not be used to directly measure the duration of typing. Instead, information about duration of typing will be obtained through client self-report, a practice used in many studies on computer keyboarding and MSD-UE (Bergquist et al., 1992; Faucett and Rempel, 1994; Marcus et al., 2002). Studies that have examined the accuracy of self-report for identifying duration vary, some suggesting that subjects are reasonably accurate (Deane et al., 1998; Faucett and Rempel, 1996), and some suggesting that subjects overestimate by as much as fourfold their actual computer use time (Homan and Armstrong, 2003). For this reason, individuals choosing to use the PeCKS as a research tool may choose to supplement duration self-reports with other methods or gathering duration, such as work sampling or activity monitoring. The PeCKS will provide frequency information on wrist, finger, and hand motions.

Upper extremity and neck posture: Many studies have focused on the association between awkward postures of the neck, shoulder, arm, and wrist and MSD-UE/musculoskeletal discomfort. Awkward postures, pronation, wrist ulnar deviation and wrist extension are hypothesized to put increased forces such as friction and shear on the tendon and tendon sheath (Goldstein et al., 1987; Marklin et al., 1999; Tanzer, 1999). Forearm pronation, wrist extension, wrist flexion, and ulnar deviation also increase carpal tunnel pressure (Rempel et al., 1998, 1997; Sommerich et al., 1998; Werner et al., 1997) which has been hypothesized to increase the risk for tendonitis and carpal tunnel syndrome (Rempel et al., 1992). Some epidemiological researches have found a relationship between posture and musculoskeletal discomfort (Bergqvist et al., 1995; Demure et al., 2000; Marcus et al., 2002), and some have not (Faucett and Rempel, 1994; Liao and Drury, 2000; Marcus et al., 2002), suggesting that neck, shoulder, arm and hand postures may or may not be a risk factor.

Although there is variety in the preferred postures among different keyboard users (Simoneau et al., 1999; Sommerich et al., 1996), research suggests that each individual's neck, shoulder, and arm postures are relatively stable and unchanging during keyboarding (Ortiz et al., 1997). This has allowed researchers measuring range of motion during keyboarding to either estimate angles, as has been suggested for other observational instruments (McAtamney and Corlett, 1993; Moore and Garg, 1995) or to measure these postures with a handheld goniometer either live or from photographs (Grandjean et al., 1982; Marcus et al., 2002; Ortiz et al., 1997). The postures assumed do not appear to be necessarily related to the anthropometrics of the keyboard user. Simoneau et al. (1999) reported very little correlation between worker anthropometrics and postures assumed during typing and hypothesized "that typing style as well as the position of the elbows probably have a more significant effect on wrist posture…" (p. 423). Wrist and hand postures also tend to be asymmetrical, with the left wrist having greater ulnar deviation than the right (Grandjean et al., 1983; Rose, 1991).

Finger postures and motions: One dynamic postural phenomenon associated with MSD-UE (Pascarelli and Kella, 1993) is the tendency some people have to activate their finger flexors and extensors by flexing and extending their wrists while typing. This "bouncing" motion can increase tendon travel (Rowe, 1987), wrist acceleration (Schoenmarklin and Marras, 1990), and wrist flexion (Tanzer, 1999), all potential risk factors for MSD-UE.

Observations of individuals using a computer keyboard have suggested that some individuals keep their forearms almost motionless and reach with their fingers to engage the keys, a pattern most often seen in touch typists, while others constantly reposition their hands and forearms to position their fingers for each key stroke. Although this phenomenon has not been described in the literature, the tendency to reach with the fingers rather than move the hand/forearm could result in increased tendon travel and more non-neutral postures, all of which have been associated with MSD-UE (Matias et al., 1998; Rempel et al., 1997; Rowe, 1987; Schoenmarklin and Marras, 1990; Tanzer, 1999). We refer to this phenomenon as hand movement or hand displacement and it refers to the overall movement of the hand/forearm during a keyboarding task separate from the hand movement initiated through each finger's keyboard strike. To differentiate between hand/finger movement and hand/forearm movement, the rater looks at the base of the third metacarpal as this point stays essentially motionless during hand/finger use, but moves if the hand/forearm unit moves.

Observations of keyboarders suggest that some individuals maintain their metacarpophalangeal (MCP) joints in hyperextension throughout the time the finger is at "rest" (Rose, 1991). Tension on the extrinsic extensors may occur if a finger joint is maintained in a hyperextended posture while the finger is at rest (i.e. not striking a key). Hypermobility, or joints which have greater flexibility than average, has been associated with MSD-UE (Pascarelli and Kella, 1993). Individuals whose finger joints "collapse" during typing (i.e. hyperextend) may be at increased risk for MSD-UE.

Some keyboard operators maintain the fifth digit and/or thumb in extension/abduction while typing (Pascarelli and Kella, 1993; Rose, 1991). This phenomenon, called isolated thumb and isolated pinkie, has been associated with MSD-UE (Pascarelli and Kella, 1993). Items on the PeCKS will quantify and provide methods to measure each of these postural elements.

Force and tension: Force is a risk factor associated with MSD-UE in industrial jobs (Bernard, 1997; Silverstein et al., 1986), though less than one for keyboarding. Keyboarding is generally considered a high-repetition/low-force work (Silverstein et al., 1986), and for most individuals keyboarding tasks rarely exceed 2–5% maximum voluntary contraction (Sommerich et al., 2002), although some individuals do exceed this limit. Studies indicate that while key strike force is somewhat dependent on keyboard activation requirements (Radwin and Ruffalo, 1999), it is also idiosyncratic, dependent upon keyboarding style (Martin et al., 1996; Sommerich et al., 1996). Forceful keying has been associated with increased carpal tunnel pressure (Rempel et al., 1997), fatigue (Radwin and Ruffalo, 1999), and MSD-UE (Feuerstein et al., 1997; Pascarelli and Kella, 1993).

Keyboarding style also can affect internal tendon forces through coordinated actions of the fingers. For example, the previously discussed isolated thumb and isolated pinkie will cause co-contractions of the MCP and proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints of the first and fifth digits, placing increased tension on surrounding tissues and muscles (Rose, 1991). Another phenomenon that may increase tension, referred to as enslavement, is the tendency of fingers to act in tandem during coordinated tasks (Li et al., 1998). For instance, when individuals exert force downward with their middle finger, their ring finger will exert a lesser downward force. This phenomenon could also increase muscular tension as the keyboarder attempts to prevent the enslaved finger from activating an inappropriate key. Identifying coordinated actions of the fingers will be essential to describing these potential problems.

2.2. Method of PeCKS item development

The above information provided the cornerstone for the development of the items used in the PeCKS. The items were further expanded and focused through discussions and ratings by experts both in biomechanics and hand therapy. The first version of the PeCKS (beta-1) had 21 items that were divided into three types: (a) items that described static body postures; (b) items that described the frequency of wrist, hand, and finger postures; (c) items that described tension and force. In all items both the right and left hand were to be assessed separately. The items were operationalized to develop a standard method of describing and measuring them. Table 1 lists the items in the PeCKS (beta-1) and their initial operationalization.

The Delphi technique, a technique which uses questionnaires to obtain a consensus of opinion in a group of experts (Powell, 2002) was performed on this version with seven experts, including three certified hand therapists, and four ergonomists whose research field is in MSD-UE (Baker and Redfern, 2003). Each item on the PeCKS (beta-1) was evaluated using a likert-style scale for (1) the likelihood of being a risk factor for MSD-UE; (2) the biomechanical or epidemiological basis for that item; (3) whether the operationalization of the PeCKS measured the item of interest, and (4) the clarity of the operationalization in identifying the item of interest (see Table 2).

Data analysis: Intraclass correlation coefficients (ICC's) (Shrout and Fleiss, 1979) were calculated for the ratings of each separate item's risk factor and rationale combined to establish the agreement between raters concerning that item's importance as a risk factor for MSD-UE, and between the operationalization and the clarity of the operationalization to determine the agreement between raters concerning how well that item was operationalized. A Cronbach's alpha for the risk factor and rationale ratings were calculated using the ratings of all the items to determine the internal consistency of those ratings (Portney and Watkins, 2000).

3. Results

The raters found all but seven items to be important risk factors for MSD-UE (Fig. 1). The seven items that were not found to be important were hand position symmetry, continuity of typing, number of fingers used, space bar activation, isolated thumb, finger enslavement, and changes in radial angle. There was general agreement among the experts about the risk factors and rationale except for hand position symmetry (ICC $r = 0.28$), continuity of typing (ICC $r = -0.67$), bouncing wrists (ICC $r = .62$), and key activation force (ICC $r = 0.67$), having an ICC of less than 0.75 (Portney and Watkins, 2000).

There was general agreement among the experts that the items' operationalization and clarity were good (Fig. 2). For many of the items, all the raters selected a "2" indicating that the operationalization accurately described the item of interest. Only in rating items in pronation and key activation force did raters express some doubts about the operationalization. Ratings for clarity were also generally high. Only hand movement appeared to be relatively unclear to raters. The Cronbach's alpha was .80.

For many of the operationalization and clarity ratings (shoulder position, elbow angle, ♯ of fingers used, wrist ulnar angle, wrist extension angle, changes in ulnar angle, changes in radial angle, finger postures, isolate thumb, and hypermobile joints), there was such a complete agreement (i.e. everyone selected the same score) that there was not enough variance to calculate an ICC. In addition, several items (shoulder position, space bar activation, wrist rest use, and finger enslavement), while having variance, had an ICC of 1.00 indicating a perfect agreement. Only the ICC's for operationalization and clarity for item hand movement (ICC $r = 0.46$) and the item isolated pinkie (ICC $r = 0.20$) indicated low agreement among raters.

A final list of items to be included in the PeCKS (beta-2) was established by removing those items that did not meet specific criteria. A priori, we decided to eliminate any item from the PeCKS (beta-1) list in which the mean rating of risk was less than 1.0, or any item in which risk rating equaled 1.0 and the rationale rating was less than or equal to 1.0. This eliminated six items (hand position symmetry, continuity of typing, ♯ of fingers used, space bar activation, changes in radial angle, and isolated thumb). Any items with a low ICC was examined to determine the reason for low rater agreement. If there was a great deal of variation between raters, this might indicate that an item should not be kept, even if it met the previous inclusion criteria. We found that the low agreement was generally caused by a highly differing score from a single expert for each item. We therefore included the two items which met our inclusion criteria (bouncing wrists, key activation force), and excluded the two items which did not meet the inclusion criteria (hand position symmetry, continuity of typing). The item related to thumb isolation was initially to be removed from the instrument, but was reinstated after discussions with the experts about these results. In addition, the ♯ of fingers used was reinstated as a marker for touch typing. An item related to neck posture suggested during the feedback process was also added. Table 3 is the final list of items included in the PeCKS (beta-2).

4. Discussion

The result of the validation procedure is the development of an initial observational instrument based upon findings in the scientific literature and confirmed by experts in the field. The PeCKS (beta-2) contains items that include arm and neck postures, repetitions, and estimates of forces. In addition, there are items that combine traditional observational items into those that reflect keyboarding styles. These items are believed to be

Table 1
PeCKS (beta-1) items, their rationale for inclusion, and their initial operationalization

PeCKS items	Rationale	Operationalization
Items of static posture		
1. Shoulder position	Shoulder elevation has been associated with neck MSD (1)	Raters estimate whether the shoulders are symmetrical
2. Shoulder angle	Shoulder flexion >35° has been associated with shoulder MSD (1, 2)	Raters use a goniometer to estimate R & L shoulder flexion angles
3. Elbow angle	Elbow flexion angle >120° and <80° associated with MSD-UE (1, 2, 3).	Raters use a goniometer to estimate R & L elbow flexion angles
4. **Hand position symmetry**	During keying hands have been reported to be slightly asymmetrical (4, 5)	Raters examine the overall posture of the hands for symmetry
Items that measure the frequency of wrist, hand, and finger postures		
5. Hand movement	Finger reaching movements result in ⇑ tendon travel and ⇑ non-neutral postures (10, 11, 12, 13, 14). Touch typing has been associated with MSD (9)	Raters observe the base of the third metacarpal of each hand to see if it displaces more the 1.5 cm while keyboarding
6. **Continuity of typing**	There is currently no evidence in the literature	Raters counts the number of pauses during 30 s of keyboarding for each hand
7. *♯ of fingers used to type*	There is currently no evidence in the literature	Raters count the number of total number of fingers on each hand used while keyboarding
8. *Spacebar activation*	Single digit use with other digit held in extension has been associated with MSD (15) and increases the static tension of the muscles (15, 16)	Raters identify which digit(s) is used to activate the space bar
9. Wrist ulnar angle	Ulnar deviation >20° has been associated with wrist MSD (17)	Raters estimate if the R or L wrist ulnar deviation is more than 20° never, occ., freq., cons or always*
10. Wrist extension angle	Wrist extension >15° has been associated with ⇑ carpal tunnel pressure and ⇑ EMG output. (1, 18, 19, 20, 21)	Raters estimate if the R or L wrist extends more than 15° never, occ., freq., cons., or always*
11. Changes in ulnar angle	Ulnar deviation has been associated with ⇑ carpal tunnel pressure, and ⇑ forces on flexor tendons (14, 16, 22, 23)	Raters estimate if the worker ⇑ R or L ulnar deviation by 10° never, occ., freq., or cons*
12. **Changes in radial angle**	There is currently no evidence in the literature	Rater estimates if the worker increases R or L radial deviation by 10° when typing never, occ., freq., or cons*
13. Changes in pronation	Pronation >80° has been associated with ⇑ carpal tunnel pressure (12, 23, 24)	Raters identify if the worker increases R or L pronation during a 15 s period
14. "Bouncing" wrists	Bouncing motion ⇑ tendon travel (10), ⇑ wrist acceleration (13), ⇑ wrist flexion (15, 25), and has been associated with MSD-UE (15)	Raters identify if the worker uses the R or L wrist position to assist finger flexors to strike keys
15. Finger postures	MCP, DIP and PIP extension ⇑ the static tension of the extensor muscles and ⇑ the forces experienced on the joints and tendons (5, 16, 26).	Raters estimate if the R or L MCP, DIP, or PIP joints are in flexion, neutral, or extension just prior to key strike
16. *Isolated thumb*	Isolated thumbs have been associated with ⇑ muscle tension and MSD (5, 15, 16)	Raters identify if the worker isolates the R or L thumb never, occ., freq., cons., or always*
17. Isolated pinkie	Isolated pinkies have been associated with ⇑ muscle tension and MSD (5, 15)	Raters identify if the worker isolates the R or L little finger never, occ., freq., cons., or always*
18. Hypermobility	Joint hypermobility has been associated with MSD-UE (15)	Raters identify if worker's R or L PIP collapses into hyperextension
Items of tension and force		
19. Wrist rest use	There is conflicting information on the effectiveness of wrist or elbow supports in preventing MSD (2, 6, 7, 8)	Raters identify if the worker supports the R or L elbow/forearm and/or the wrist
20. Key activation force	High force key activation has been associated with MSD and ⇑ carpal tunnel pressure (12, 15, 27)	Raters estimate the force used during key activation (low, moderate, high) on the R and L
21. Finger enslavement	Non-isolated movements ⇑ overall muscle tension which has been associated with MSD (5, 15, 16)	Raters identify if the worker has enslavement of nearby fingers on the R or L never, occ., freq., cons., or always*

*Never = 0% of the time, occ. = occasionally = 1–30% of the time, freq. = frequently = 31–60% of the time, cons. = constantly = 61–99% of the time and always = 100% of the time. (1) McAtamney and Corlett, 1993; (2) Marcus et al., 2002; (3) Faucett and Rempel, 1994; (4) Grandjean et al., 1983; (5) Rose, 1991; (6) Aaras et al., 1997; (7) Carter and Banister, 1994; (8) Fernstrom et al., 1994; (9) Hedge et al., 2002; (10) Rowe, 1987; (11) Matias et al., 1998; (12) Rempel et al., 1997; (13) Schoenmarklin and Marras, 1990; (14) Tanzer, 1999; (15) Pascarelli and Kella, 1993; (16) Goldstein et al., 1987; (17) Hunting et al., 1981; (18) Hedge and Powers, 1995; (19) Marklin et al., 1999; (20) Simoneau and Marklin, 2001; (21) Moore and Garg, 1995; (22) Sommerich et al., 1998; (23) Werner et al., 1997; (24) Rempel et al., 1998; (25) Smith et al., 1977; (26) Harding et al., 1993; (27) Feuerstein et al., 1997. Bolded items indicated those items excluded from the PeCKS beta-2 after receiving low scores during the content evaluation. Italicized items indicated those items that received a low score but were included in the PeCKS (beta-2.). R—right, L—left; MCP—metacarpophalangeal; PIP—proximal interphalangeal; DIP—distal interphalangeal.

Table 2
Rating areas and rating scales for Delphi analysis of the PeCKS (beta-1)

Area to be rated	Rating scale
1. The degree that the item is a risk factor for MSD-UE	• 0—not a risk factor • 1—a slight risk factor • 2—a moderate risk factor • 3—a strong risk factor
2. The degree that the rationale for the item had a strong biomechanical or epidemiological basis	• 0—no basis • 1—a slight basis • 2—a moderate basis • 3—a strong basis
3. Will the operationalized method measure the item of interest	• 0—No, not at all • 1—Somewhat • 2—Yes, very much
4. The clarity of the operationalization in identifying the item of interest	• 0—very unclear • 1—somewhat unclear • 2—somewhat clear • 3—very clear

important in describing the complex motions of keyboarding using an observational instrument.

The expert evaluators gave higher risk ratings to those items that measured body and wrist postures, and key activation force compared to finger postures. This is not unexpected as these are the risk factors for computer-related MSD-UE most often described in the literature. Additional items identified as moderate risk factors were those related to finger and hand postures that promote joint co-contractions during typing, increasing the overall tension of the hand during keyboarding (wrist rest use, isolate pinkie). This supports the perception that MSD-UE may be related to stresses on the tendons related to co-contractions of joints.

Generally, all raters felt that the operationalization of the items would measure the item of interest. The lowest mean was for the item which measured key force activation, which was felt to be a large risk factor for MSD-UE. There was some concern that forces would be very difficult to estimate through observational methods. The other area that had a low operationalization score was that related to hand movement. Reviewers indicated that they were not clear as to what this item would measure, and suggested additional pictures and clarification of the method. This low agreement on hand

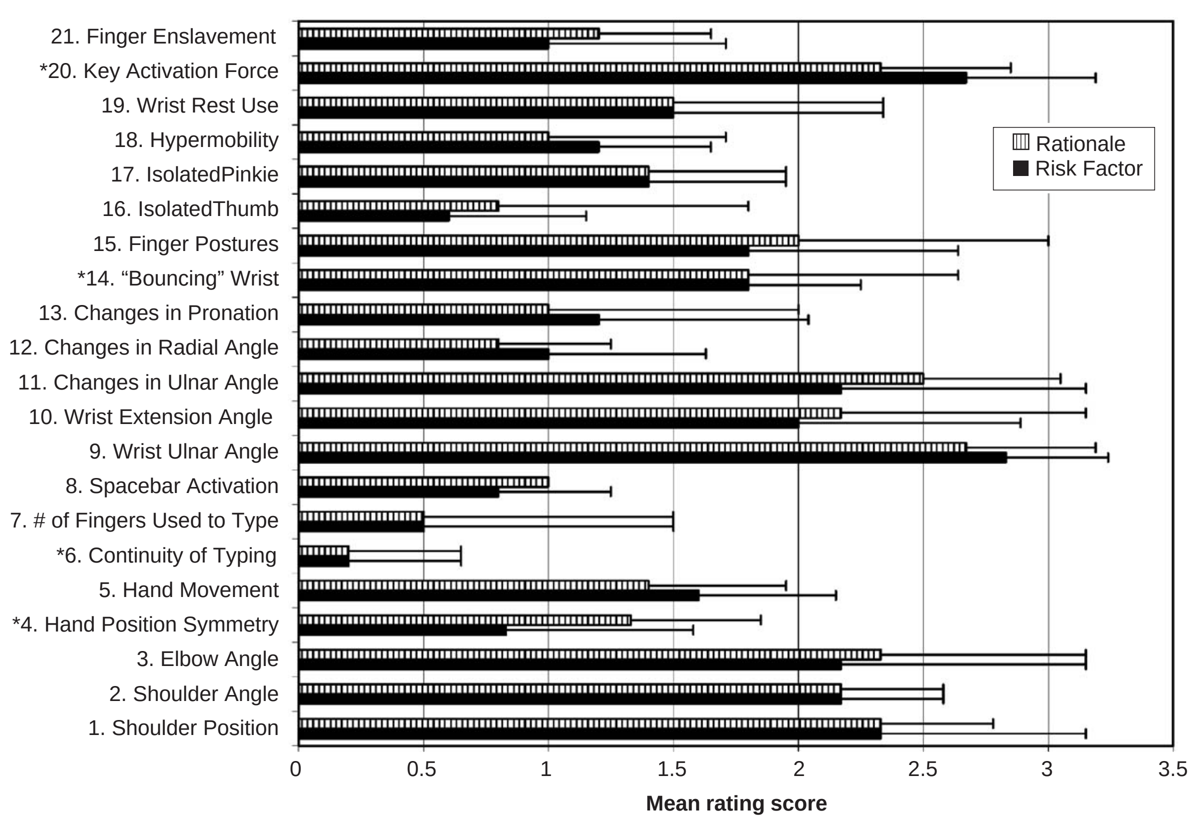

Fig. 1. Mean ratings of the seven raters of the (1) degree that the rationale for an item on the PeCKS had a strong biomechanical or epidemiological basis; (2) degree that an item of the PeCKS is a risk factor for MSD-UE. Error bars are the standard deviations for each rating. An asterisk next to the item number indicates that the ICC for this item was below 0.75.

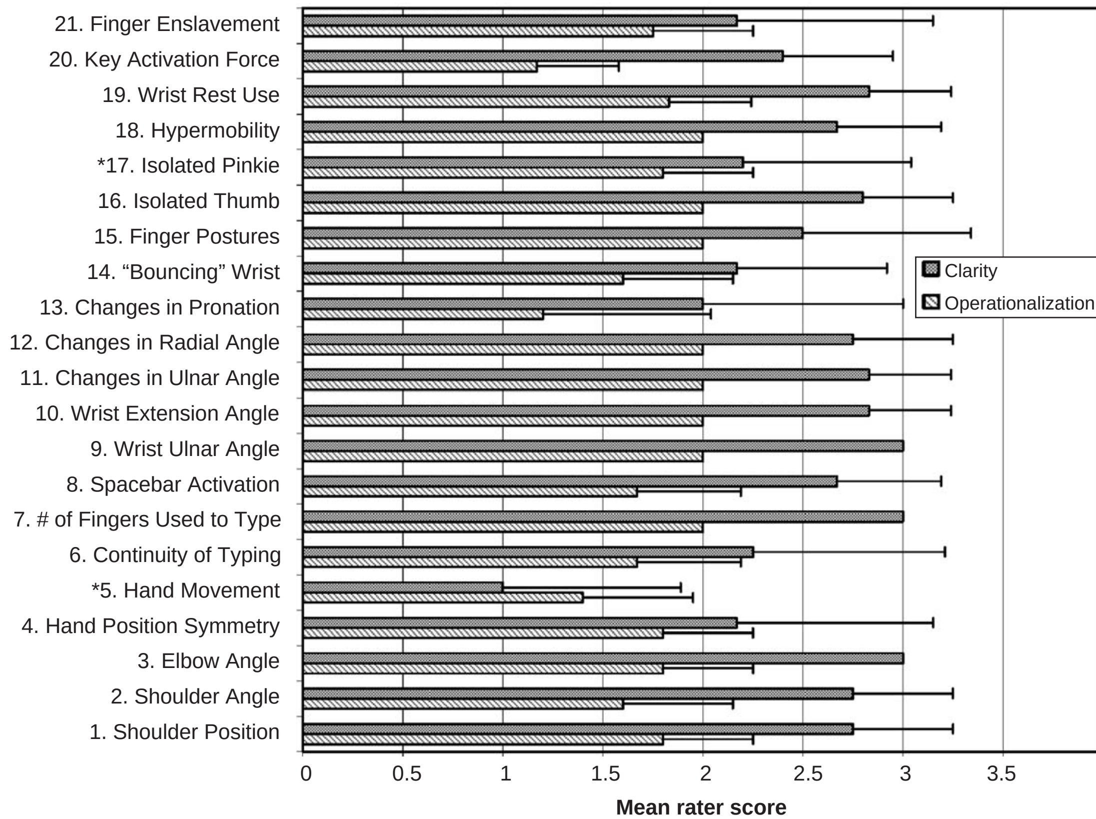

Fig. 2. Mean ratings of the seven raters of (1) the operationalized method; (2) the clarity of the operationalization in identifying the item of interest. Error bars are the standard deviations for each rating. An asterisk next to the item number indicates that the ICC for this item was below 0.75.

Table 3
Items to be included in the PeCKS (beta-2)

Items of static posture	Items of frequency	Items of force and tension
• Neck posture • Shoulder position • Shoulder angle • Elbow angle	• Hand movement • # of fingers • Wrist ulnar angle • Changes in ulnar angle • Wrist extension angle • Changes in pronation • Finger postures • "Bouncing" wrist • Isolated first digit • Isolated fifth digit • Hypermobile joints	• Key activation force • Finger enslavement • Wrist rest use • Overall hand tension

movement may have been due to a poor understanding of the overall item by several of the raters.

The Cronbach's alpha of 0.80 suggests that although the reviewers were measuring the items in a similar way, they also each brought a slightly different perspective on the instrument. This combination is important because it suggests that the experts represent a spectrum of opinions and ideas about MSD-UE and computer keyboard use. Thus, we believe that the instrument has content that covers the construct of interest.

4.1. Further development of the PeCKS

This article describes the method used to develop an instrument developed from evidence based on content for a criterion-based observation instrument used to document computer keyboarding style. A description of the actual operationalization of the instrument was not addressed in this article as the instrument has not been fully developed, and therefore the precise criterion and scales are still being completed. Future development of the PeCKS (beta-2) will first focus on developing the reliability of the instrument and then in doing further studies to validate it as a method to document keyboarding styles associated with MSD-UE. To establish the inter-rater reliability of the instrument, video recordings of individuals typing will be rated by several raters using the PeCKS and compared using ICC. Intra-rater reliability will be obtained by comparing the ratings of the same rater over several time periods. Once good reliability has been obtained, the instrument will be validated further by comparing observational measures obtained using the PeCKS (beta-2) with the kinematic measures obtained using a motion capture system. Studies will examine the difference in scores for varied settings: between live assessment and video taped assessment; between laboratory-based assessment and worksite use. To examine evidence based on relations to other variables, sometime referred to as predictive validity, associations with MSD-UE will be explored by comparing PeCKS scores obtained from computer keyboarders with MSD-UE to those without MSD-UE. We will also assess the relative contribution of the different items on the PeCKS and their association with MSD-UE so that we can develop a weighting system to improve the sensitivity of the instrument. These validation studies will help to develop an instrument that is useful both as a research tool and a clinical assessment. The PeCKS will then be used in field studies to assess computer environments and to develop interventions to reduce risky styles.

An additional area that will eventually need to be quantified to understand computer use and MSD-UE is the use of alternate input devices (e.g. mouse, trackball). The PeCKS currently focuses exclusively on computer keyboard use. As alternate input devices appear also to be potential sources of MSD-UE (Kryger et al., 2003), future aspects of this instrument will need to address this issue.

Once the PeCKS has been refined in this way, it will be useful for both clinicians and researchers who are working with computer keyboard users. The instrument will be useful as an evaluation tool for clinicians to assess clients with computer-related MSD-UE. Clinicians can use the PeCKS to identify which risk factors are present and develop an intervention plan to reduce these risk factors. Researchers can use the PeCKS to document the outcome of ergonomic interventions aimed at preventing MSD-UE in computer users.

5. Conclusion

With the increasing use of computer both within and without the workplace, the ability to accurately and quickly describe the kinematics of the body, arm, hand, and fingers during computer keyboarding is an important step towards understanding and controlling the occurrence of computer-related MSD-UE. The development of an observational instrument to measure personal keyboarding style is an important step for the evaluation of computer keyboarding. An observational instrument, termed the PeCKS, has been initially developed to capture important aspects of keyboarding. The systematic method used, a thorough literature review combined with expert consensus, has refined the items to be included, and highlighted potential strengths and weaknesses. Further, the expert evaluations suggest that the instrument covers a spectrum of risk factors associated with MSD-UE, and will be a useful tool for assessing keyboarding style as one of many possible risk factors for MSD-UE. This PeCKS (beta-2) version establishes a finite list of observable items to define keyboarding styles.

Currently, further refinement and validation studies are underway to complete the process of developing the instrument for use by ergonomist and clinicians. Initial use of the instrument from video taped typing performances suggests that the instrument is quick ($\sim$10 min) and generally reliable to use, although several items need further clarification and refinement to have adequate reliability. Once these studies are complete, the instrument should be useful for many different purposes and provide assessors with a quantifiable means to measure personal keyboarding style.

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