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Applied Ergonomics 40 (2009) 136–144

APPLIED ERGONOMICS

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Rater reliability and concurrent validity of the Keyboard Personal Computer Style instrument (K-PeCS)

Nancy A. Baker[a,*], James R. Cook[b], Mark S. Redfern[c]

[a]Department of Occupational Therapy, School of Health and Rehabilitation Sciences, University of Pittsburgh, 5012 Forbes Tower, Pittsburgh, PA 15260, USA

[b]Department of Otolaryngology, 519 Ear and Eye Institute, University of Pittsburgh, Pittsburgh, PA 15260, USA

[c]Department of Bioengineering, 749 Benedum Hall, University of Pittsburgh, Pittsburgh, PA 15260, USA

Received 12 July 2007; accepted 20 December 2007

Abstract

This paper describes the inter-rater and intra-rater reliability, and the concurrent validity of an observational instrument, the Keyboard Personal Computer Style instrument (K-PeCS), which assesses stereotypical postures and movements associated with computer keyboard use. Three trained raters independently rated the video clips of 45 computer keyboard users to ascertain inter-rater reliability, and then re-rated a sub-sample of 15 video clips to ascertain intra-rater reliability. Concurrent validity was assessed by comparing the ratings obtained using the K-PeCS to scores developed from a 3D motion analysis system. The overall K-PeCS had excellent reliability [inter-rater: intra-class correlation coefficients (ICC) = .90; intra-rater: ICC = .92]. Most individual items on the K-PeCS had from good to excellent reliability, although six items fell below ICC = .75. Those K-PeCS items that were assessed for concurrent validity compared favorably to the motion analysis data for all but two items. These results suggest that most items on the K-PeCS can be used to reliably document computer keyboarding style.

Keywords: VDT evaluation; MSD-UE; Instrument development

1. Introduction

As the use of computers continues to increase both at work and at home (Cheeseman Day et al., 2005) it has become increasingly important for therapists and human factors personnel to be able to accurately document how computer users interact with their computer keyboards. Although conventional wisdom asserts that postures assumed during keyboarding are related to the development of musculoskeletal disorders of the upper extremity (MSD-UE) (Carter and Banister, 1994; Tittiranonda et al., 1999), the association between postures and MSD-UE have not been well supported in the literature. Gerr et al. (2006) recently completed a review of the evidence related to postures and MSD-UE. They reported that there were only a small number of studies that supported an association between computer use and MSD-UE. They cited the lack of valid and reliable methods to accurately measure postural exposures during keyboard use as one reason for this lack of support. The dearth of epidemiological studies which examine the association between keyboard-related wrist, hand, and digit postures and MSD-UE may reflect the lack of appropriate measurement tools to ascertain these exposures quickly and easily while at a job site.

Methods to measure job tasks can be broadly categorized as direct methods and observational methods (Li and Buckle, 1999). Direct methods involve attaching a device to the keyboard user, such as an electric goniometer or an electrode, to record kinematic data, while in observational methods the researcher observes and documents key items without any devices attached to the keyboard user. Direct methods tend to be more precise than observational methods (Spielholz et al., 2001), but require more

*Corresponding author. Tel.: +1 412 383 6607; fax: +1 412 383 6613.
E-mail address: nab36@pitt.edu (N.A. Baker).

0003-6870/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.apergo.2007.12.008

equipment, and provide less clinically interpretable information. Ideally, both methods are used to evaluate a job task. However, many of the direct methods are expensive, non-portable, and invasive, making observational instruments a good choice for onsite evaluations.

Observational instruments have frequently been used for ergonomic assessments and have been reported to be a generally reliable method to evaluate the postures and frequencies of work task demands (Genaidy et al., 1993; David, 2005). Several observational methods to evaluate upper extremity work are described in the literature. These include: Upper Extremity Checklist (UEC) (Keyserling et al., 1993); Rapid Upper Limb Assessment (RULA) (McAtamney and Corlett, 1993); Rapid Upper Limb Assessment for Computer Users (Lueder, 1996); The Strain Index (Moore and Garg, 1995); the Postural and Repetitive Risk-Factors Index (PRRI) (James et al., 1997), a rating scale for assessing repetitive hand tasks (Latko et al., 1997) and the OCRA (Colombini, 1998). Although these instruments have been show to be useful to examine jobs where workers do many different hand intensive tasks, for an observational tool to be useful for assessing keyboard use the instrument must be able to both document postures and actions of the body, arms, hands, and digits, and be able to differentiate between individuals performing the same task. While each of the above observational instruments addresses some of these requirements, none appear to meet both. For example, The Rapid Upper Limb Assessment for Computer Users described by Lueder and colleagues (1996) evaluates body and wrist postures, but does not evaluate hand and digit postures; the method described by Latko et al. (1997) is a useful to quantify hand use in diverse assembly tasks, but lacks the detail needed to discriminate between users who perform the same task but whose postures and actions differ. Thus, there is currently no reliable and accurate assessment tool available that can be used to document the postures and actions of the neck, arm, hand, and digits during keyboard use.

A new observational instrument, the Keyboard Personal Computer Style instrument (K-PeCS), has been developed to assess computer keyboarding style; commonly seen stereotypical upper extremity postures and coordinated movements associated with computer keyboard use. The general development of the items used in this instrument are detailed elsewhere (Baker and Redfern, 2005), but the measurement properties of the instrument have yet to be described.

The purpose of this study was to describe the inter-rater reliability, intra-rater reliability, and concurrent validity of the K-PeCS instrument. Reliability is defined as the reproducibility of K-PeCS items within and across raters. Validity, or the extent to which an instrument measures what it is intended to measure, has several constructs associated with it. For this study we looked at concurrent validity which assesses the accuracy of an instrument in comparison to a "gold standard" (Gandek and Ware, 1998; Portney and Watkins, 2000). We compared the ratings obtained with the K-PeCS instrument to kinematics recorded using a VICON™ motion system as the "gold standard". The VICON™ simultaneously measured the kinematics of each subject's keyboard use while it was being captured on video for analyses by raters using the K-PeCS.

2. Method

This study was approved by the Institutional Review Board of the University of Pittsburgh.

2.1. Subjects

Forty-five computer users between the ages of 18 and 65 were recruited from faculty, staff, and students of the University of Pittsburgh. Subjects had to be familiar with using a computer and to be able to use a keyboard continuously for 20 min. Both expert and non-expert typists were recruited in order to obtain a variety of different keyboarding styles. The subjects' mean age was 33.1 years ($\pm$12.7). They were 71% female (32), 73% white (33), and 91% (41) right handed, with approximately half (24, 53%) reporting that they had touch typing training (expert typists). The mean hours of computer use a day was 5.3 ($\pm$2.7).

2.2. K-PeCS instrument

The K-PeCS is a 19-item rating instrument that documents the frequency of stereotypical motions and postures that are used by computer keyboard users during routine keyboarding tasks. Many of the items are divided into right and left side measurements, and for the digit postures, they are also broken down by digits 2 through 5. This allows for more concise identification of body and hand postures. K-PeCS items can be divided into three general categories: items of static posture in which the keyboard user's postures remain essentially unchanging; items of dynamic posture (frequencies) in which the keyboard user periodically assumes a posture thought to be a risk factor for MSD-UE, but does not necessarily maintain that posture throughout the task; and items of force and tension which describe keyboard activation forces and the use of supports. Table 1 lists the items rated on the K-PeCS. For all items the rater observes the keyboard user and determines which criteria for each item best matches the user's keyboarding style.

2.3. Laboratory set-up

The subjects used a keyboard at a computer workstation set-up in a laboratory (Fig. 1). Although the desktop height remained at a constant 29″ to standardize video and VICON™ camera angles, the subjects were allowed to adjust the chair to conform to their preferred workstation configuration. If necessary, foot support was provided.

Table 1
Items on the K-PeCS and their rating criteria

#	Item	Question on the K-PeCS	Rating
Items of static posture			
1	Torso angle	Generally, what is the angle of the keyboard user's torso to the horizontal plane?	(1) The torso angle to the horizontal plane is greater than 105° (2) The torso angle to the horizontal plane is between 90° and 105° (3) The torso angle to the horizontal plane is less than 90°
3	Neck flexion angle	Generally, what is the displacement angle and position of the head?	(1) Head forward less than 10° (2) Head forward between 11° and 20° (3) Head forward between 21 and 30° (4) Head forward greater than 30°
4	Shoulder flexion angle	Generally, what is the flexion angle of the shoulders?	(1) 0–20° (2) 21–35° (3) >35°
5	Elbow flexion angle	Generally, what is the angle of the elbows?	(1) <79° (2) 80–120° (3) >120°
Items of dynamic posture			
8	Wrist/hand movement(displacement)	Does the keyboard user move his/her hands while typing?	(1) The keyboard user moves his/her hand occasionally to reach for keys (2) The keyboard user moves his/her hand often to reach for keys (3) The keyboard user moves his/her hand most of the time to reach for keys
10	Wrist ulnar angle	Does the keyboard user exceed 20° of ulnar deviation?	(1) Never exceeds 20° ulnar deviation (2) Occasionally exceeds 20° ulnar deviation (3) Frequently exceeds 20° ulnar deviation (4) Always exceeds 20° ulnar deviation
11	Wrist extension angle	Does the keyboard user exceed 15° of wrist extension?	(1) Never exceeds 15° wrist extension (2) Occasionally exceeds 15° wrist extension (3) Frequently exceeds 15° wrist extension (4) Always exceeds 15° wrist extension
12	Changes in pronation	Does keyboard user ever rotate his/her forearm (increase pronation or supination)?	(1) Yes, the keyboard user does rotate his/her forearm (2) No, the keyboard user does not rotate his/her forearm
13	Isolated 5th digit	Does the keyboard user isolate the 5th digit?	(1) Never isolates the 5th digit (2) Occasionally isolates the 5th digit (3) Frequently isolates the 5th digit (4) Always isolates the 5th digit
14	Isolated thumb	Does the keyboard user isolate the thumb?	(1) Never isolates the thumb (2) Occasionally isolates the thumb (3) Frequently isolates the thumb (4) Always isolates the thumb
15	Space bar activation	What finger does the keyboard user use to strike the space bar?	(1) Right thumb (2) Right index (3) Other
16	No. of digits used to type	How many digits does the keyboard user use to strike the keys?	(1) 1 digit (2) 2 digits (3) 3 digits (4) 4 digits (5) 5 digits

Table 1 (*continued*)

#	Item	Question on the K-PeCS	Rating
17	MCP hyperextension	Does the keyboard user hyperextend the MCP joints?	(1) Never hyperextends the MCP joint (2) Occasionally hyperextends the MCP joint (3) Frequently hyperextends the MCP joint (4) Always hyperextends the MCP joint
18	PIP/DIP curve	Are the keyboard user's PIP/DIP joints generally curved (>25°) or generally straight (<25°)?	(1) PIP/DIP curved (2) PIP/DIP straight
19	Hypermobility	Do the DIP joints ever "collapse" when the digits strike the keys (hypermobility)?	(1) No, the DIP does not collapse (hyperextend) (2) Yes, the DIP does collapse (hyperextend)
Items of force or tension			
2	Back rest use	Does the keyboard user rest at least 2/3 of the back against the back rest while using the computer?	(1) Yes, the keyboard user rests 2/3 of the back against the backrest all the time (2) Yes, the keyboard user rests 2/3 of the back against the backrest during breaks (3) No, the keyboard user does not rest 2/3 of the back against the backrest
6	Forearm support use	Does the keyboard user support his/her forearms/elbows on an arm rest or table?	(1) Yes, both forearms/elbows (2) No, the right forearm/elbow is unsupported (3) No, the left forearm/elbow is unsupported (4) No, both forearms/elbows are unsupported
7	Wrist support use	Does the keyboard user support his/her wrist(s) on the wrist pad or table?	(1) Yes, the wrist is supported while using the keyboard (2) The wrist is unsupported while using the keyboard, and supported during pauses. (3) No, wrist is never supported.
9	Force	Generally, what kind of force does the keyboard user use to strike the keys?	(1) Low force (2) Moderate force (3) High force

All items except 1, 2, 3, and 9 are measured on both the right and left sides; Items 17 and 18 are measured separately for digits 2–5.

Subjects typed from an electronic keyboarding program, Typing Master Pro™,[1] which automatically advanced the text as the keyboard user progressed. This program also documented typing rate and speed.

Five digital video cameras were positioned around the subject (as shown in Fig. 1), three with the field of vision focused on the wrists and hands only, and two positioned to capture full body movements. The VICON™,[2] a motion measurement system (VICON 612 system with 5 M2 cameras) was positioned around the computer workstation to capture 3-dimensional data. The hand, wrist, and digit movements were derived from tracking 42 passive markers positioned on the dorsal surface of both hands. This passive system (no hard-wires) and the markers small size (4 mm) helped to reduce the chances that the measurement system was changing movement patterns. The set-up of the VICON™, marker placement, and the models used to develop the kinematics are described more fully elsewhere (Baker et al., 2007a).

2.4. Protocol

Informed consent was obtained after subjects had been orientated to the purpose of the study. After the subjects had completed a demographic questionnaire, VICON™ markers were attached to the subjects' hands and wrists (Cook et al., 2007). The subjects typed for a total of 20 min. No data were collected during the first 10 min to allow the subjects time to acclimate to the laboratory workstation. Then 3 1-min trials of the synchronized VICON™ and video data spaced out over the second 10-min time period were collected (one trial at the start of the 10 min, one trial at 5 min, and 1 trial at 9 min). Only 1 min of data acquisition was required as keyboarding is highly stereotypical (Martin et al., 1996; James et al., 1997).

[1]Typing Master Finland, Inc., Helsinki, Finland—http://www.typing-master.com/index.asp?go=company

[2]Vicon Motion Systems Inc., Lake Forest, CA, USA—http://www.vicon.com/jsp/index.jsp

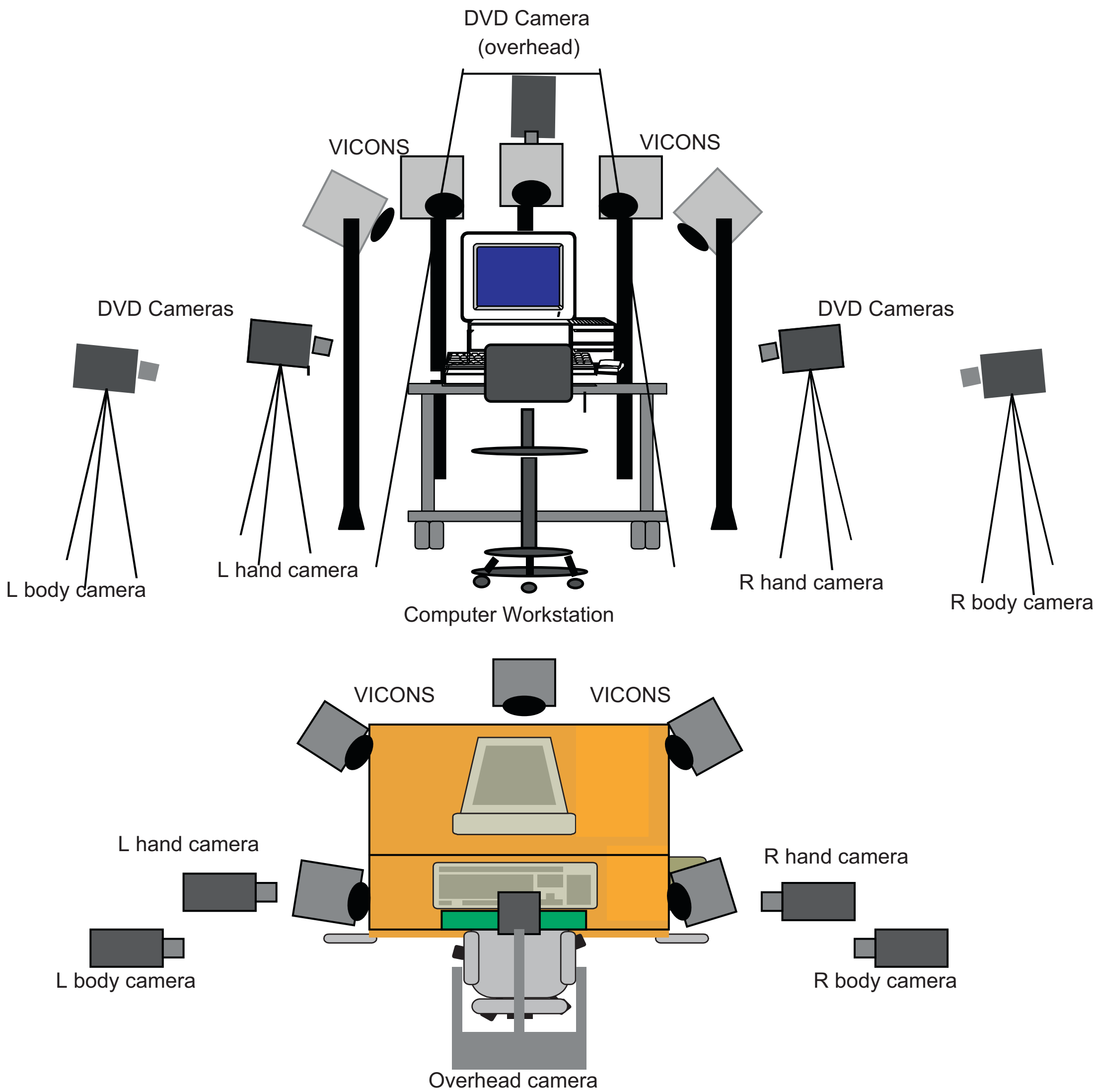

Fig. 1. Configuration of the data acquisition equipment.

2.5. Data processing and data analysis

Video recordings from one trial for each subject was digitized into a video movie (clip) that had all five views (right full body, right hand, left full body, left hand, and overhead). Prior to video assessment, three raters, all experienced occupational therapists, were trained to use the K-PeCS. First, raters rated practice clips together. If ratings did not agree, the raters discussed methods to further define the criterion that constituted each item so that ratings could reach consensus. If consensus could not be reached, the developer of the instrument (NB) was considered to be the gold standard. Refinements in criteria were documented in a rating manual which was provided to the raters. Once the raters demonstrated good reliability on group rated items, they were given clips to rate independently. To assess inter-rater reliability they independently rated 45 clips with the K-PeCS. The three raters also rated a subset of 15 clips twice, with at least a week between each rating, to establish intra-rater reliability.

To evaluate the validity of the K-PeCS rating system, the VICON™ data for items #8, 10, 11, 13, 14, 17, and 18 (Table 1) were first converted into angles as a function of time (for postures) or pathlengths (for hand displacement) using methods described elsewhere (Cook et al., 2007). A program was developed in LabVIEW 7.1[3] to quantify equivalent values that could easily be compared to the raters' evaluations using the K-PeCS. A comparison was then made between the raters and the motion analysis values.

The following describes the methods used to develop each VICON™ value related to the K-PeCS score:

- *Hand/wrist movement (displacement) (Item #8)*: For hand/wrist movement or displacement a keyboard user moves the entire wrist/hand unit to strike the keys rather than just reaching with the digits. Hand/wrist

[3]National Instruments Corporation, Austin Texas—http://www.ni.com/

displacement was quantified as the pathlength of the position timeseries of a virtual marker at the midpoint between the ulnar and radial styloids. Increased values resulted from increased hand displacement in the plane of the desk.

- *Duration of wrist and finger postures (Items #10, 11, 14, 17)*: These K-PeCS items evaluated the time (never, occasionally, frequently, or always) spent in a posture exceeding a target angle (see Table 1 for target values). For example, the target wrist angle was 20° of ulnar deviation (Item #10) and 15° of extension (item #11). The time duration was calculated from the VICON™ data as the percentage of time that the angular deviation of a body part exceeded its corresponding target angle.
- *5th digit isolation (Item #13)*: Several studies (Rose, 1991; Pascarelli and Kella, 1993; Baker et al., 2007b) have commented that keyboard users may hyperextend and/or adduct their 5th digit continuously while engaged in typing tasks. This K-PeCS item evaluated the time (never, occasionally, frequently, or always) spent in a posture exceeding the target angles. The program calculated the amount of time the 5th digit MCP was extended or adducted more than 0°, resulting in two values. These values were divided by trial length resulting in the percentage of time that the MCP was adducted or hyperextended. Higher percentages meant that the 5th digit was more often in an isolated posture.
- *PIP/DIP curved (Item #18)*: The amount of time that the PIP joint of the 2nd, 3rd, 4th, or 5th digits was flexed greater than the target angle of 25° was calculated. These values were divided by the trial length resulting in a percentage of time that the PIP joints of each of the digits were curved.

2.6. Statistical analysis

Intra-class correlation coefficients (ICC) were used to calculate the reliability of each item and the overall K-PeCS instrument (Shrout and Fleiss, 1979). Where appropriate, right and left side measurements as well as individual finger measurements were combined to form one composite measurement for each item assessed.

Concurrent validity was assessed on a sub-sample of 15 subjects rated by the same rater (NB). A non-parametric test, the Kruskal Wallis one-way analysis of variance by ranks test, was used as the K-PeCS data were both ordinal and not evenly distributed. This analysis first combines all data into a single group and ranks it from lowest to highest. The ranks from each grouping variable are then summed separately (Portney and Watkins, 2000). For our analyses the K-PeCS rating acted as the grouping variable for each item. We then looked to see if those subjects rated as "never" had a smaller summed ranking than those subjects rated as "occasional", and those rated "occasional" had a smaller summed ranking than those rated as "frequent", etc. If the null hypothesis were true we would expect the summed ranks to be equally distributed between the groups, if the alternate hypothesis was true we would expect to see differences in the distribution of rankings. If significance was achieved, we completed Mann–Whitney U tests to identify which items were significantly different from each other.

3. Results

The overall K-PeCS inter-rater ICC was .90 ($p<.001$), which indicates that the instrument, as a whole, had excellent reliability. The inter-rater reliability of individual items was generally above .75 ($p<.001$) which is indicative of good reliability (Portney and Watkins, 2000) (see Table 2). Notable exceptions were the torso angle (ICC = .71; $p<.001$), force (ICC = .67; $p<.001$), isolated thumb (ICC = .63; $p<.001$) and hypermobility (ICC = .33; $p<.001$).

Intra-rater reliability was also excellent (ICC = .92; $p<.001$). A pattern of lower reliability levels for individual items was noted for some of the same items found to have poor inter-rater reliability: force (ICC = .67; p = .04) and isolated thumb (ICC = .62; $p<.001$), although torso angle and hypermobility had good intra-rater reliability. In addition, ulnar deviation angle (ICC = .71, $p<.001$) and PIP/DIP curve (ICC = .73; $p<.001$) had only moderate intra-rater reliability.

Table 3 lists each K-PeCS item with the VICON™ score for each criterion; the mean pathlength in millimeters for hand displacement, and the mean percent time that each

Table 2
Inter-rater and intra-rater reliability of the K-PeCS

#	Item	Inter-rater reliability (ICC)	Intra-rater reliability (ICC)
1	Torso angle	0.71	0.87
2	Back rest use	0.87	0.93
3	Neck flexion angle	0.85	0.81
4	Shoulder flexion angle	0.93	0.96
5	Elbow flexion angle	0.95	0.93
6	Forearm support use	0.87	0.80
7	Wrist support use	0.94	0.94
8	Wrist/hand movement	0.75	0.79
9	Force	0.67	0.67
10	Wrist ulnar angle	0.77	0.71
11	Wrist extension angle	0.89	0.87
12	Changes in pronation	0.85	0.83
13	Isolated 5th digit	0.90	0.87
14	Isolated thumb	0.63	0.62
15	Space bar activation	0.86	0.90
16	No. of digits used to type	0.91	0.83
17	MCP hyperextension	0.93	0.94
18	PIP/DIP curve	0.89	0.73
19	Hypermobility	0.33	0.78

All p-values were significant at $<.001$.

Table 3
Ranking of the scores obtained using the VICON™ by scores obtained using the K-PeCS

Item	*n*	Item rating	Mean (*sd*)	*p*-Value
			mm/min	
#8—Wrist/hand movement	23	Occasionally	1843.7 (626.1)[bc]	<.001
	5	Frequently	3284.7 (972.3)[ac]	
	6	Most of the time	3691.6 (1042.0)[ab]	
			% time	
#10—Wrist ulnar angle	9	Never	29 (41)	.69
	3	Occasionally	29 (47)	
	9	Frequently	33 (37)	
	13	Constantly	43 (42)	
			% time	
#11—Wrist extension angle	17	Never	80 (25)[bcd]	.001
	4	Occasionally	99 (01)[a]	
	9	Frequently	98 (04)[a]	
	4	Constantly	99 (00)[a]	
			% time	
#13—Isolated 5th digit	10	Never	10 (14)[cd]	<.001
	4	Occasionally	20 (23)[d]	
	9	Frequently	34 (28)[ad]	
	9	Constantly	78 (19)[abc]	
			% time	
#14—Isolated thumb	19	Never	53 (38)	.15
	7	Occasionally	81 (31)	
	3	Frequently	67 (40)	
	3	Constantly	94 (10)	
			% time	
#17—MCP hyperextension	93	Never	6 (11)[bcd]	<.001
	12	Occasionally	19 (19)[ad]	
	11	Frequently	24 (7)[ad]	
	20	Constantly	28 (6)[abc]	
			% time	
#18—PIP/DIP curved	23	No	87 (22)	<.001
	113	Yes	32 (30)	

All items combined results from the right and left sides. Items 17 and 18 also included results from digits 2 to 5. The superscript letters indicate which means were significantly different from each other at $p \leqslant .01$.

criterion was exceeded for all other items. For most of the items, the mean ranking of the VICON™ score by K-PeCS criteria indicated that those items rated as occurring "never" were smaller than those rated as "occasionally", which were smaller than those rated as "frequently", which were smaller than those rated "constantly", or in the case of dichotomous ratings, the ranking of an item that did not occur was lower than the ranking of an item that did occur. The exceptions were for wrist ulnar deviation angle ($p = .69$), and isolated thumb ($p = .15$). In these cases the rankings for two of the ratings were reversed; "never" and "occasionally" for wrist ulnar angle, and "occasionally" and "frequently" for isolated thumb. All items that had the correct ranking order also achieved significance, indicating that there was a significant difference between at least two of the rankings. Post hoc analysis (Table 3) shows the results of the Mann *U* Whitney and indicates which criteria were significantly different for each item.

4. Discussion

The K-PeCS demonstrated good overall reliability, suggesting that, with trained, experienced occupational therapists as raters, the performances of keyboard users can be reproduced between raters and from time to time. The ranking of the VICON values by K-PeCS criteria suggests that the K-PeCS was adequately identifying different motions and different frequencies. Raters were able to accurately discriminate the motions and patterns demonstrated by keyboard users, and rate those motions according to simple frequencies. This suggests that the K-PeCS has adequate concurrent validity, at least for those items evaluated. That the K-PeCS appears to have concurrent validity, as well as content validity (Baker and Redfern, 2005) suggests that it can accurately describe items of typing style in keyboard users.

As with other observational instruments, the K-PeCS has several advantages over direct measurements: it is quick to administer, requiring about 10 min to complete; the results are easy to interpret, and require no additional calculations or manipulations to identify potential problem areas; and, although it was not used onsite in this study, it can be used for either live or videotaped evaluations. The K-PeCS, therefore, appears to be a useful method to document many items of computer keyboarding style.

However, the K-PeCS has several limitations. Although the instrument is, as a whole, reliable, several individual items had poor to moderate reliability; both inter-rater reliability and intra-rater reliability had four items lower than .75. The lower reliability related to items assessing postures, such as torso angle and wrist ulnar deviation, is probably related to the difficulty of consistently identifying the axis and moment arms of the angle on the body. For torso angle it is particularly difficult to identify the exact position of the greater trochanter of the femur on which to place the axis, particularly if the subject is heavy or wearing dark clothing. It is also difficult to determine a "straight" line for the torso from the greater trochanter to the shoulder acromion process, particularly if the torso is slumped forward or if the shoulder is protracted. Marking these two points prior to rating this item might increase its reliability. Rating ulnar deviation has been reported to be a problem in other studies (Spielholz et al., 2001). For this instrument it was difficult to rate this motion reliably as some subjects displaced their hands during typing, which shifts the base of the 3rd metacarpal. In addition it is sometimes unclear whether the wrist is extended or ulnarily deviated when using a video to make this determination. Marking the base of the 3rd metacarpal and rating a live subject instead of a video image may improve this reliability.

Reliability for rating the isolated thumb, particularly on the left, requires the rater to determine whether the thumb is held in a position of tension or is simply resting without moving. This determination is somewhat subjective, and explains the low reliability for this item. These items reliability can be improved by having raters indicate whether the thumb is adducted at the palm or above the palm level, and ignoring any other tension indicators.

The moderate reliability of the item on force for this study was somewhat surprising. During instrument development several iterations of reliability were completed to help define the items. In previous reliability trials, force had an ICC of .93, indicating excellent reliability. Just prior to this final rating session, each item was reviewed with the raters, and it was noted to them that most of the force ratings were moderate, with only occasional ratings of high or low force. It is possible this comment caused the raters to over think their force responses, and try to second guess what force score to give. Despite moderate reliability, the associations between force and MSD-UE cited in the literature (Pascarelli and Kella, 1993; Feuerstein et al., 1997; Rempel et al., 1997) suggest that having a measure of force is an important item for an instrument describing keyboarding style. Those using the K-PeCS to evaluate keyboarding style for epidemiological studies may benefit from using a consensus method to rate keyboard force and other items with lower reliability.

The items that did not have significant concurrent validity were those items, which only had moderate reliability (ulnar deviation and thumb isolation). Improving the reliability of these K-PeCS items should also help to improve the concurrent validity. While the K-PeCS demonstrated good concurrent validity for most of the items measured, many items were not measured, such as torso, shoulder, and elbow postures and, therefore, the validity of these items is still questionable. Further study of the concurrent validity of other items would strengthen the psychometrics of the K-PeCS.

We anticipate as others start to use the K-PeCS to document items of keyboarding style, they will start to identify which items provide useful information. Thus, as the K-PeCS is used, it will continue to be refined. For example, readers examining the previous discussion of the K-PeCS (Baker and Redfern, 2005) will identify that the following items have been omitted from this most recent version of the K-PeCS; shoulder position, "bouncing" wrist, changes in ulnar angle, finger enslavement, and overall hand tension. These items were omitted after several iterations of developing the criteria indicated that it was impossible to objectively define the constructs; this lead to very poor consensus amongst the raters. These items were therefore removed from the final instrument. In addition, new items were added as postures or styles were identified during the continued observation of individuals using a keyboard. These items were torso angle, backrest use, and forearm support.

Those interested in using the K-PeCS should note that in this study we did not examine whether individuals from other disciplines (e.g. ergonomists, human factors personnel) could achieve the same level of reliability. Therefore, whether the K-PeCS could be used reliably by individuals who are not occupational therapists is not known. In addition, while the K-PeCS identifies items of keyboarding style that have been associated with MSD-UE in the literature (Baker and Redfern, 2005), there is no data which suggests that any K-PeCS item can actually identify those who have MSD-UE or who have the potential to develop MSD-UE.

We are currently completing studies to examine the predictive validity of items of the K-PeCS. We hope to be able to build a predictive model to identify which items discriminate between individuals with and without MSD-UE. These models could be used to develop a taxonomy of different keyboarding styles. Style would be defined as a combination of the individual K-PeCS items describing a keyboardist's postures and movements. By defining styles, important interactions among posture and motions, as well as individual risk factors, can be incorporated in the identification of those individuals who may be at risk for MSD-UE. This has been suggested as an important feature influencing prediction of MSD-UE (Moore et al., 1991; Feuerstein, 1996; Sommerich et al., 1996).

In the long-term, the utility of the final K-PeCS instrument will be in the ability of individual items and ultimately overall styles to discriminate between those with and without MSD-UE. Although it cannot yet be used to identify those at risk for MSD-UE, the K-PeCS provides therapists and potentially other personnel with the ability to accurately and reliably document items of personal keyboarding style.

Acknowledgments

The authors would like to acknowledge the support of Grant #5 K01 OH007826–01A1 from the National Institute for Occupational Safety and Health, the Competitive Medical Research Fund of the UPMC Health System, and University of Pittsburgh Central Research Development Fund. They would also like to thank Erin Hale, Rakie Cham, Norman Gustafson, and Emily Eckel for their assistance in developing the K-PeCS.

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