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The Association Between Rheumatoid Arthritis Related Structural Changes in Hands and Computer Keyboard Operation

Nancy A. Baker · Norman P. Gustafson · Joan Rogers

Abstract *Introduction* This cross-sectional study examined the effect of structural changes caused by rheumatoid arthritis (RA) on computer keyboarding style to provide insights on how changes may affect worker performance. *Method* Computer keyboarding styles, as measured by the keyboard-personal computer style instrument, were compared between 45 keyboard operators with RA and 29 without. A severity of structural changes score (SSCS) was assigned after recruitment by observing subjects' hands while operating a keyboard. Significant differences between each item of keyboarding style by diagnosis were identified through Chi square analyses. Logistic regression models with age, diagnosis, SSCS, and touch typing training as the predicators further evaluated the effect of structural changes on each item of personal keyboarding style. *Results* Significantly more keyboard operators with RA used high force keystrokes, did not use a wrist rest, moved their hands to strike keys, maintained their wrists and fingers in a fixed position and used fewer than two fingers to activate keys. The amount of variance explained by each model varied from 8 to 56%. SSCS was the most common predictor of keyboarding style (54% of significant models), followed by age (35% of significant models), diagnosis (19% of significant models), and touch typing training (15% of significant models). *Conclusion* Severity of structural changes and age are significant predictors of keyboarding style for computer operators with RA. The keyboarding styles used by computer operators with RA appear to reduce typing productivity and have the potential to put stress on joints already affected by RA. Computer operators with RA may benefit from worksite modifications that address keyboarding style such as alternate keyboards.

Keywords Occupational health · Biomechanics · Arthritis · Joint disease · Typing · Productivity

Introduction

Injuries and disorders which cause structural changes to the architecture of the hand, such as rheumatoid arthritis (RA), scleroderma, flexor tendon injuries, or burns, can cause temporary or permanent work disability [1]. Hand and finger injuries are the second most common cause of lost days at work of any type of injury [2]. The average time off work is 8–10 weeks [1, 3], although more severe trauma leads to longer periods of sick time [3, 4]. Despite injuries, over 84% of those injured return to employment by 1-year post injury [1, 3, 4]. While traumatic injuries are a significant cause of work disability, diseases that cause progressive structural changes to the hand also have a profound effect on long term work disability.

Rheumatoid arthritis is a progressive systemic autoimmune disease that affects synovial joints and associated tendons and ligaments. Studies suggest that workers with RA have a high prevalence of premature work cessation [5–8], with a recent US study [9] reporting that the prevalence of premature work cessation was 23% in the first 1–3 years post diagnosis, and 35% after 10 years. There has been only limited research on the effect of hand structural changes on work performance specifically in workers with RA. People with RA often have significant structural deformities of the hands such as carpal subluxation, metacarpophalangeal (MCP) volar subluxation, swan neck or boutonnière deformities, and ulnar drift. Studies

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have suggested that structural changes associated with RA are associated with limitations in hand function such as decreased grip, dexterity, and general motor performance [10–12]. Hand function is a key requirement for employment, and 83% of workers with RA report extensive occupational hand use [13]. Thus, structural changes in the hand should be a predictor of work disability. However, a recent systematic review [14] of predictive factors of work disability for workers with arthritis, reported that structural changes were inconsistently associated with work disability; in some studies they were strong predictors and others they were not predictive at all. This seeming inconsistency, that structural changes limit hand function, an important requirement for many job tasks, yet does not consistently predict work disability, suggests that further analysis is needed to examine the association between specific hand intensive work tasks and the presence of structural changes to elucidate the connection between structural changes in hand architecture and work performance.

One hand intensive task that is common for many workers is computer operation [15, 16], including entering information using a computer keyboard. To operate a standard keyboard, workers must be able to accurately strike individual keys, requiring both stability and mobility of the proximal and distal muscle systems. The degree to which each of these muscle systems is used depends upon the skill of the typist (i.e., whether the keyboard operator has been trained in touch typing) and the structural integrity of the wrists, hands, and digits. The actual key strike is accomplished through a complex interaction of intrinsic and extrinsic muscle activation at the MCP and proximal interphalangeal (PIP) joints: including the extensor digitorum communis and lumbricals to extend the digit in preparation for keystrike, and the extrinsic flexors and lumbricals to overcome resistance during the key strike [17]. In addition to motions at the MCP/PIP joint, the keyboard operator initiates movements and forces at the wrists and elbows. An additional consideration for typing is the distal transverse arch at the metacarpal head level which causes the hand to slope downward from the index finger side to the small finger side at the level of the MCP joint, creating a curved structure [18]. Keyboard operators must functionally adapt to the typically non-adjustable, flat surface of a standard keyboard by "flattening" the transverse arch to accomplish the task of typing. This "flattening" is typically accomplished by extending the 3rd, 4th, and 5th MCP joints to almost 75% of their full range. This extension results in approximately 30% maximum voluntary contractions of the finger extensors [19]. In many cases, the keyboard operator will hyperextend the MCP joint, and also either fully extend or fully flex the PIP/distal interphalangeal (DIP) joints [19–21]. These flattening postures require flexibility of the hand joints, as well as adequate digit extension, in particular the extensor digitorum communis. [22]. Since workers with RA can experience fixed structural changes at the wrist joints (volar subluxation), MCP joints (volar subluxation and ulnar drift), and PIP joints (swan neck and boutonnière deformities) as well as the potential for rupture of the extensor digitorum communis, they may have significant difficulty positioning themselves to operate the keyboard and activate the keys.

Research on computer keyboard operation has identified that task performance when using a keyboard varies between keyboard operators, even those without structural changes [23]. Aspects of keyboard task performance, also called personal keyboarding style, such as the number of fingers used, body, wrist and hand postures, and force, are related to typing speed [24] and can differ between the left and right sides [23]. Examining the general effect that a diagnosis of RA has on personal keyboarding style, and the more specific effect that structural changes related to RA has on personal keyboarding style can provide further insights into the effect structural changes have on worker performance. This study, therefore, examined the effect of structural changes on keyboarding performance in two ways. First, it compared the personal keyboarding style of those with RA to those without RA, without including the extent to which the keyboard users had structural changes. Second, it examined the effect of structural changes by modeling the associations between personal keyboarding style and predictors of keyboarding style including age, diagnosis, severity of structural changes, and training in touch typing. The research questions examined in this study: are there significant differences in keyboarding style between people with and without a diagnosis of RA; and what predictors (age, severity of structural changes, training in touch typing, or a diagnosis of RA) best explain differences in keyboarding style and productivity?

Method

Study Design

This was a cross-sectional study with an historical comparison cohort.

Subjects

Subjects with RA were recruited from the University of Pittsburgh Medical Center (UPMC) Arthritis Network Research Registry. This IRB-approved registry recruits people with arthritis diagnoses, such as RA, fibromyalgia, osteoarthritis, osteoporosis, and gout, from one University-based and two community-based rheumatology practices in western Pennsylvania. Patients interested in participating in arthritis-related studies are placed on the Registry's confidential list. The Registry is an honest broker system; studies using the system are not provided with a list of the registrants. Instead, to access registrants, principal investigators submit an IRB-approved recruitment letter. The Registry mails the letter with their own cover letter to registrants who meet study inclusion criteria, such as age or diagnoses. Registrants interested in participating in a study contact study personnel. The Registry provides study personnel with the number of registrants meeting study inclusion criteria, but does not provide any other identifying information, so it is impossible to compare respondents with non-respondents. For this study 1,100 registrants met the inclusion criteria. Subjects with RA were included in this study if they were adults with RA, had experience using the computer, and reported having some involvement of the upper extremity. They were excluded if they: experienced co-morbidities in the upper extremities, such as active neurological disorders or fractures, had other rheumatic diseases, were not able to type continuously on a keyboard, or did not speak English.

The comparison cohort, subjects without RA, was recruited for a study examining the reliability of an instrument which measured personal keyboarding style: the keyboard-personal computer style (K-PeCS) instrument. These subjects were recruited from faculty, staff, and students of the University of Pittsburgh. Subjects had to be: between the ages of 18 and 65, familiar with using a computer, and able to type on a keyboard continuously for up to 20 min. Both studies were approved by the University of Pittsburgh Institutional Review Board.

Instruments

Severity of Structural Changes Score

The severity of structural changes score (SSCS) provides a marker of the number and severity of the RA-related structural changes to the hands. Raters examined each subject's hands on video tape for the following visible structural changes: carpal subluxation, ulnar dorsal subluxation, MCP volar subluxation, intrinsic plus positioning, swan neck deformity, boutonnière deformity, ulnar drift, Type I thumb deformity, Type III thumb deformity, Heberden's nodes, Bouchard nodules, wrist fixed in flexion, and/or intrinsic atrophy. Based on the number and severity of the observed changes, each subject's hands were rated as no visible structural change (hand had no visible structural changes), mild to moderate structural changes (hand had two or less visible structural changes and these were mild) or severe structural changes (hand had three or more visible structural changes or the changes were severely deforming). The right and left side scores were summed to provide an SSCS from 2 to 6, with a score of 2 indicating no visible structural changes. All subjects without RA were given an SSCS of 2, as they had none of the above structural changes.

Keyboard—Personal Computer Style Instrument

Computer keyboard postures and behaviors were obtained using the keyboard-personal computer style instrument (K-PeCS), a 19-item criterion based observational instrument [25]. The K-PeCS documents three general categories of keyboard postures and behaviors: items of static posture, dynamic posture, and tension and force. Items of static posture are body postures that remain essentially unchanged (torso angle, neck angle, shoulder angle, and elbow angle; Table 1). These items are rated using ordinal ratings that describe a range of item specific postures (e.g., Shoulder angle: ≤20°, 20°–30°, >30°). Items of dynamic posture occur with different frequencies in different operators (hand displacement, wrist ulnar deviation >20°, wrist extension >15°, changes in pronation, isolated fifth digit, isolated thumb, number of fingers, space bar activation, MCP hyperextension, PIP/DIP curve and DIP hypermobility) and are primarily rated using either dichotomous ratings of occur/does not occur or ordinal scales of frequency or degree to which the keyboard operator exceeds a criterion posture (i.e., never, occasional, frequent, always). Items of tension and force describe keyboard activation forces (low, moderate, high) and the use of supports (backrest use, forearm support, wrist support) [26]. The K-PeCS has demonstrated good inter-/intra-rater reliability and validity [26] as well as the ability to distinguish between individual keyboard operator's behaviors [23].

Productivity

Subjects typed a standard paragraph. Speed (words per minute), gross accuracy (percent correct), and net speed (words per minute/accuracy) were acquired with TypingMaster Pro$^{\text{TM}}$,[1] an on screen typing test program.

Video Recordings

Three digital video recordings of the subjects were made for rating with the K-PeCS, two lateral views of the wrist and hands (right and left) and one overhead view of the wrists and hands. In addition two full body lateral digital pictures (right and left) were taken to document body postures.

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[1] TypingMaster Finland, Inc., available at http://www.typingmaster.com/.

Table 1 Items on the K-PeCS and the results of chi square and logistical regression

K-PeCS item	Scoring	Side	Chi Sq.	Regression	
			P	R^2	*P*
Torso angle	1) Upright (90°–105°)		0.25	–	0.13
	2) Leaning (<90°, >105°)				
Back rest use	1) Yes		0.06	0.13	0.009
	2) No				
Neck flexion angle	1) Neutral (≤10°)		<0.001	0.26	<0.001
	2) Non-neutral (>10°)				
Shoulder flexion angle	1) Neutral (≤20°)	*R*	0.22	–	0.13
	2) Non-neutral (>20°)	*L*	0.001	0.29	<0.001
Elbow flexion angle	1) Neutral (80°–120°)	*R*	0.53	–	0.15
	2) Non-neutral (<80°, >120°)	*L*	0.96	0.08	0.05
Forearm support use	1) Yes		0.48	–	0.54
	2) No				
Forearm rotation	1) No forearm rotation	*R*	0.76	0.10	0.02
	2) Forearm rotation	*L*	0.32	0.14	0.02
Wrist support use	1) Yes	*R*	0.006	0.29	<0.001
	2) No	*L*	0.001	0.40	<0.001
Hand displacement	1) Does not move hands	*R*	<0.001	0.42	<0.001
	2) Moves hands	*L*	<0.001	0.56	<0.001
Wrist ulnar angle	1) Neutral (≤20°)	*R*	0.004	0.22	<0.001
	2) Non-neutral (>20°)	*L*	0.003	0.24	<0.001
Wrist extension angle	1) Neutral (≤15°)	*R*	0.76	–	0.14
	2) Non-neutral (>15°)	*L*	0.19	0.14	0.03
Force	1) Low/moderate force		0.04	0.11	0.02
	2) High force				
Isolated 5th digit	1) Neutral (no 5th isolation)	*R*	0.16	0.17	0.002
	2) Non-neutral (5th isolation)	*L*	0.88	0.08	0.04
# of digits to type	1) Two finger typist (≤2 digits)	*R*	0.004	0.20	0.002
	2) Multi-finger typist (3–5 digits)	*L*	0.02	0.21	0.006
MCP hyperextension	1) Neutral (MCP extension ≤0)	*R* 4th	0.009	0.19	0.001
	2) Non-neutral (MCP extension >0)	*R* 5th	0.005	0.18	0.001
		L 4th	<0.001	0.47	<0.001
		L 5th	0.007	0.22	<0.001
PIP/DIP curve	1) Curved	*R* 4th	0.17	0.25	0.001
	2) Straight	*R* 5th	0.17	–	0.07
		L 4th	0.11	0.41	<0.001
		L 5th	0.51	0.23	0.001
DIP hypermobility	1) No	*R*	0.83	–	0.20
	2) Yes	*L*	0.01	0.13	0.01

MCP metacarpophalangeal; *PIP* proximal interphalangeal; *DIP* distal interphalangeal

Procedure

We obtained informed consent from all subjects. Subjects completed a demographic questionnaire, which included a question asking whether they had received touch typing training, as touch typing training has been shown to be an important predictor of both personal keyboarding style and productivity [24, 27]. Video data on keyboarding style for the K-PeCS rating was obtained from each cohort (RA and comparison) at a different laboratory computer workstation. In both cases, subjects were asked to position the computer and the chair so that they were comfortable during the typing test. The cohort with RA completed the paragraph typing test as part of a larger study examining typing and mouse skills. They typed on the computer at a variety of tasks for approximately 15 min prior to starting the paragraph task. The comparison cohort completed only a single typing task. They typed for 10 min to acclimate to the computer workstation before video recordings were made. Thus, both cohorts had a short acclimation period before they were video recorded for rating purposes.

Data Processing

The videos were turned into 1 min video clips for rating with the K-PeCS. The videos were co-rated by two trained raters (occupational therapists). All ratings with more than two criteria were dichotomized (see Table 1). After rating the subjects with RA the raters ascertained the degree of visible impairment and assigned the SSCS.

Data Analyses

Data were analyzed using SPSS version 16.1. Descriptive statistics were run to check the data. To determine if there were significant differences in demographic data for people with RA and people without RA, we completed independent t-tests for age, and Mann–Whitney tests for categorical data (sex, and touch typing training). There were significant differences between groups for age ($P < 0.001$).

We completed an initial evaluation of differences in items of the K-PeCS by diagnosis using chi square analyses. To further evaluate the predictors of personal keyboarding style we completed stepwise, backward, logistic regressions with each item of the K-PeCS as the outcome (dependent) variable, and age, diagnosis (which defined cases from controls), SSCS, and touch typing training as the predicator (independent) variables. We also examined the association between productivity and these same predictor variables using stepwise, backward multiple regressions. As this is an exploratory study, we chose not to use a Bonferroni correction, and set alpha at 0.05.

Results

Subjects

There were 45 computer users in the RA group and 29 in the comparison group without RA. The mean age of the sample was 47 years, however, the mean age of subjects with RA was significantly higher (56 years) than those without RA (33 years). Both samples were primarily female and right-handed. More than half of both samples had been trained in touch typing. Subjects without RA typed significantly faster than those with RA, but both groups were equally accurate. About half the subjects with RA (42%) did not have visible impairments, while a little more than a quarter of the subjects with RA (27%) had severe visible impairments in both hands (Table 2).

Table 2 Demographics and typing variables

	All ($n = 74$)	RA ($n = 45$)	No RA ($n = 29$)
Age	47.3 ± 15.4	56.2 ± 8.5	33.0 ± 13.0
Sex (F)	58 (78%)	38 (84%)	20 (69%)
Hand dominance (*R*)	65 (88%)	39 (87%)	26 (93%)
SSCS			
2 (no visible impairment)		19 (42%)	29 (100%)
3		2 (4%)	
4		8 (18%)	
5		4 (9%)	
6 (severe impairment)		12 (27%)	
Touch typing training (yes)	51 (69%)	33 (73%)	18 (62%)
Productivity			
Words per minute (wpm)	32.8 ± 17.6	23.4 ± 11.8	47.1 ± 15.2
Percent accuracy	89.8 ± 11.9	90.7 ± 13.9	88.4 ± 8.2
wpm/accuracy	30.7 ± 17.1	22.5 ± 11.8	43.2 ± 16.5

Differences in K-PeCS Items Between People with and Without RA

The body and arm postures (Fig. 1) of both those with and without RA were generally neutral. The exception was neck flexion, where significantly more people with RA maintained a head flexion angle >10° and a left shoulder flexion angle <20°. There were no significant differences in the use of supports (back, forearm; Fig. 1). Significantly fewer people with RA used a wrist support and significantly more displaced (moved) their hands while typing (Fig. 2). More people with RA maintained their wrist and hands in fixed neutral postures (no ulnar deviation, no MCP hyperextension), and more used higher force and fewer digits (Figs. 2, 3). Significantly more people with RA experienced left DIP hypermobility (the DIP hyperextends during keystrike), although not right DIP hypermobility (Fig. 3).

Logistic Regression

Of the 33 logistic regression models, 26 were significant (79%; Table 1). Only one predictor variable remained in the model after the stepwise regression was completed in 77% of the models (Table 3). The amount of variance explained by each model varied from 8 (left elbow flexion, left isolated 5th digit) to 56% (left hand displacement; Table 1). SSCS was the most common predictor of keyboarding style (54% of significant models), followed by

Fig. 1 Body and arm items: comparison of the percentage of keyboard operators using each item of keyboarding style related to the body and arm between computer operators with and without RA. An * under the *bars* indicates that there was a significant difference between those with and without RA for that item of keyboarding style

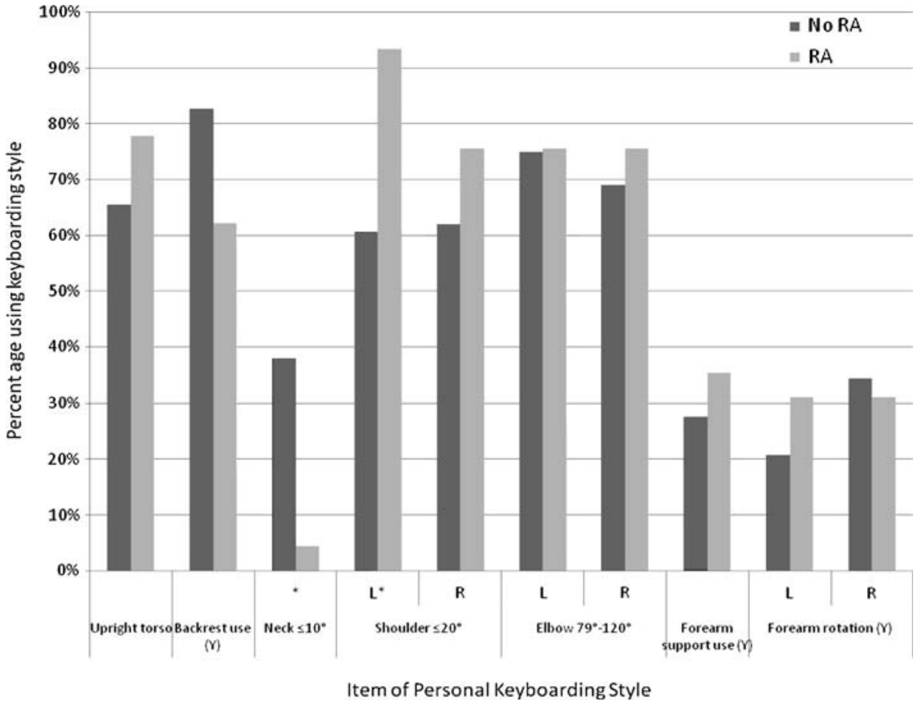
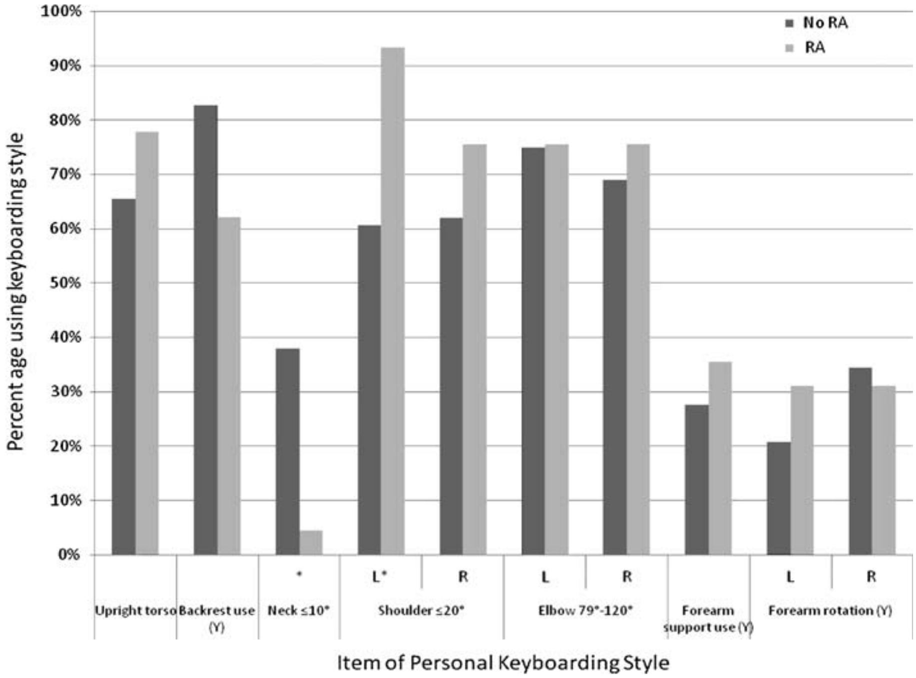


Fig. 2 Wrist and hand items: comparison of the percentage of keyboard operators using each item of keyboarding style related to the wrist and hand between computer operators with and without RA. An * under the *bars* indicates that there was a significant difference between those with and without RA for that item of keyboarding style



age (35% of significant models), diagnosis (19% of significant models), and touch typing training (15% of significant models; Table 3).

In the multiple regression models examining productivity, diagnosis ($P < 0.001$; $r^2 = -0.72$) and touch typing training ($P < 0.001$; $r^2 = 0.46$) explained 56% (model $P < 0.001$) of the variance in typing speed (wpm). Touch typing training alone ($P = 0.003$; $r^2 = 0.35$) explained 12% ($P = 0.003$) of the variance in accuracy. For the combination of speed and accuracy, diagnosis ($P < 0.001$; $r^2 = -0.62$) and touch typing training ($P < 0.001$; $r^2 = 0.34$) explained 46% of the variance ($P < 0.001$).

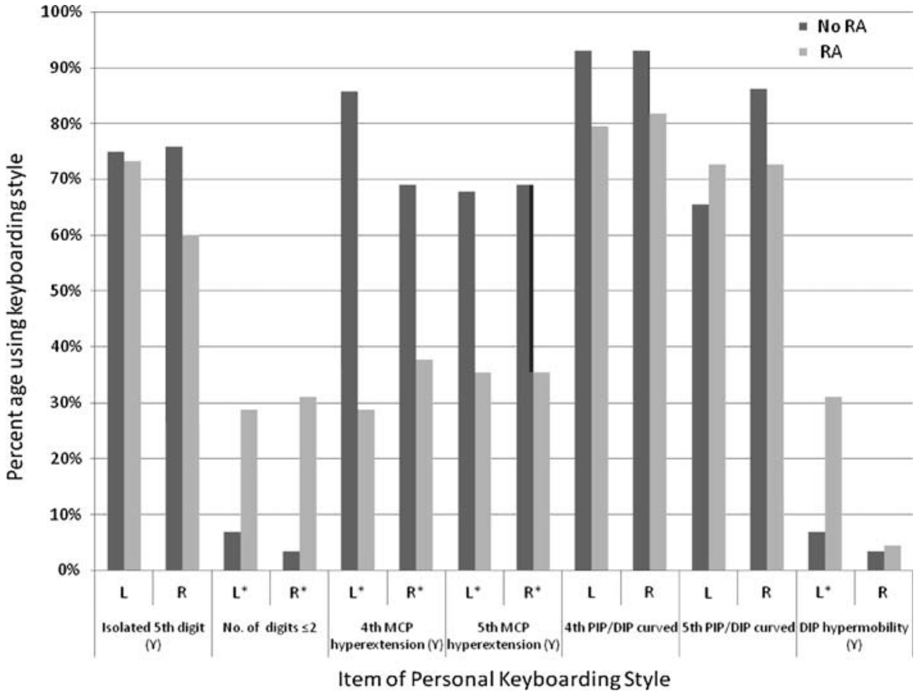


Fig. 3 Digit items: comparison of the percentage of keyboard operators using each item of keyboarding style related to the digits between computer operators with and without RA. An * under the *bars* indicates that there was a significant difference between those with and without RA for that item of keyboarding style

Discussion

This study examined the general effect that a diagnosis of RA has on personal keyboarding style, and the more specific effect that structural changes related to RA have on personal keyboarding style. The general pattern which emerged from the study data suggests that keyboard operators with RA tend to use proximal movements of the elbows to position their hands and strike the keys while maintaining their hand and wrist joints in one position. Typically, keyboard operators tend to use less movement at the elbow and wrist and more at the fingers [28]. Keyboard operators with RA also use fewer digits while typing. Using more proximal muscle joint groups and fewer fingers leads to “hunt and peck” typing method. This method is the opposite of touch typing in which the hands are positioned over home keys and motor memory, rather than visual input, is used to guide the digits to the correct keys [24, 27].

The digits of keyboard operators with RA may be fixed in MCP flexion and PIP/DIP extension, a position caused by tight intrinsic hand muscles commonly referred to as an “intrinsic plus.” This tightness can prevent active MCP extension needed to strike keys without moving the wrist or forearm as well as the ability to abduct the digits to position them over the keys. It also limits the keyboard operator’s ability to reciprocally extend the MPC/flex the PIP during the preparatory phase of keystrike. Intrinsic tightness combined with flexor tightness may produce a drag when a digit is lifted into extension, creating increased passive tension on the flexors. This tension may result in more force used to depress the keys, another difference in personal keyboarding style indicated in this study. An additional possible explanation of this increased force during key activation is the tendency for individuals with RA to use more proximal muscle activity.

Proximal body postures, such as torso and shoulder angle, were generally similar between those with and without RA, possibly because these postures generally require stability rather than mobility. The exception was neck flexion where 96% of those with RA flexed their head more than 10°, compared to the 62% of those without RA. This tendency to flex the neck is probably a consequence of using the “hunt and peck” method which requires visual input: increased neck flexion represents the need to look at the digits while typing.

Results from the logistic regression support the importance of changes in hand structure as the driving force behind differences in keyboarding style between those with and without RA. The more severe in nature and number of visible structural changes, the greater the odds of having a different keyboarding style. Visible structural changes in the hands increased the odds of not using a backrest (OR = 1.52), possibly because it was a marker of other structural changes of the body or because computer operators were leaning forward to look at the keys. Visible structural changes were protective for non-neutral wrist ulnar angles (OR: $R = 0.55$, $L = 0.47$) left wrist extension angles (OR: $L = 0.55$), and left MCP joint hyperextension angles (OR: 4th = 0.64; 5th = 0.54), indicating that operators with RA’s wrist and finger joints were less

Table 3 Predictor variables associated with K-PeCS items and the interpretation of odds ratios

K-PeCS item	OR	95% CI	*P*	Interpretation
Predictor—age				
Shoulder flexion angle (*L*)	0.92	0.88, 0.97	0.001	>Age = neutral
Wrist support use (R)	1.06	1.02, 1.10	0.002	>Age = no wrst supp
Wrist support use (*L*)	1.10	1.05, 1.15	<0.001	>Age = no wrst supp
Hand displacement (*R*)	1.10	1.05, 1.15	<0.001	>Age = moves hands
Hand displacement (*L*)	1.14	1.08, 1.20	<0.001	>Age = moves hands
Isolated 5th digit (*R*)	0.95	0.91, 0.98	0.007	>Age = neutral
MCP hyperextension (R4th)	0.95	0.91, 0.98	0.002	>Age = neutral
MCP hyperextension (R5th)	0.95	0.92, 0.98	0.003	>Age = neutral
MCP hyperextension (L4th)	0.92	0.87, 0.97	0.002	>Age = neutral
Predictor—diagnosis				
Neck flex angle	0.08	0.02, 0.42	0.003	RA = non neutral
Wrist extension angle (L)	0.14	0.02, 0.93	0.04	RA = non neutral
# digits (*R*)	12.20	1.50, 98.91	0.02	RA = ≤2 digits
PIP/DIP curve (L5th)	8.69	1.49, 50.63	0.02	RA = curved
DIP hypermobility (*L*)	0.17	0.04, 0.82	0.03	RA = DIP hypermob
Predictor—SSCS				
Backrest use	1.52	1.11, 2.09	0.01	>Sev = no backrest
Elbow flexion angle (*L*)	1.40	1.01, 1.94	0.05	>Sev = non neutral
Forearm rotation (L)	1.51	1.05, 2.16	0.03	>Sev = forearm rot
Wrist ulnar angle (*R*)	0.55	0.39, 0.78	0.001	>Sev = neutral
Wrist ulnar angle (*L*)	0.47	0.28, 0.78	0.004	>Sev = neutral
Wrist extension angle (L)	0.55	0.32, 0.95	0.03	>Sev = neutral
Force	1.47	1.07, 2.01	0.02	>Sev = high
Isolated 5th digit (*L*)	0.71	0.52, 0.98	0.04	>Sev = neutral
# digits (L)	0.56	0.37, 0.85	0.007	>Sev = ≤2 digits
MCP hyperextension (L4th)	0.64	0.41, 0.99	0.04	>Sev = neutral
MCP hyperextension (L5th)	0.54	0.36, 0.79	0.002	>Sev = neutral
PIP/DIP curve (R4th)	1.97	1.28, 3.03	0.002	>Sev = straight
PIP/DIP curve (L4th)	2.53	1.56, 4.11	<0.001	>Sev = straight
PIP/DIP curve (L5th)	2.27	1.33, 3.86	0.003	>Sev = straight
Predictor—touch typing training				
Forearm rotation (*R*)	3.46	1.22, 9.82	0.02	Touch type = no arm rot
Forearm rotation (L)	3.66	1.07, 12.55	0.04	Touch type = no arm rot
Wrist support use (R)	0.32	0.10, 0.98	0.05	Touch type = use wrst supp
# of digits (L)	0.20	0.05, 0.88	0.03	Touch type = >2 digits

Italicized K-PeCS items have more than 1 predictor

MCP metacarpophalangeal; *PIP* proximal interphalangeal; *DIP* distal interphalangeal; *SSCS* severity of structural changes score; *wrst* wrist; *hypermob* hypermobility; *sev* severity of structural changes; *rot* rotation; *supp* support

mobile than operators without RA and were fixed in one position. Visible structural changes increased the odds of having straight fingers when typing (OR: 4th $R = 1.97$, $L = 2.53$; 5th $L = 2.27$), probably secondary to either “intrinsic tightness” or swan neck deformities. People with RA also were less likely to use multiple digits while typing (OR: $L = 0.56$). People with visible structural changes were 1.47 time more likely to use high force.

Age was also a significant predictor of differences in keyboarding style. In our models older age was indicative of fixed, neutral postures of the MCP joints (OR: 4th $R = 0.95$; 5th $R = 0.95$, $L = 0.92$) and greater movement of the hands (OR: $R = 1.10$; $L = 1.14$) combined with a greater tendency not to use wrist supports (OR: $R = 1.06$; $L = 1.10$). These results indicate that older adults were moving their individual joints less and their hands more to access the keyboards. As hand strength, dexterity and mobility decrease with age, these may exacerbate the effect of having RA on older adults, further affecting their keyboarding style. While severe structural changes were a stronger predictor of wrist and finger postures, age was a stronger predictor of hand movement and wrist support use. Thus, although structural changes can influence the ability to independently move joints, which would tend to increase hand movement, the tendency to move the hands while typing is related overall to age. The significant difference in hand movement noted in the subjects with RA may reflect their significantly older age combined with the structural changes of their hands.

Training in touch typing, which was about equally distributed between the two groups, was primarily a predictor of forearm rotation. Non-touch typists had much greater odds of rotating their forearms than those who were trained (OR: $R = 3.46$; L 3.66). Forearm rotation occurs during "hunt and peck" typing when the typists rotates the hands out of the way to "peek" at the keys underneath the hands. Non-touch typists routinely do this when they are scanning the keyboard to find letters. Although touch typing should also have been the best predictor of number of fingers—the hallmark of touch typing is using all the fingers—diagnosis and impairment both were stronger predictors. This result may indicate that while many subjects with RA had been trained in touch typing, they could no longer use the techniques due to the severity of their structural changes.

The keyboarding styles predominating in people with RA could have an effect on both hand architecture and productivity. The use of straight finger typing combined with high force has the potential to place high torque on the already compromised joint architecture of the hands, increasing the potential damage that can occur while typing. Studies have suggested that a curved finger posture which reduces key contact at the finger tip angle during keystrike reduces the overall biomechanical stresses on all the finger joints [29]. Thus, a flexed MCP joint combined with a straight PIP joint, a common posture for keyboard operators with RA increases the forces acting on already weakened joints. In general, people with RA were much older than those without RA, and those who were older tended to move their hands more and not use a wrist rest because they do move their hands. This overall style has the potential to cause fatigue as the keyboard operator must exert more energy to move the hands and shift attention between the keyboard and screen. In addition, these styles have been associated with slower typing speeds [24]. This study indicates that although a comparable number of people with RA have been trained in touch typing, their productivity is significantly lower than people without RA, although their accuracy is the same. Multiple regression models indicate that touch typing training and diagnosis play the strongest role in explaining this diminished typing productivity.

Limitations

This study used subjects from two separate studies, and these subjects used two different laboratory workstations. Although these laboratory computer workstations were similar in set-up, they both had adjustable keyboard trays, monitors, and chairs, and subjects from both studies were encouraged to adjust the workstation to their preferred configuration, it is possible that some aspect of the workstation affected keyboarding style. Therefore, it is possible that some of the differences in keyboarding style were related to the computer workstation set-up. This limitation is particularly true for models where diagnosis was the primary predictor of style as each diagnosis used a different workstation. The rating of severity of structural changes was accomplished by observing subjects typing, not by actually examining the hands. Therefore, there may have been subtle structural changes in both the subjects and controls hands that might have been missed. Each item of keyboarding style on the K-PeCS was analyzed separately, leading to the possibility of type I error.

Conclusions

People with RA can have different keyboarding styles than people without RA, and these differences are primarily due to the severity of structural changes in the hand and age. These changes appear to affect overall productivity which could seriously affect a worker with RA's ability to maintain employment standards. The keyboarding styles used by computer operators with RA generally require greater energy expenditure, which could lead to fatigue. They also have the potential to exacerbate existing problems with hand architecture of the joints—putting additional stress on already affected joints.

Based on the results of this study it would appear that computer operators with RA could benefit from changes to their computer workstations to reduce the effect of structural changes of the hand on keyboarding style. These workstation changes should aim at addressing keyboarding styles that may reduce productivity, such as "hunt and peck" styles, and reduce stresses on already affected joints. Possible changes could include alternative, angled keyboards, keys which have a softer activation requirement, and/or moveable wrist supports, all of which could reduce the stresses that a flat, typical keyboard place on the hand. For those without severe structural changes, training in touch typing might be an option, while for keyboard operators with severe structural changes, voice activated software may be the best option to reduce biomechanical stresses while improving productivity.

The results of this study may apply to any injury or illness which compromises hand structure. Individuals with severe structural changes, such as contractures, scarring, and joint immobilization may also demonstrate changes in personal keyboarding style, and these changes may interfere with productivity as well as cause stress on already compromised joints. Further research is needed to understand how structural changes associated with injuries and illnesses affect computer task performance, and also to test potential workstation changes to determine which are most effective at reducing the effect of structural changes on keyboard operation and other computer tasks.

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