A COMPARISON OF A KLOCKENBURG STYLE SPLIT KEYBOARD AND A STANDARD PC KEYBOARD ON TYPING SPEED AND POSTURE

A Thesis

by

HENRY EITT AUSTIN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2005

Major Subject: Safety Engineering

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Approved by:

Co-Chairs of Committee,	J. Steven Moore
	J. J. Congleton
Committee Members,	Gordon Vos
Head of Department,	Ken Hall

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ABSTRACT

A Comparison of a Klockenburg Style Split Keyboard and a Standard PC Keyboard on Typing Speed and Posture. (December 2005)

Henry Eitt Austin, B.S., Texas A&M University

Co-Chairs of Advisory Committee: Dr. J. Steven Moore
Dr. Jerome J. Congleton

The current study compares biomechanical and productivity outcomes related to the use of a Klockenburg (split and angled) style keyboard as opposed to the use of a standard PC 101 style keyboard among office workers. The study used 10 subjects (5 male and 5 female) who were employees of a large insurance company. Subjects were categorized by job classification, including 5 exempt and 5 nonexempt employees. Each subject was evaluated on both of the keyboards in a laboratory setting after three weeks of familiarization with the keyboards at their workstation. Productivity was measured as words per minute. In the lab, biomechanical outcomes included angular measures of forearm pronation/supination, wrist flexion/extension, wrist radial/ulnar deviation and neck angle. Lab results showed that the Klockenburg keyboard negatively impacted productivity and neck posture, while forearm pronation/supination and wrist radial/ulnar deviation were in more neutral positions. There was no significant difference in wrist extension between the two keyboards. In the field, the Klockenburg keyboard did not impact productivity.

ACKNOWLEDGMENTS

I would like to thank the staff that I have worked with in the Department of Nuclear Engineering, especially the Safety Engineering group and the National Science Foundation Center for Ergonomics for helping me in all of the details involved in successfully completing this program. I would also like to thank Randy Notzon and Michael Johnson for their continual help and assistance in this process.

I have been impressed with the depth and breadth of the knowledge of the faculty and students in the Texas A&M University Safety Engineering program. In that regard, I would specifically like to mention Drs. Moore, Congleton, Gaines, Almendola and Vos. I thank Dr. Congleton for encouraging me into this program and him and Drs. Moore and Vos for getting me through it.

I would like to give my love and thanks to my parents, the late Col. Herbert W. and Cynthia Austin for giving me my start and keeping me going on the right track. And to John and Patsy Yantis for giving me the greatest gift of my life, my wife Nancy. And for Nancy, the love of my life, my son Taylor and my daughter Hailey who give my life purpose and joy.

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INTRODUCTION

Wrist Posture and Keyboards

The keyboard is the primary interface device between people and computers. Concern exists in both the lay and scientific communities that computer keyboards may place users at increased risk of upper extremity disorders.[1] Awkward or extreme postures have been cited as ergonomic risk factors.[2] The postures that computer users develop while using the standard PC 101 style keyboard used by most computer users have been key components of interest to researchers.[3] There is also evidence that the use of an alternative style keyboard might improve typing speed and accuracy over the standard 101 keyboard.[3]

National Research Priority

The National Institute for Occupational Safety and Health (NIOSH) National Occupational Research Agenda for Musculoskeletal Disorders, identified that "Research should investigate the mechanical environment factors that affect posture, movement, force, exertion and the interface between the worker and the equipment of the task".[4] The awkward postures most focused on for potentially causing injury include wrist extension, ulnar deviation, increased pronation and neck flexion.[5] Awkward postures have been a focus for study and concern

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This thesis follows the style and format of the *Journal of Occupational and Environmental Hygiene*.

however; there is no definitive evidence that awkward wrist postures cause injury.

Eighty Year Old Issue

The conventional wisdom is to believe that the issues involved with the human/keyboard interface are relatively new phenomena. However, it was reported by Kroemer that Klockenburg investigated this situation in 1926 some forty years before the advent of the personal computer.[6] As reported, Klockenburg built a keyboard and arranged it in a split and angled presentation in order to reduce wrist deviations of the operator on all axes. Nakaseko et al (1985) found that a split keyboard markedly reduced static muscle load in the arm-shoulder area.[1] Cramer and Trumbo found that operator error rates were reduced using an alternative style of keyboard that was angled at 44 deg. or 66 deg.[7]

OBJECTIVES

The primary objective was to determine if switching to an alternative, Klockenburg style, split keyboard would improve the speed of the subjects over the use of a standard PC 101 keyboard. The secondary objective of this study was to determine if use of the Klockenburg keyboard would improve the users' posture while working.

METHODS

Participant Demographics

The ten volunteer subjects for this study were all employees of a large insurance company located in the Southwestern United States. Five of the subjects were exempt employees and five were nonexempt employees (this was not split along gender lines). Five of the volunteers were male and five were female. The ethnicity of the volunteers was: 3 Hispanic, 1 African American and the rest of the subjects were Caucasian. Subjects' mean age was 39 ± 9 years (range: 25-56 years). Their mean height was 68.25 ± 3 inches (range: 64-73.5 inches).

Participant Recruitment and Selection

Test subjects were asked if they would like to participate in the study and that it would be completed while they were doing their typical daily work. Subjects were required to comply with the following: obtain their manager's permission to participate; use their computer at least three hours per day; plan to not miss more than four days of the scheduled study time and agree to extend required data collection time to compensate for any days missed. Each subject spent a total of about eight weeks in data collection. Subjects were presented with the "Informed Consent Form" (Appendix A). Agreement with the terms on the informed consent form was necessary for participation in the study. The subjects were covered by workers' compensation insurance while completing the study. No subject would be penalized by the company or any individual if the requirements in the informed consent form were found to be unfavorable to them. Participation was absolutely voluntary. All experimental data and questionnaire forms remain locked in a file cabinet in the office of the Principal Investigator. Only the Principal Investigator and his committee have access to this information.

Control Keyboards

The control keyboards were standard 101 style, QWERTY, PC keyboards that the subjects have been using for their daily work for at least several months.

Treatment Keyboards

The treatment keyboards were modified Goldtouch keyboards. Standard split Goldtouch keyboards were taken apart, had the locking mechanisms removed and had longer cables between the two halves of the keyboard added. This modification allowed the keyboard halves to be moved farther apart and to move them in different ways. The keyboards were then mounted on custom made acrylic plastic holders. The holders were built to provide a 45° tilt to each side of the boards as described by Klockenburg.[3] These holders were then mounted on a base plate that would allow them to be moved as necessary and tightened down to set the neutral posture for each user. The volunteers were introduced to the Klockenburg keyboards and then assisted in setting the keyboard to provide the least amount of wrist deviation in any plane. They could and did modify the adjustments to their own tastes.

Cameras

All data were captured on the right side of all subjects. Four video cameras and four 8mm video recorders were used to capture all posture data. Two small 2”X2” video cameras were mounted on stands and placed on the work surface in close proximity to the keyboard without interfering with subject keying actions.

Posture Capture

Wrist extension occurs when the wrist is bent up. Ulnar deviation occurs when the wrist is bent out toward the little finger. Pronation occurs when the hands are rotated from a handshake position to a flat palm down position. The two small cameras were leveled and placed at locations that would provide straight camera views for the capture of wrist pronation/supination and radial/ulnar deviation. A reference grid was developed and marked upon clear acrylic plastic and placed in front of the lens of one camera to provide a reference for measuring wrist rotation for pronation/supination. When the grid was placed upon the camera, it was leveled to ensure proper alignment. Only the center grid lines were used in order to reduce the influence of parallax. The third camera was set up to capture a full right side view of the subject. The last camera was set up to the right side to capture right wrist flexion/extension. The angles of movement were later measured and catalogued using the Vision 3000 2D video analysis system.

Anatomical Markers and Measurements

Anatomical landmarks were located using information from the American Medical Association Guides to the Evaluation of Permanent Impairment Third Edition.[8,9,10] Reflective plastic material with adhesive backing manufactured by 3M® was cut into 1” diameter circles that had ink dots in their centers. These circles were placed over the anatomical landmarks to be used for measurement. The circles were used for location of the measurement points by the Vision 3000® system. The landmarks used were all on the right side of the body and were located by palpation. They were:

(1) The points utilized to measure radial/ulnar deviation - the top of the third knuckle, the third tendon at the axis for flexion and extension of the wrist and the proximal musculo-tendonous junction of the extensor digitorum communis, which can be palpated with the wrist in extension.

(2) The points utilized to measure wrist flexion/extension - the outside of the fifth knuckle, just below the head of the ulna and the lateral epicondyle of the elbow.

(3) The points utilized to measure pronation/supination - a balsa wood T (90 deg.) was built and fastened upside down just behind the dot at the axis for flexion and extension of the wrist. This fixture was used as a reference point to measure wrist rotation.

(4) The points used to measure the neck angle are the greater trochanter, the greater tuberosity on the top of the humerus and the mastoid process.

The Test Procedure

This study was approved by the IRB. The subject was first presented with an "Informed Consent Form". After the subject read the form, he or she was given the opportunity to discuss the form and ask any questions about the experiment. The subject was then requested to sign the "Informed Consent Form" if he or she wanted to participate in the study.

Phase I

The first phase consisted of three weeks of measuring the keying habits of each subject at their own workstation. The Office Athlete™ software was installed upon their computers and recorded the number of keystrokes, number of mouse clicks and feet of mouse travel.

Phase II

The second phase was accomplished in one of the insurance company's Ergonomics Labs. The adjustable workstation was set up to match the heights (desk, chair and monitor) that the test subject has at their own workstation. Each subject was provided their same keyboard that they used daily.

Each subject was given ten minutes to familiarize themselves with the lab workstation and keyboard. The subject was then asked to type a specific verse for 5 minutes. They were directed to type as much as they could at a reasonable speed for them and to not correct any mistakes

Phase III

The third phase of the study consisted of replacing the subject's standard keyboard (at their desk) with the modified Gold Touch keyboard. The subjects then worked with the Gold Touch keyboard for three weeks. The Office Athlete software was utilized to capture the same data.

Phase IV

The fourth phase returned the subjects to the lab to repeat the Phase II tests with the modified keyboard. Data collection took approximately 8 weeks total.

Laboratory Video Tape Sessions

The Vision 3000® 2D video analysis system by Promatek was used to analyze the video taped postures for all of the sessions. Each session resulted in the capture of 5 minutes of videotape on each of four different cameras. This resulted in a total of 20 minutes of videotape per session per subject. Since there were two video taped sessions per subject, the total amount of videotape to be analyzed was forty minutes per subject. The video recorders recorded at a rate of thirty frames per second resulting in a total of 9000 frames captured per camera per session. Each session resulted in 36,000 frames per subject for a total of 72,000 frames videoed per subject for the two sessions. In total, 720,000 frames of videotape were used for this study.

The Vision 3000 system can capture a total of 100 frames for analysis per videotape analysis session. The system can be set to capture every X frame up to the 99th frame. With a total of 9,000 frames of videotape per camera per lab session, the Vision 3000 system was set to capture every 99th frame. This resulted in a total of 90 frames captured by the Vision 3000 system per camera per five-minute lab session. Each video "capture" event lasted 2 hours times 80 five minute tapes for a total of 160 hours of video capture time. Each screen of the Vision System can display thirty individual video frames. These frames were displayed in five rows of six frames each.

For each lab session, there were three pages of video frames. In order to introduce random chance into the selection of video frames analyzed, a random number between 1 and 6 was picked out of a box and recorded. This number was the number of the frame that was chosen in each row of video frames for analysis. The final number of frames that went through full analysis per camera per lab session was fifteen. This resulted in a total of 60 frames analyzed per subject per lab session and each analysis session lasted 45 minutes. With four video analysis sessions per subject per lab session and a total of 80 analysis sessions in the study, over 60 hours was spent on frame analysis and logging. 1200 video frames were analyzed for the entire study.

Video Tape Analysis

The vision 3000 system can be used in automatic or manual video frame marking modes. In marking a frame, the reference markers (reflective circles) to be analyzed are connected with lines on the computer. The three reference dots are connected with a line by the computer. The computer measures the angle that is formed by the line and stores it. Due to the difficulties and very strict color contrast required for the automatic marking function to work, the frames were marked manually.

The Vision 3000 system operates with pre-built "libraries" of reference data that calibrate the system to the body part, the direction of the view, what location is zero degrees and which direction indicates "positive" movement and which indicates "negative" movement. However the libraries needed for this study did not exist. As a result, libraries were built for each of the postures to be analyzed. For each analysis session, the proper library is chosen and the system then compares the lines on each frame to the reference library. The output of the analysis is an angle measurement in degrees.

For system calibration, the measurement of flexion and extension, zero degrees was established to be when the three dots were aligned on the side of the forearm, wrist and hand. Flexion resulted in a positive angle while extension resulted in a negative angle. For the measurement of Pronation and supination, the wrist being held horizontal was set as zero degrees. For the measurement of radial and ulnar deviation, zero degrees was set with the three dots on the top of the forearm being aligned. A radial deviation resulted in a positive angle while an ulnar deviation resulted in a negative number.

Statistical Analysis

Descriptive statistics were first performed to summarize the characteristics of the volunteer population.

Variables

The dependent variables were:

Productivity: Words per minute in the field and the lab.

Biomechanics: Neck angle, wrist flexion / extension, wrist pronation / supination and wrist radial / ulnar deviation all in the lab.

The Independent variables were:

The control keyboard and the Klockenburg keyboard in the field and the lab.

Data were analyzed using the Linear Model for a combined within and between factor ANOVA:

$$y_{ijk} = \mu + a_i + ß_k + (aß)_{ik} + e_{ijk}$$

i = 1, 2 (job classifications)

j = 1, …, b (individuals)

k = 1, …, r (time or keyboard)

Where:

y_{ijk} = Individual observations

μ = Overall mean

a_i = Effect due to the i-th level of the between factor (job classification)

$ß_k$ = Effect due to the j-th level of the within factor (time or keyboard)

$(a\beta)_{ik}$ = Interactions amongst a and β

e_{ijk} = Deviation of a response from its mean value (error)

RESULTS

Age

The mean age of all of the subjects was 38.7 years ranging from 25 to 56 years.

Height

The mean height of all the subjects was 68.25 inches ranging from 64 to 73.5 inches.

Field Study Findings (Stages I and III)

Words per Minute (Field)

The line in the center of the box in Figure I represents the median value. The box represents 50% of the data points between 25% and 75% or the inter quartile range (IQR). Several of the boxes show variability with the outliers, extremes and with the medians not in the middle of the boxes.

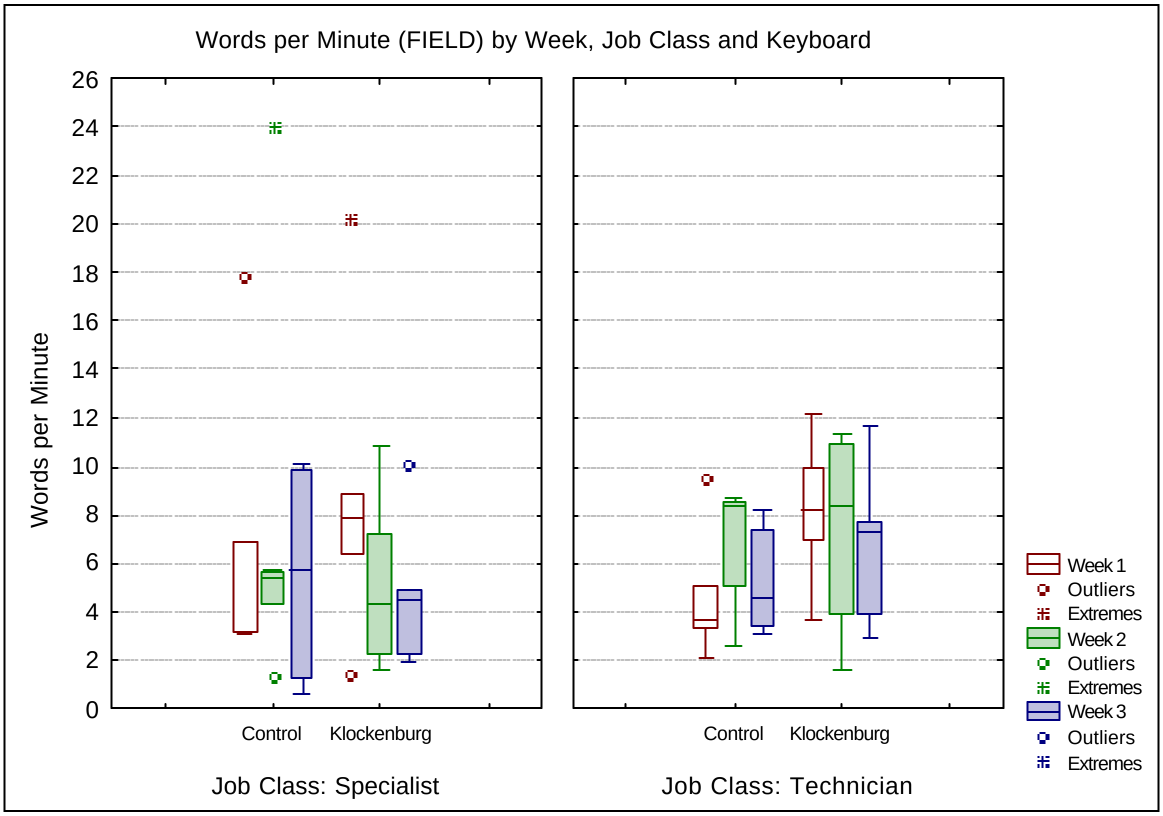

FIGURE I. Words per minute (field) by week, job class and keyboard box plot

Repeated measures ANOVA further demonstrates the variability that was illustrated in the box plot. None of the tested variables or interactions fit the model of $p<0.05$. (Table II).

Table I. Words per minute (field) by week, job class and keyboard descriptives

Effect	Level of Factor	Level of Factor	N	WPM-W1 Mean ± CI	WPM-W1 Std.Dev	WPM-W1 Std Err.	WPM-W2 Mean ± CI	WPM-W2 Std.Dev	WPM-W2 Std Err.	WPM-W3 Mean ± CI	WPM-W3 Std.Dev	WPM-W3 Std Err.
Total			20.0	7.3 (5.0,9.7)	4.9	1.1	6.8 (4.4,9.2)	5.2	1.2	5.5 (4.0,7.1)	3.3	0.7
Job Class	Specialist		10.0	8.2 (3.8,12.7)	6.2	2.0	6.6 (1.9,11.5)	6.7	2.1	5.1 (2.5,7.8)	3.7	1.2
Job Class	Technician		10.0	6.2 (4.0,8.9)	3.4	1.1	6.9 (4.5,9.4)	3.4	1.1	5.9 (3.9,8.0)	2.9	0.9
Keyboard	Control		10.0	6.1 (2.8,9.5)	4.7	1.5	7.3 (2.8, 11.9)	6.4	2.0	5.4 (3.0,7.8)	3.4	1.1
Keyboard	Klockenburg		10.0	8.5 (4.9,12.2)	5.1	1.6	6.2 (3.4,9.1)	4.0	1.3	5.6 (3.3,8.1)	3.3	1.1
Job Class*Keyboard	Specialist	Control	5.0	7.5 (0.1,15.0)	6.0	2.7	8.1 (-3.1,19.4)	9.1	4.1	5.5 (-0.1,11.1)	4.5	2.0
Job Class*Keyboard	Specialist	Klockenburg	5.0	8.9 (0.3,17.6)	6.9	3.1	5.2 (0.5,10.0)	3.8	1.7	4.7 (0.7,8.8)	3.3	1.5
Job Class*Keyboard	Technician	Control	5.0	4.7 (1.2,8.3)	2.8	1.3	6.6 (3.2,10.1)	2.7	1.2	5.2 (2.4,8.2)	2.3	1.0
Job Class*Keyboard	Technician	Klockenburg	5.0	8.2 (4.2,12.2)	3.2	1.4	7.2 (1.9,12.6)	4.3	1.9	6.6 (2.3,10.9)	3.5	1.5

Table II. Words per minute (field) by week, job classification and keyboard repeated measures ANOVA

Effect	SS	Degrees Of Freedom	MS	F	p
Job Class	0.7	1.0	0.7	0.0	0.9
Keyboard	4.0	1.0	4.0	0.1	0.8
Job Class*Keyboard	24.9	1.0	24.9	0.5	0.5
Error	848.8	16.0	53.0		
TIME	34.6	2.0	17.3	2.2	0.1
TIME*Job Class	19.3	2.0	9.6	1.2	0.3
TIME*Keyboard	32.4	2.0	16.2	2.1	0.1
TIME*Job Class*Keyboard	1.5	2.0	0.7	0.1	0.9
Error	247.1	32.0	7.7		

Laboratory Findings (Stages II and IV)

Words per Minute (Lab)

Figure II illustrates a grouping of the words per minute (lab) medians by keyboard in a boxplot.

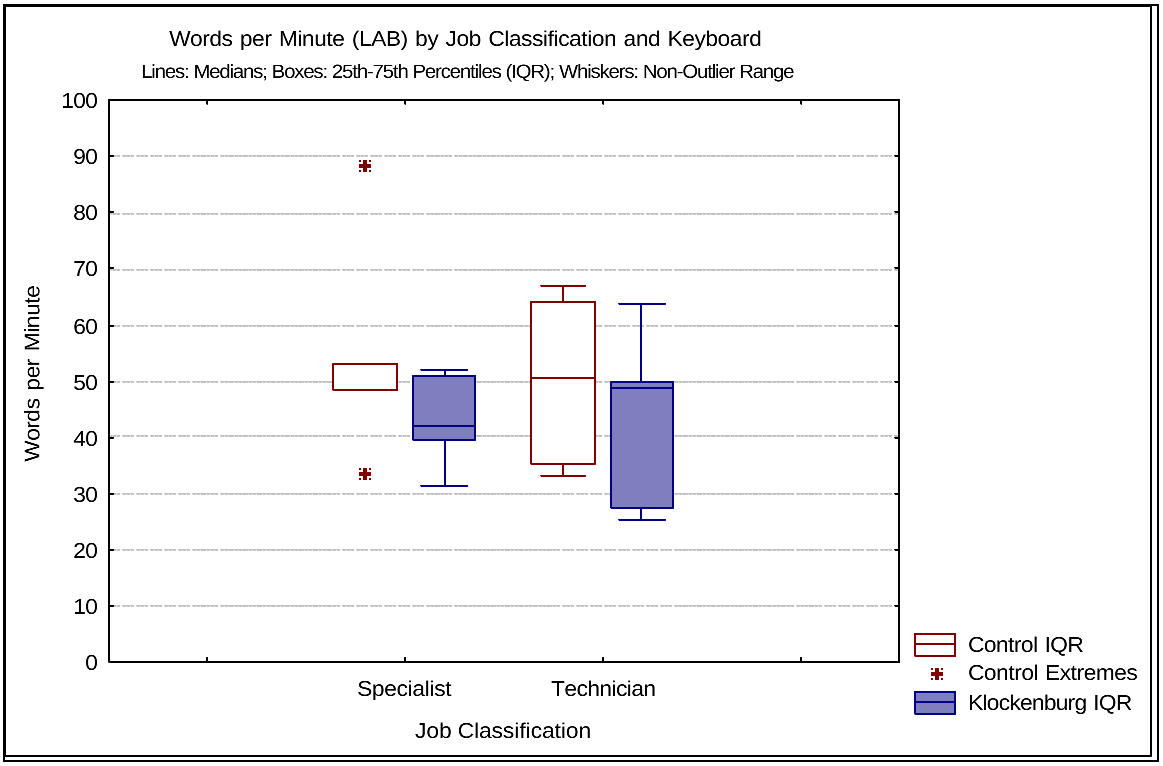

Figure II. Words per minute (lab) by job classification and keyboard box plot

The descriptive statistics in Table III illustrate a difference of words per minute (lab) means by keyboard.

Table III. Words per minute (lab) by job classification and keyboard descriptive statistics

Effect	Level of Factor	N	WPM-C Mean ± CI (LCL,UCL)	WPM-C Std. Dev	WPM-C Std. Error	WPM-K Mean ± CI (LCL,UCL)	WPM-K Std. Dev.	WPM-K Std. Error
Total		10	52.2 (39.9,64.6)	17.3	5.5	43.1 (34.4,51.9)	12.2	3.9
Job Class	Specialist	5	54.3 (29.2,79.5)	20.3	9.1	43.2 (32.7,53.8)	8.5	3.8
Job Class	Technician	5	50.0 (30.6,69.6)	15.7	7.0	43.0 (22.9,63.2)	16.2	7.3

Table IV demonstrates that the variable keyboard is statistically significant with a $p<0.001$.

Table IV. Words per minute (lab) by job classification and keyboard ANOVA

Effect	SS	Degrees Of Freedom	MS	F	p
Job Class	25.0	1.0	25.0	0.1	0.816
Error	3458.2	8.0	432.3		
KEYBOARD	409.7	1.0	409.7	6.4	0.036
KEYBOARD*Job Class	21.1	1.0	21.1	0.3	0.583
Error	514.1	8.0	64.3		

Figure III illustrates a difference in the means between the control and Klockenburg keyboards.

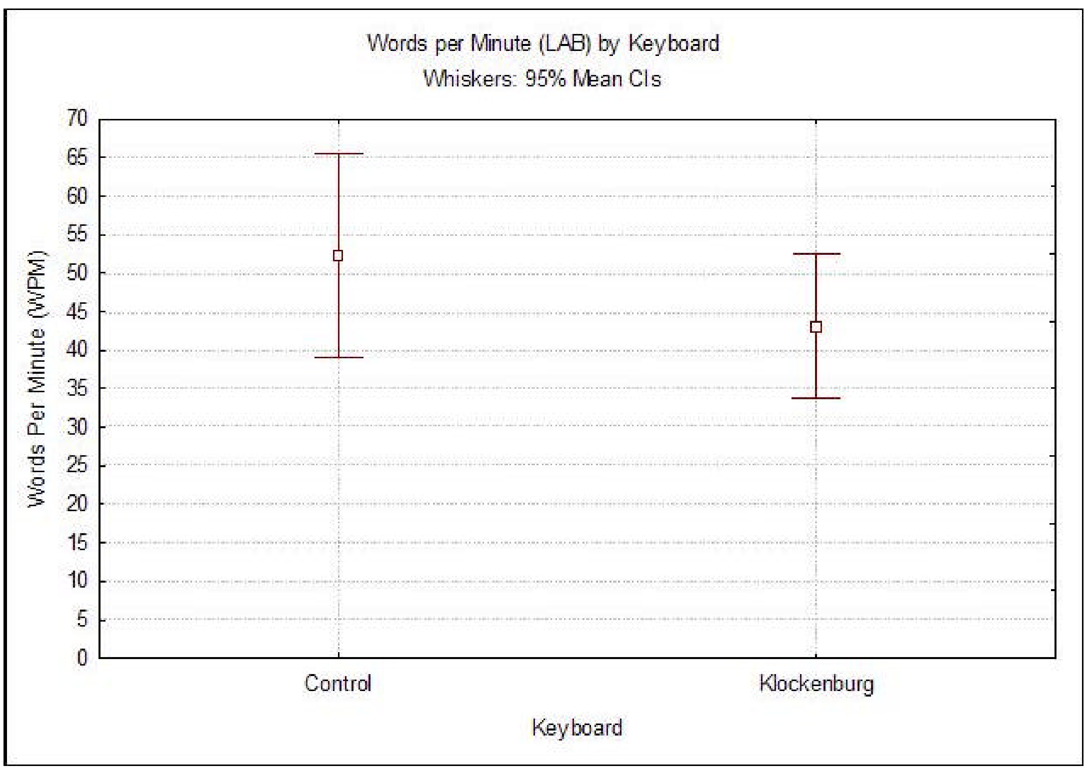

Figure III. Words per minute (lab) keyboard mean plot

The Tukey HSD test confirms the difference in the means of the keyboards (Table V). Homogeneous subsets are defined by column.

Table V. Words per minute (lab) keyboard using Tukey HSD

Cell No.	Keyboard	Means	set 1	set 2
1	WPM-K	43.2	****	
2	WPM-C	52.2		****

Biomechanics – Neck Angle

The neck angle box plot (Figure IV) illustrates a grouping of the median angles by keyboard.

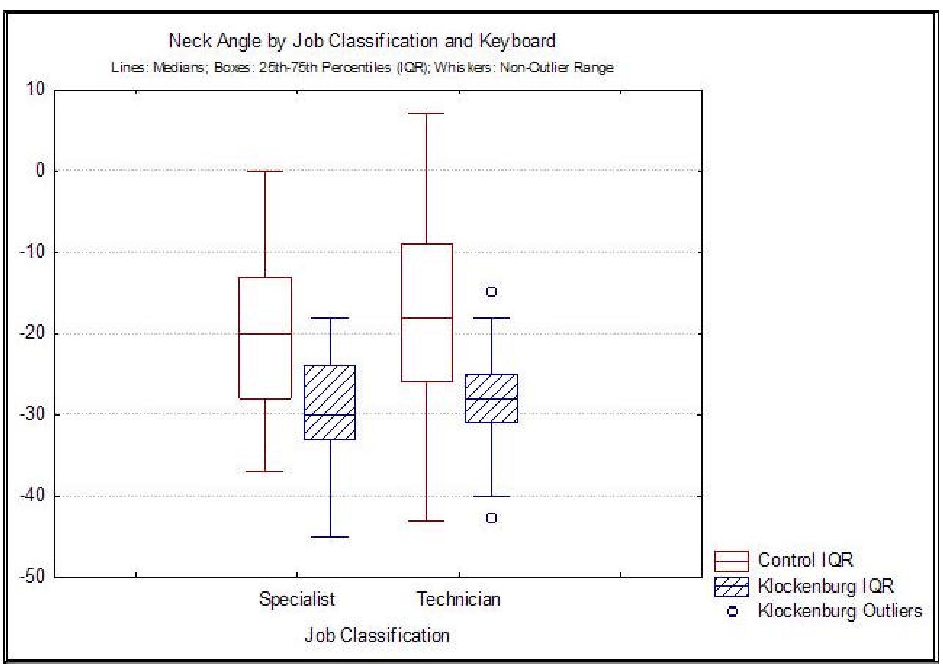

Figure IV. Neck angle by job classification and keyboard box plot

The descriptive statistics in Table VI illustrate that the means of the keyboard variables for the neck angle appear to be different.

Table VI. Neck angle by job classification and keyboard descriptive statistics

Effect	Level of Factor	N	Neck-CTRL Mean ± CI (LCL,UCL)	Neck-CTRL Std. Dev.	Neck-CTRL Std. Error	Neck-KLB Mean ± CI (LCL,UCL)	Neck-KLB Std. Dev.	Neck-KLB Std. Error
Total		150	-18.2 (-20.0, -16.4)	11.1	0.9	-28.7 (-29.7,-27.7)	6.1	0.5
Job Class	Specialist	75	-19.5 (-21.7,-17.3)	9.7	1.1	-29.6 (-31.2,-28.0)	6.8	0.8
Job Class	Technician	75	-16.8(-19.7,-14.1)	12.2	1.4	-27.8 (-29.0,-26.6)	5.2	0.6

ANOVA analysis of the Neck angle variables illustrates that the keyboard means in Table VII, are significant at $p<0.001$.

Table VII. Neck angle by job classification and keyboard ANOVA

Effect	SS	Degrees Of Freedom	MS	F	p
Job Class	365.6	1	365.6	3.9	0.052
Error	14040.3	148	94.9		
KEYBOARD	8291.3	1	8291.3	130.4	<0.001
KEYBOARD*Job Class	13.2	1	13.2	0.2	0.650
Error	9408.4	148	63.6		

Figure V illustrates the difference of the means by keyboard in the box plot.

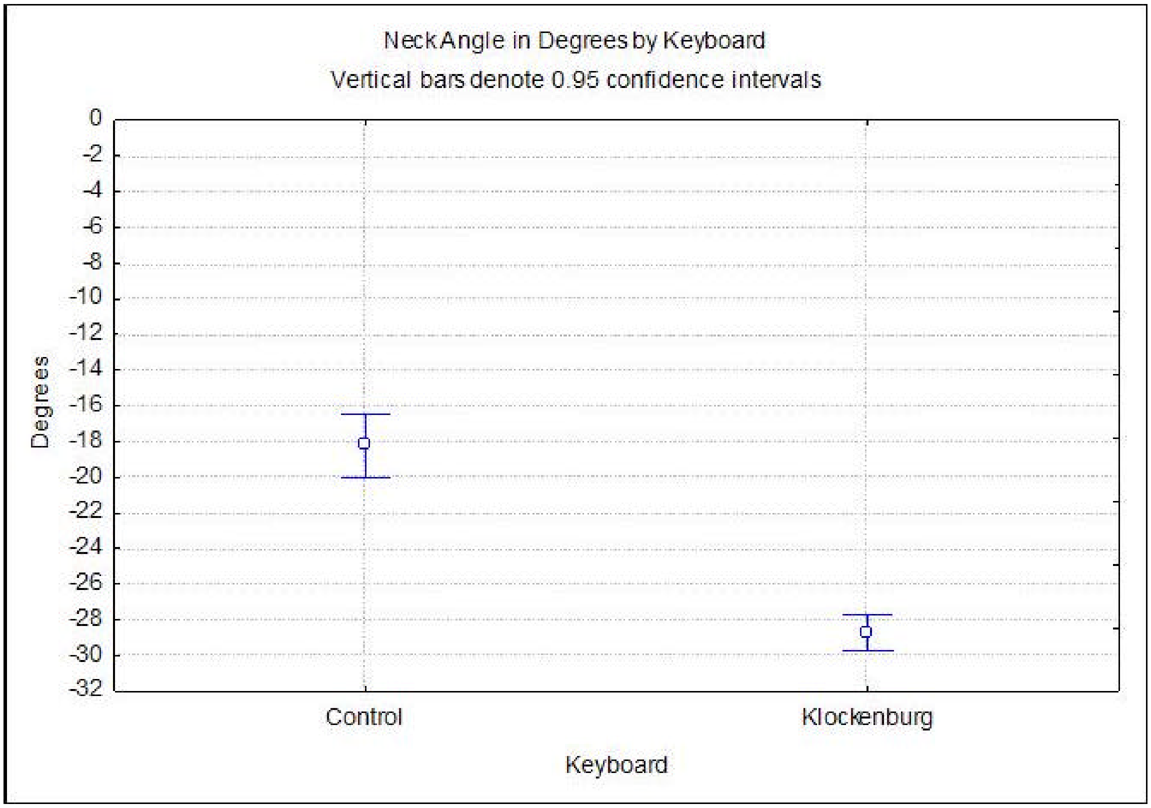

Figure V. Neck angle by keyboard means plot

The Tukey HSD test illustrated in Table VIII shows that the two keyboard means are significantly different.

Table VIII. Neck angle Tukey HSD

Effect	KEYBOARD	Means	1	2
2	Neck-KLB	-28.7	****	
1	Neck-CTRL	-18.2		****

Biomechanics – Wrist F/E

Figure VI illustrates that wrist F/E medians are grouped closely by job classification and by keyboard.

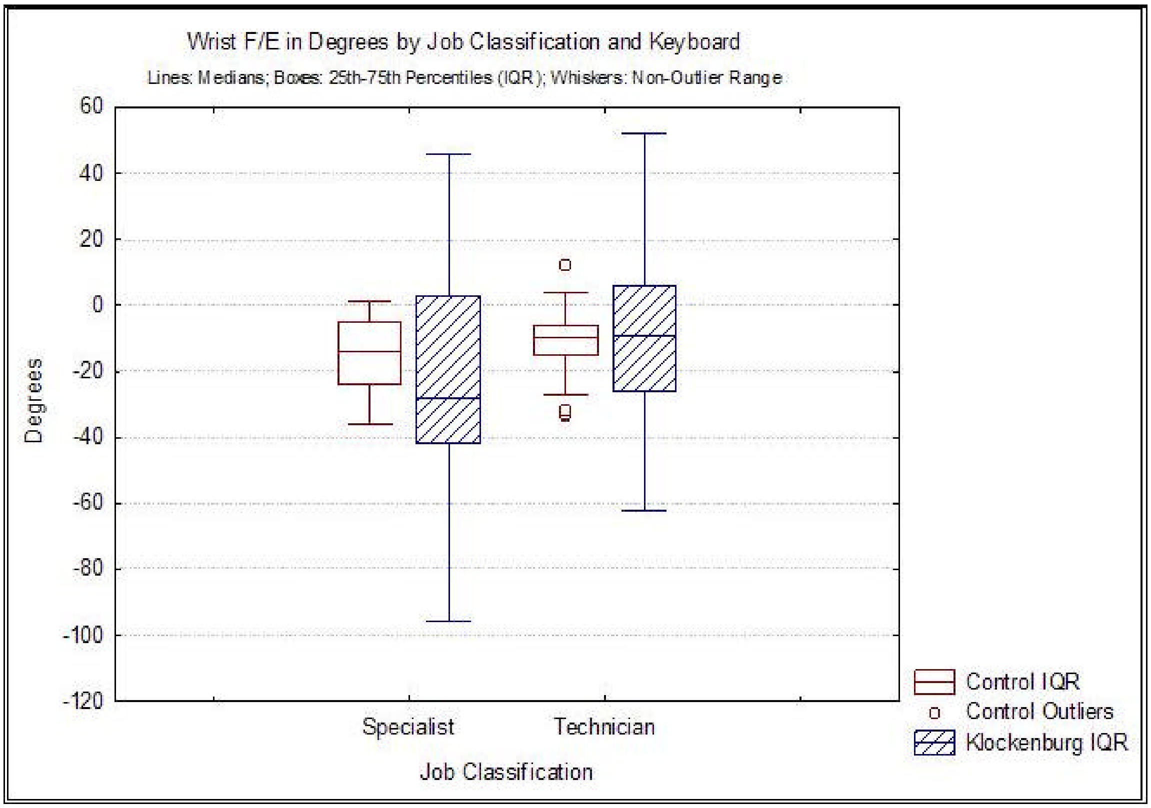

Figure VI: Wrist F/E in degrees by job classification

The descriptive statistics in Table IX show that the means are also grouped closely.

Table IX. Wrist F/E in degrees descriptive statistics

Effect	Level of Factor	N	WristFE-CTRL Mean ± CI (LCL,UCL)	WristFE-CTRL Std. Dev.	WristFE-CTRL Std. Error	WristFE-KLB Mean ± CI (LCL,UCL)	WristFE-KLB Std. Dev.	WristFE-KLB Std. Error
Total		150.0	-12.7 (-14.2,-11.3)	9.1	0.7	-16.9 (-21.8,-12.1)	29.9	2.4
Job Class	Specialist	75.0	-14.7 (-16.9,-12.5)	9.6	1.1	-24.5 (-32.5,-16.6)	34.6	4.0
Job Class	Technician	75.0	-10.7 (-12.6,-8.9)	8.1	0.9	-9.3 (-14.4,-4.2)	22.2	2.6

The repeated measures ANOVA for wrist flexion/extension illustrates statistical significance in the variables job classification and the interaction of keyboard and job classification (see Table X).

Table X. Wrist F/E ANOVA

Effect	SS	Degr. Of Freedom	MS	F	p
job class	6921.6	1.0	6921.6	13.9	<0.001
Error	73873.9	148.0	499.1		
KEYBOARD	1327.2	1.0	1327.2	3.1	0.078
KEYBOARD*job class	2402.7	1.0	2402.7	5.7	0.018
Error	62525.6	148.0	422.5		

The wrist flexion/extension means are demonstrated graphically to be different by type of job classification in the mean plot Figure VII.

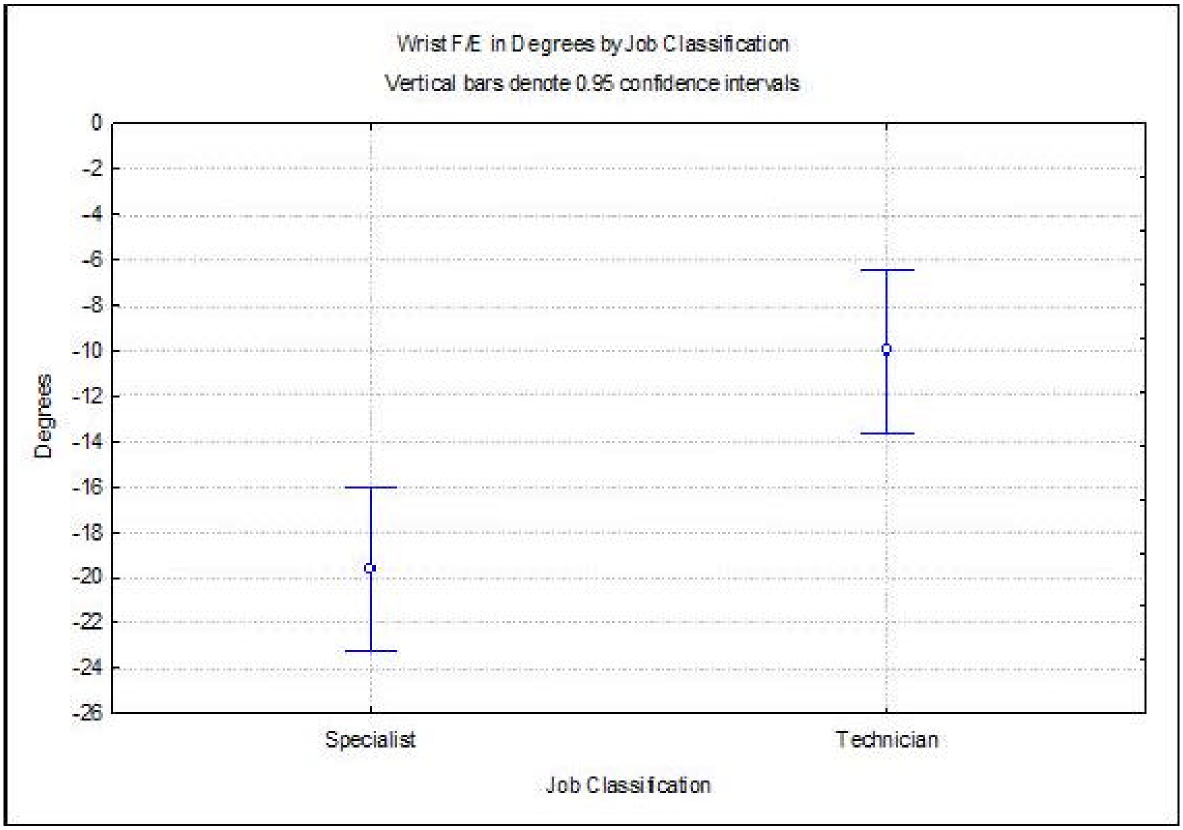

Figure VII. Wrist F/E in degrees job classification mean plot

Figure VIII illustrates the interaction between keyboard and job classification. The nonparallelism of the mean profiles illustrates the interaction of the factors.

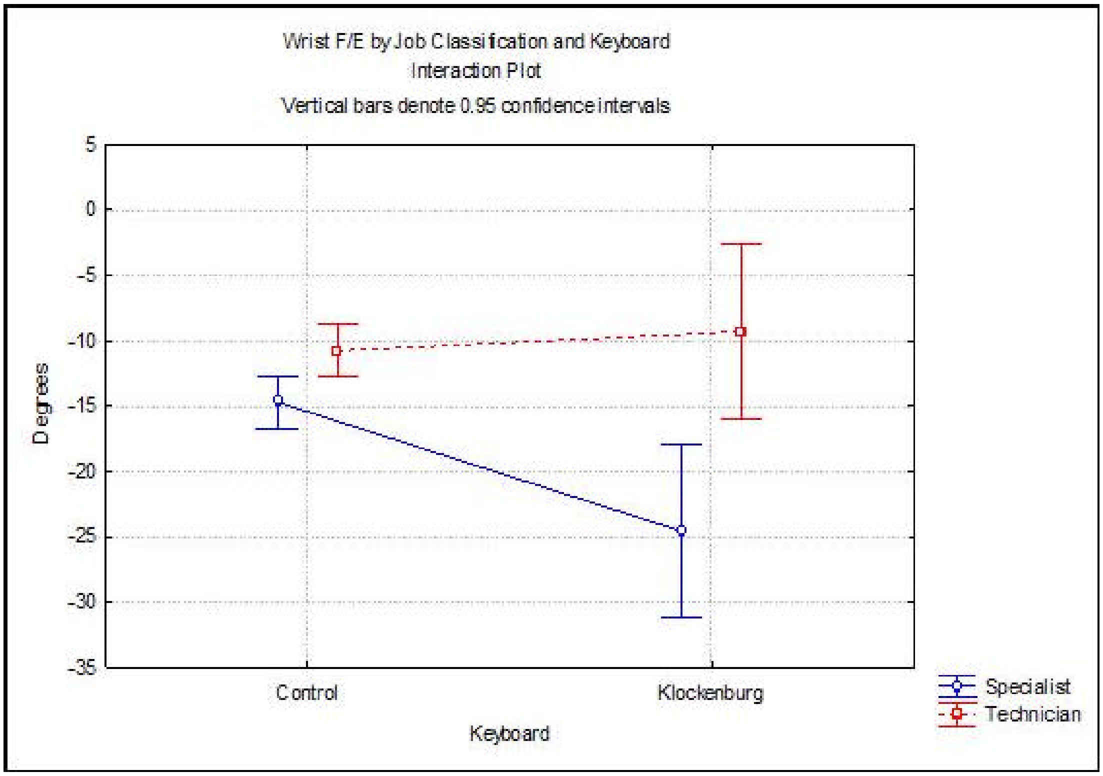

Figure VIII. Wrist F/E keyboard and job classification interaction plot

The Tukey HSD plot in Table XI shows a statistically significant difference of the within factor using Tukey HSD.

Table XI: Wrist F/E job classification using Tukey HSD

Cell Number	Job Class	DV_1 Mean	1	2
1	Specialist	-19.6	****	
2	Technician	-10.0		****

Table XII shows that three of the means are close and the fourth is significantly different using Tukey HSD.

Table XII: Wrist F/E by job classification using Tukey HSD

Cell Number	Job Class	KEYBOARD	DV_1 Mean	1	2
2	Specialist	WristFE-KLB	-24.6		****
1	Specialist	WristFE-CTRL	-14.7	****	
3	Technician	WristFE-CTRL	-10.8	****	
4	Technician	WristFE-KLB	-9.3	****	

Biomechanics – Wrist P/S

Wrist pronation/supination median groupings are shown in the Figure IX median box plot by job classification and by keyboard.

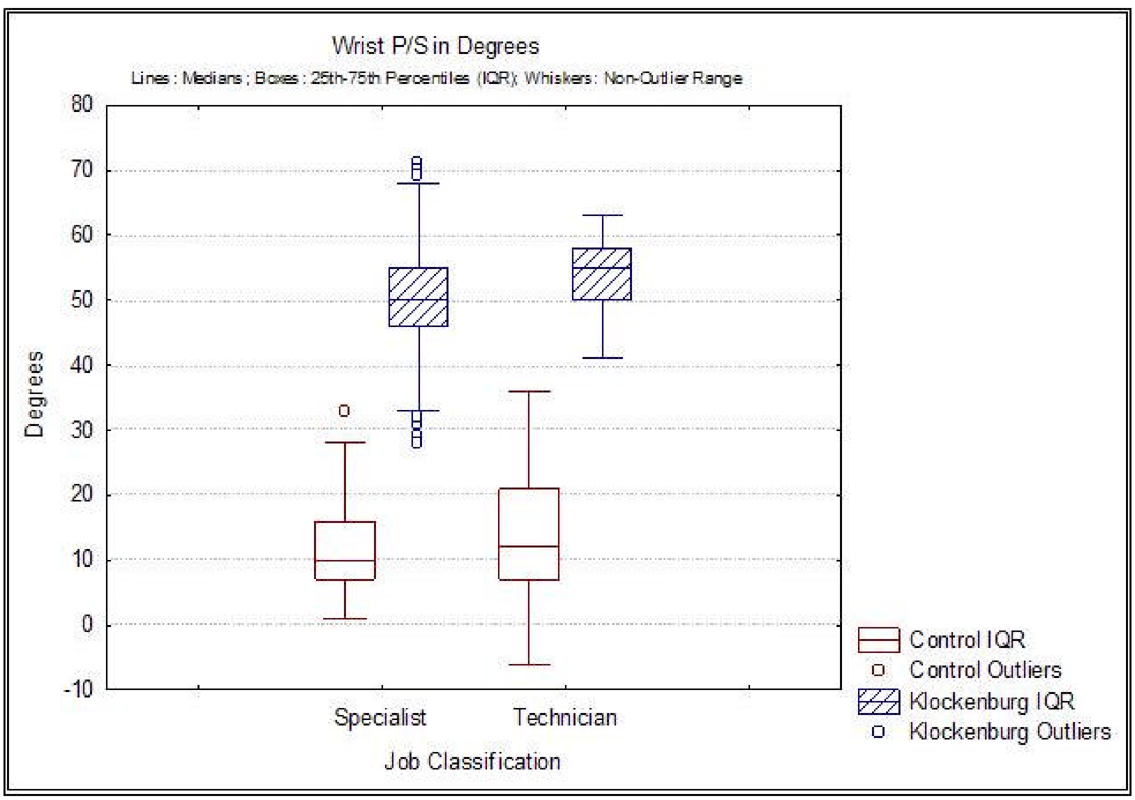

Figure IX. Wrist P/S median box plot

Table XIII descriptive statistics of wrist pronation/supination by job class illustrates that the means are very close by keyboard.

Table XIII. Wrist P/S keyboard by job class descriptives statistics

Effect	Level of Factor	N	WristPS-CTRL Median ± CI (LCL,UCL)	WristPS-CTRL Std. Dev.	WristPS-CTRL Std. Error	WristPS-KLB Median ± CI (LCL,UCL)	WristPS-KLB	WristPS-KLB
Total		150.0	12.9 (11.5,14.3)	8.7	0.7	52.0 (50.6,53.4)	8.5	0.7
Job Class	Specialist	75.0	11.8 (10.3,13.4)	6.7	0.8	50.2 (47.8,52.7)	10.6	1.2
Job Class	Technician	75.0	14.0 (11.6,16.4)	10.3	1.2	53.7 (52.6,54.9)	5.1	0.6

Table XIV shows that Job Classification and Keyboard by Job Classification variables are statistically significant.

Table XIV. Wrist P/S keyboard by job class ANOVA

Effect	SS	Degrees Of Freedom	MS	F	p
job class	602.1	1.0	602.1	7.6	<0.01
Error	11649.9	148.0	78.7		
KEYBOARD	114660.8	1.0	114660.8	1717.9	<0.001
KEYBOARD*job class	31.4	1.0	31.4	0.5	0.494
Error	9878.4	148.0	66.7		

The difference in the wrist pronation/supination means by keyboard is illustrated in Figure X.

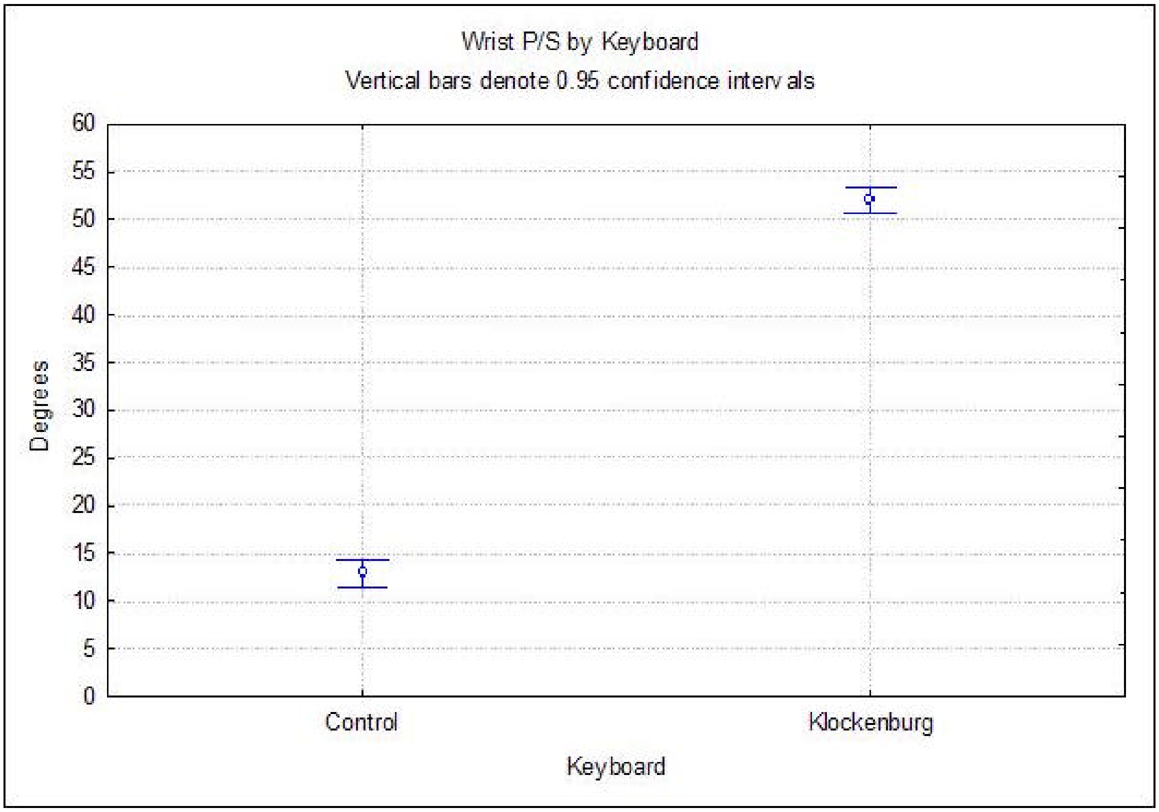

Figure X. Wrist P/S by keyboard

Table XV shows that the wrist pronation/supination by keyboard means are significantly different using Tukey HSD.

Table XV. Wrist P/S by keyboard using Tukey HSD

Cell Number	Job Class	DV_1 Mean	1	2
1	Specialist	31.0	****	
2	Technician	33.9		****

Table XVI shows that the wrist pronation/supination by job classification means are significantly different using Tukey HSD.

Table XVI. Wrist P/S by job class using Tukey HSD

Cell Number	KEYBOARD	DV_1 Mean	1	2
1	WristPS-CTRL	12.9	****	
2	WristPS-KLB	52.0		****

Biomechanics – Wrist R/U

In Figure XI the wrist radial/ulnar medians appear to be grouped by keyboard**.**

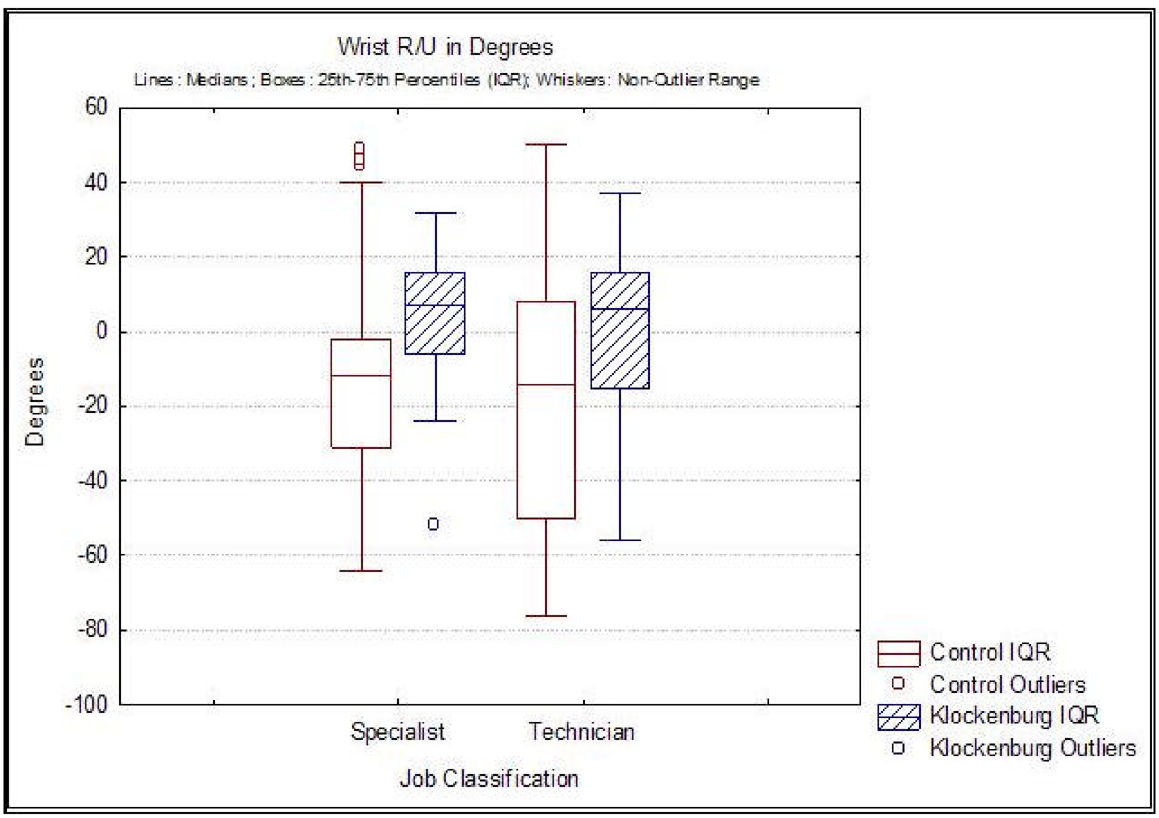

Figure XI. Wrist R/U median box plot

It can be seen in Table XVII that the wrist radial/ulnar means are grouped by keyboard.

Table XVII. Wrist R/U by job class descriptive statistics

Effect	Level of Factor	N	WristRU-CTRL Mean ± CI (LCL,UCL)	Wrist RU-CTRL Std. Dev.	WristRU-CTRL Std. Error	WristRU-KLB Mean ± CI (LCL,UCL)	WristRU-KLB Std. Dev.	WristRU-KLB Std. Error
Total		150.0	-13.1 (-18.7,-7.7)	33.6	2.7	2.8 (0.0,5.6)	17.4	1.4
Job Class	Specialist	75.0	-10.2 (-17.0,-3.5)	29.1	3.4	4.8 (1.2,8.5)	15.8	1.8
Job Class	Technician	75.0	-16.0 (-24.7,-7.4)	37.5	4.3	0.8 (-3.5,5.2)	18.8	2.2

The repeated measures ANOVA in Table XVIII confirms that the means of the keyboard variable are statistically significant.

Table XVIII. Wrist R/U by job class ANOVA

Effect	SS	Degrees Of Freedom	MS	F	p
Job Class	1791.0	1.0	1791.0	2.4	0.124
Error	110625.2	148.0	747.5		
KEYBOARD	19120.1	1.0	19120.1	28.0	<0.001
KEYBOARD*Job Class	59.0	1.0	59.0	0.1	0.769
Error	101040.5	148.0	682.7		

The mean plot in Figure XII illustrates that the keyboard means are different.

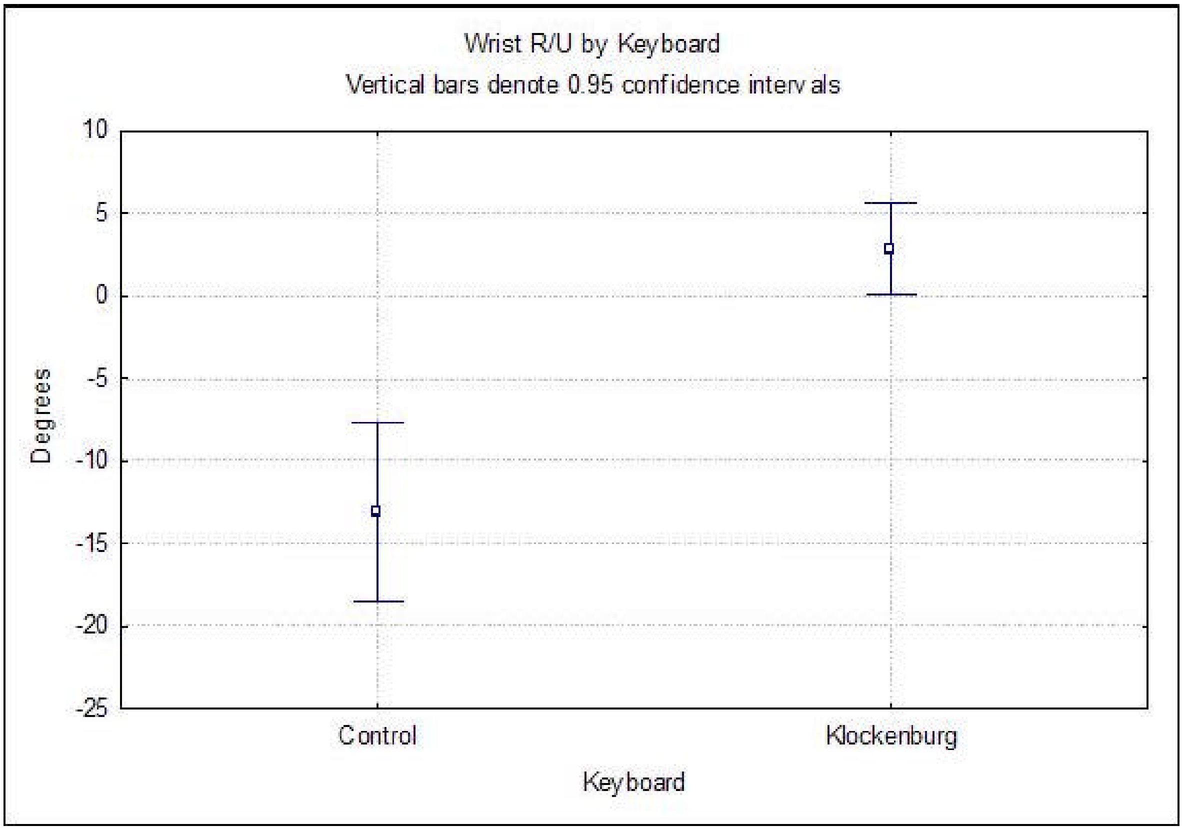

Figure XII. Wrist R/U by keyboard mean plot

Table XIX confirms the difference in the keyboard means by using Tukey HSD.

Table XIX. Wrist R/U by keyboard using Tukey HSD

Effect	KEYBOARD	DV_1 Mean	1	2
1	WristRU-CTRL	-13.1	****	
2	WristRU-KLB	2.8		****

DISCUSSION AND CONCLUSION

The results of this study suggest that in the field the Klockenburg keyboard did not impact productivity (WPM) but it is noted that the words per minute typed by these employees is not particularly high. This is due to the varied tasks that are undertaken in the daily course of their work. In the lab the Klockenburg keyboard decreased productivity (WPM); reduced pronation; reduced ulnar deviation; increased neck angle and did not impact wrist extension. Wrist extension was essentially the same on both keyboards. It was however approximately 5° less than the 18° found by Simoneau and Marklin(12) and the 20° found by Hedge and Powers.(11) The fact that the two were similar is consistent with Simoneau and Marklin(12) who stated that at 30° keyboard tilt there was "…only minimal effect on wrist extension." Simoneau and Marklin also found that wrist extension can be influenced by the height of the elbow in relation to the wrist with measurements ranging from 6° to 26°.(12) This could account for the 5° difference in wrist deviation found here in comparison to the findings of Simoneau and Marklin and others.

Many of the subjects demonstrated wrist extension on the Klockenburg keyboard as well as with the standard keyboard. The addition of a palm rest on the Klockenburg keyboard halves might eliminate the extension issue. A difference of 10° in wrist pronation was found between a standard keyboard and an alternative keyboard with a 25° opening angle between keyboard halves by Nakaseko et al.(1) The results appear to agree with findings of Simoneau and

Marklin who found ulnar deviation on a standard keyboard was found to be 14° in eleven touch typists.[12]

This study does not appear to agree with the findings of Simoneau and Marklin who stated that "participants quickly adapted to new keyboard slope angles and keyboard height, even with only 5 min of practice."[12] Two of the subjects maintained use of their test keyboards after the conclusion of the study. The other eight subjects returned to using their standard keyboards.

Future Studies and Study Improvements

Future studies should incorporate more subjects to have the ability to gain statistical significance in the words/error aspect of the study. Results indicate that the typists were spending more time looking down at the Klockenburg keyboard than with the standard PC 101 keyboard. It would be helpful to compare the neck/head posture of touch typists to non-touch typists in the future. The large amount of time necessary to compile all of the data from the videotape analysis was a constraint on this study. Other researchers have used electronic goniometers with success which would possibly make the use of more subjects easier due to the time involved in working with video tape. It would also be interesting to focus on the difference in mouse use versus keying patterns. Does the type of keyboard lead the user to use the mouse more or less? Also, is any potential negative impact of one type of deviation is lessened or magnified in the presence of another. For instance, does the potential impact (if any) of wrist extension lessen if the forearm is less pronated? Future studies should add palm rests to the Klockenburg keyboard to reduce wrist extension.

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APPENDIX A

Informed Consent Form

A Comparison of a Klockenburg Split Style Keyboard and a Standard PC Keyboard on Body Postures, Comfort, Speed and error Rates

Primary Investigator: Henry Eitt Austin

Graduate Committee Chair: Dr. J. Steven Moore

The primary researcher is currently a graduate student pursuing a Master's degree (M.S.) in Safety Engineering.

This study will be conducted in four phases and will occur at my desk and in the Ergonomics Lab located in AP3E of the USAA Home Office Building. The entire study will run about eight weeks. Ten subjects will be involved in the study. Since this study is entirely voluntary, I understand that I may withdraw or not answer any questions at any time without any penalty or prejudice toward me by USAA or anyone else. Participants will be required to comply with the following: obtain their manager's permission to participate; use their computer at least three hours per day; not plan to miss more than four days of the scheduled study time and agrees to extend data collection time to compensate for any days missed.

The purpose of this study is to answer the following question: Which keyboard is preferred by users and is better for posture, comfort, speed and error rates, the standard PC keyboard or the Klockenburg type of Split Keyboard? I understand that USAA would like to know which is the best equipment for use by its 25,000 employees.

I understand that I will have several body measurements taken. The body measurements that will be taken are: height, shoulder height, standing eye height, shoulder breadth, elbow height, forearm length, upper arm length, standing knuckle height, sitting shoulder height, sitting elbow rest height, sitting knee height, sitting popliteal height, thigh clearance and elbow to finger tip. I will be requested to fill out a questionnaire and body part discomfort survey at the end of each week during Phase I and Phase III for a total of six surveys. I understand that I may refuse to answer any questions that I choose not to with no penalty or prejudice toward me.

I understand that the information from my testing may be used for reports and research and that my identity will not be revealed. Data will be grouped and presented as average values. Data regarding one single subject will not be presented individually. I understand that I will receive neither additional compensation nor other consideration for my participation in this study. I also understand that portions of my participation in this study will be videotaped and used to gather data on my postures. The videotapes will be kept secure and will not be used for any purpose other than for data collection and illustration in this study. None of the data collected will be used to judge my daily work.

Phase I

The first part of the experiment will be at my desk. Office Athlete™ software will be installed on my computer and will track the number of keystrokes, number of mouse clicks and feet of mouse movement I perform on a daily basis. I will do my typical work and print the data out at the end of the day on Thursdays. I will also fill out a comfort survey at the end of the day on Thursday (or my last workday of the week). This phase of the study will last three weeks. If I am out of the office for a day or more, this phase of the study will be extended for me until three full weeks of data has been gathered.

Phase II

After the completion of Phase I, I will be scheduled into the Ergonomics Lab on AP3E for Phase II. This phase of the study will take about 45 minutes of my time. The first part of the lab time will consist of measuring and recording several physical body measures. The measures that will be taken were listed above. If I am a female, I understand that there will be another female present during this phase of the study and Phase IV. I will also be asked to provide my age.

After the measurements are taken, I will sit at an adjustable workstation that has been set up to match the heights and measures of the workstation I use daily. I will verify that the workstation appears to match the setup of mine. I will then have adhesive reflective markers placed on my skin and/or clothes that will be used as reference points for measurements taken from videotape of the session by computer software. These markers will be placed on: tempromandibular joint (jaw), shoulder, hip, knee, ankle, wrist top and side, forearm, and my third knuckle. A balsawood "T" will also be taped to the top of my wrist. All markers will be placed upon the right side of my body. These markers will be used to evaluate my body postures in relation to the two keyboards. I will be given ten minutes to familiarize myself with the workstation and keyboard. I understand that I am to type at a comfortable speed and that there is no grading or impact to the study based upon my typing ability or speed. When told to start, I will then proceed to type a passage from a paper that is placed to the left side of the computer monitor. I will type for five full minutes. I will stop typing when told the time has expired. I will not correct any mistakes I make while typing. My results on one keyboard will be compared to my results on the other keyboard. When I am finished with typing the passage, I will be free to leave.

Phase III

This phase of the study will also take place at my desk. It will be the same as the first phase, except my standard PC keyboard will be replaced with a modified, split keyboard. I will be assisted with setup of the new keyboard to become familiar with it. Office Athlete software will already be installed on my computer and will track the number of keystrokes, number of mouse clicks and feet of mouse movement on a daily basis. I will do my typical work and print the data out at the end of the day on Thursdays (or my last workday of the week). I will also fill out a comfort survey at the end of the day on Thursday. This phase of the study will last three weeks. If I am out of the office for a day or more, this phase of the study will be extended for me until three full weeks of data has been gathered.

Phase IV

The final phase of the study will take place in the AP3E Ergonomics Lab. I will sit at an adjustable workstation that has been set up to match the heights and measures of the workstation I use daily. I will verify that the workstation and keyboard appear to match the setup of mine. I will then have reflective markers placed on my skin and/or clothes that will be used as reference points for measurements taken from videotape of the session by computer software. These markers will be placed on the same locations as in Phase II. These markers will be used to evaluate my body postures in relation to the two keyboards. When told to start, I will then proceed to type a passage from a paper that is placed to the left side of the computer monitor. I will type for five full minutes. I will stop typing when told to stop. I will not correct any mistakes I make while typing. I will be given ten minutes to familiarize myself with the workstation and reading from the prepared text. I understand that I am to type at a comfortable speed and that there is no grading or impact to the study based upon my typing ability or speed.

My results on one keyboard will be compared to my results on the other keyboard. When I am finished with typing the passage, I will be finished with the experiment.

All information that is gathered during the course of this experiment will remain confidential. Access to any of the data is restricted to the primary investigator and his committee. In place of using my name, a code letter will be used to indicate which videotapes and paperwork are related to me. All data will be stored for three years after the end of the study in the AP3 Ergonomics Lab, USAA San Antonio, Texas. After three years, the tapes will be destroyed.
This research study has been reviewed and approved by the Institutional review Board-Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, the Institutional review Board may be contacted through Dr. Michael W. Buckley, IRB Coordinator, Office of Vice President for Research and Associate Provost for Graduate Studies at (409) 845-8585.

I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.

I have been given a copy of this consent form.

______________________________ ______________________

Subject Signature Date

______________________________ ______________________

Signature of Principal Investigator Date

If I have any further questions, I may contact the following people:

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