A Historical Sampling of OERC-Sponsored Research

Retest Reliability in Ergonomic Studies
Franzblau A, University of Michigan

MSD studies usually involve the use of workers surveys but there are few reports on survey retest reliability. This study by the University of Michigan found good test-retest correlations after re-administering a symptom survey to 148 workers.

Publication:
Franzblau A., Test-Retest Reliability of an Upper Extremity Discomfort Survey in an Industrial Population, Scandinavian Journal of Work, Environment & Health, 1997;23:299-307.

Activation Force and Travel Effects on Overexertion in Repetitive Key Tapping
Radwin, R. University of Wisconsin, Madison, Presentation, 1997

The OERC funded two pilot studies to investigate the effects on force applied in a tapping experiment by varying make force, make travel and over travel. The first pilot study found that peak force exerted decreased 24% and key-tapping rate increased 2% when over travel was distended from 0.0 to 3.0 mm. These results indicate that a key switch mechanism that provide adequate over travel might enable operators to exert less force during repetitive key tapping without inhibiting performance. The second pilot studies investigated the short-term effects of key over travel and make force on discomfort and localized muscle fatigue. Fatigue occurred in all cases. There were no changes in subjective discomfort when over travel was increased. Increasing key over travel did not reduce localized fatigue but reducing force did result in a small but statistically significant reduction in fatigue. Therefore, an optimum design to reduce fatigue must consider both key force and key over travel.

Publications:
Radwin, R. G., and One-Jang Jeng, Activation Force and Travel Effects on Overexertion in Repetitive Key Tapping, Human Factors, 1997, 39(1), 130-140.
Radwin, R. G., and Ruffalo, B. A., Computer Key Switch Force-Displacement Characteristics and Short-term Effects on Localized Fatigue, Ergonomics, 1999, Vol. 42, No 1, 160-170

Research Tool for Input Devices
Rempel D. University of California San Francisco/Berkeley

The Kensington Technology Group has developed a software program to automatically collect data concerning mouse and keyboard use in research studies. The data collected includes keystrokes, characterization of mouse use, combined keyboard and mouse activities and periods of input device inactivity. A user written program allows the researcher to extract the information of interest to the study being performed. This program is available at no charge thru the Office Ergonomics Research Committee. Reduced Muscle Oxygenation Can Cause Muscle Fatigue at Low Levels of Muscle Contraction In the workplace, localized muscle fatigue is a limiting factor for repeated static work. Fatigue, defined as reduction in muscle force production, occurs as a function of time and static exertion. Although the cause of fatigue is multifactorial, reduced blood flow and muscle oxygenation may directly cause a reduction in force. Near infrared spectroscopy (NIRS) is a tool available for measuring tissue oxygenation (TO2) noninvasively. If such a tool is sensitive enough to measure oxygenation at low levels of muscle contraction, then we may be able to assess muscle fatigue noninvasively and objectively. In experiments conducted by the University of California, Berkeley and San Francisco, supported in part by the OERC, tissue oxygenation at different levels of MVC decreased from resting baseline. NIRS was sensitive to TO2 changes at levels of 10% maximum voluntary contraction or more. In the second experiment, mean TO2 and mean twitch force decreased from resting baseline. Reduced twitch force is strongly associated with reduced TO2 ($r^2=0.99$). These results indicate that 7% reduction in TO2 significantly decreases muscle force production. Because reduced TO2 is associated with muscle fatigue, NIRS may prove to be a

valuable tool to assess fatigue objectively. However, studies to test the NIRS capability out in the field are warranted.

Publication:
Rempel D, Murthy G., Tal R., Bach J., Reduced Muscle Oxygenation Can Cause Muscle Fatigue at Low Levels of Muscle Contraction, Journal of Orthopedic Research, 15:507-511, 1997

Effect of Arm Support Options while Mousing
Wells, R. University of Waterloo

This study by the University of Waterloo, Canada investigated whether there is a difference in muscle activity and movement accuracy between the different postures currently recommended for using a mouse; arm supported at the wrist, forearm support, elbow support and movement from the shoulder joint with the arm unsupported. It found that the discomfort and electromyographic data favor the use of arm and elbow support for mouse use.

Publication:
Wells, R., Lee, I.H., and Bao, S., Investigation of upper limb support conditions for mouse use, Proceedings of the 29th Annual Conference of the Human Factors Association of Canada - 1997

Characterization of the Muscle Load Patterns in Computer Input Device Tasks
Martin, B. J. University of Michigan, 1998

Surface EMGs have been successfully used to characterize muscle load and fatigue for large muscle groups. The reliability of surface EMGs to accurately measure the activity in the small muscles employed in computer input device tasks is not known. The OERC funded part of a larger study by the Universities of Michigan and California - San Francisco to compare muscle load patterns in computer input device tasks measured by surface and fine wire EMG electrodes that were imbedded in target muscles. The study found that the degree of correlation between the two methods varies depending on the muscles involved.

Publications:
Martin, B. J., Rempel, D. J., Dennerlein, J., Serina, E., Armstrong, T. J., EMG Analysis Of Muscle Load In Keyboard Work, International Conference on Occupational Disorders of the Upper Extremities, Ann Arbor, Michigan, October 24-25, 1996

Martin, B. J., and Rempel, D. M., Muscle Activity During Computer Input Device Use, International Conference on Occupational Disorders of the Upper Extremities, Ann Arbor, Michigan, October 24-25, 1996

Jacobson M., Rempel D., Martin B., Keir P., Dennerlein J., Comparison of surface to indwelling extrinsic finger EMG during use of computer pointing devices, The Human Factors and Ergonomics Society 42nd Annual Meeting - 1998

Assessment of the Effects of Computer Monitor Placement on User Biomechanics and Comfort
Psihogios, J. P. North Carolina State University

This study by North Carolina State University was conducted to characterize effects of computer monitor viewing angle on operators. The study was conducted in two phases: a controlled laboratory experiment followed by field verification. In the lab, three viewing angles were studied: 0, -17.5, and -35 deg, from horizontal to center of screen. Effects of monitor size and keyboard familiarity were also investigated. Muscle activity, body posture, visual acuity, performance, discomfort, and preference data were collected. In general, muscle activity was greater at -35 deg than at 0 deg; and greater for a smaller monitor than a larger one. Head postures were affected by viewing angle, but trunk postures were not. Touch typists kept their heads more upright than non-touch typists. Mousing performance slowed slightly at 0 deg. Subjects' rank order preferences were for the -17.5 deg, followed by the 0 deg, followed by the -35 deg angle. Results suggest there could be benefits to using a larger monitor with viewing angle between -17.5 to 0 deg

for screen-intensive work. The field study found little difference between the 0 and -17.5 deg locations in terms of user preference or discomfort, and confirms the results of the lab study that users should be able to exercise control of monitor placement, within that 0 to -17.5 deg range.

Publications:
Psihogios, J.P., (1998) Masters Thesis: The Effects of VDT Placement on User Posture and Comfort: A Field Study, North Carolina State University.

Sommerich, C.M., Joines, S.M.B., Psihogios, J.P. (1998), Effects of VDT viewing angle on user biomechanics, comfort, and preference, The Human Factors and Ergonomics Society 42nd Annual Meeting, Oct 1998.

Psihogios, J.P., Sommerich, C.M., Mirka, GM, and Moon, SD, Effects of VDT placement on user posture and comfort, The Human Factors and Ergonomics Society 42nd Annual Meeting, Oct 1998.

Marconi Research Conference 1998 Estimating Muscle Load Using Surface EMG Amplitude: Introduction
Rempel D. University of California, San Francisco/Berkeley

Since muscle load may be related to performance, fatigue, discomfort and injury, researchers and practitioners are increasing using surface electromyography to assess muscle load during work to evaluate the demands of jobs, tools, workstations and tasks. However, several factors can limit the value of sEMG to accurately assess muscle load such as poor signals, cross talk due to proximity of other muscles, artifacts due to motion and skin movement and other factors. The objective of this December 98 symposium was to discuss the question, "Under what circumstances surface EMG amplitude can be used to estimate loads of upper extremity and neck muscles during the performance of precision tasks such as use of a keyboard, monitor viewing, etc." The participants were a mix of those doing fundamental sEMG research and those applying the technology.

Publications:
Proceedings of the Marconi Research Conference 1998, Estimating Muscle Load Using Surface EMG Amplitude, Ergonomics Program, University of California-San Francisco and Berkeley, December 11-14, 1998.

Rempel D., Martin B., Sommerich C., Clancy A., Wells R., Kadefors, R., Estimating Forearm and Neck Muscle Load Using Surface EMG Amplitude: Methodolic Issues, Proceedings of the Triennial Congress of the International Ergonomics Association and the Annual Meeting of the Human Factors and Ergonomics Society, San Diego, California, 2000 5-525 - 5-528

Effect of Computer Keyboard Slope and Height on Wrist Extension Angle
Marklin, R.W, Simoneau, G.G. Marquette University

The goal of this laboratory study was to determine the systematic effect that varying the slope angle of a computer keyboard along with varying wrist height have on wrist extension angle while subjects typed. Thirty subjects typed on a keyboard whose slope was adjusted to +15°, +7.5°, 0°, -7.5°, and -15°. Ten subjects had the height of the keyboard set such that their wrists were at the same height as their elbows; another ten subjects typed with the keyboard height set such that their wrists were five cm above their elbows; the remaining ten subjects were tested at a keyboard height that placed their wrists four cm below their elbows. Results showed that as keyboard slope angle moved downward from +15º to -15º, wrist extension decreased approximately 13º (22º at +15º slope to 9º at -15º slope). Wrist extension decreased from 21.8º when the typists' wrists were four cm below elbow height to 7.3º when the wrists were five cm above elbow height. The combination of keyboard slope and wrist height that minimized wrist extension was a - 15º-keyboard slope with the wrists positioned five cm above elbow height. This combination resulted in a wrist extension angle of 1.5º. Keyboard slope and the height of the wrist (and therefore the keyboard) relative to the elbow did not impair typing performance. Based on carpal tunnel pressure studies, histological studies of tendons, and modeling of the wrist, it appears that keyboards that can be sloped

downward could be beneficial with respect to etiology of MSDs of the wrist.

Publications:
Simoneau, G.G., Marklin, R.W., and Harrison L., Effect of Computer Slope on Users' Wrist Extension Angle, Physical Therapy '99, Scientific Meeting & Exposition of the American Physical Therapy Association, Washington, DC, June 4-7, 1999

Simoneau, G.G. and Marklin, R.W., Effect of computer keyboard slope and height on wrist extension angle, Human Factors, Summer 2001, 287- 298 Simoneau, G.G., Marklin, R.W., and Berman, J., Effect of Computer Keyboard Slope on Wrist Position and Forearm EMG of Asymptomatic Typists, submitted to Physical Therapy.

Simoneau, G.G., Marklin, R.W., Berman, J.E., Garrison, M.K., Bielefield, T.M., Computer keyboard slope: wrist extension angle and forearm musculature activation, Proceedings of Int. Society of Biomechanics (ISB) Congress, July 8-13, 2001, Zurich, Switzerland.

Simoneau, G.G., Berman, J.E., Garrison, M.K., Welsch, S.E., and Marklin, R.W., Computer keyboard slope: wrist extension angle and forearm musculature activation, Arthritis Research Conference, March 23-25, 2001, San Diego, CA.

Simoneau, G.G. and Marklin, R. W., Effect Of Computer Keyboard Slope And Height On Wrist Extension Angle, Proceedings of the 3rd Australian and New Zealand Society of Biomechanics Conference, Queensland, Australia, Jan. 31 to Feb. 1, 2000.

Marklin, R.W. and Simoneau, G.G., Electromyographic Activity Of Forearm Flexor And Extensor Muscles From Typing On Negatively Sloped Computer Keyboards, the American Industrial Hygiene Conference and Exposition, Orlando, FL, May 20-25, 2000

Predicting Clinical Outcomes and Lost Time from Work in Occupational Upper Extremity Disorders. Feuerstein, M. Uniformed Services University of the Health Sciences

This study by the Uniformed Services University of the Health Sciences developed a screening tool and tested its validity in a clinical setting. The screening tool sought to prospectively examine which individuals might be more likely to experience prolonged recovery duration from a work-related upper extremity disorder. Eighty-seven study participants completed a baseline survey, and were followed up at 1, 3, and 12 months with a post-baseline questionnaire. The results indicate that ergonomic and psychosocial stress, pain severity, and pain coping style predict clinical outcome at shorter intervals, while number of past treatments/providers, recommendations for surgery and pain coping style predict longer-term outcome. The resulting prognostic screen provides a simple tool that assesses the multidimensional nature of WRUEDs and predicts clinical outcome. Furthermore, the findings suggest the importance of early intervention that addresses physical and psychosocial stressors at work.

Publications:

Feuerstein, M., Huang, G.D., Haufler, A.J., and Miller, J.K. (2000), Development of a Screen for Predicting Clinical Outcomes in Patients with Work-Related Upper Extremity Disorders, Journal of Occupational & Environmental Medicine. 42(7):749-761.

Effect of Ergonomic Interventions and Stress Management on Lost Time and Health Outcomes in Upper Extremity Musculoskeletal Disorders Feuerstein, M. Uniformed Services University of the Health Sciences

There is data that suggests both ergonomic and psychosocial factors can influence lost time, symptoms, and other critical work and health outcomes in workers with occupational upper extremity disorders. However, there are no controlled trials that determine the effects of ergonomic and psychosocial interventions on these outcomes. This study by the Uniformed Services University of the Health Sciences, in affiliation with

the Georgetown University Medical Center, is a randomized controlled investigation of the effects of ergonomic intervention vs. stress management vs. integrated ergonomic intervention and stress management vs. no treatment. The specific objective of this study is to determine the differential effects of the three interventions on lost workdays, symptoms, functional limitation, mental health, job stress, and problem solving skills immediately following treatment and at six and twelve months post treatment.

Stress Reactivity in Carpal Tunnel Syndrome
Feuerstein, M. Uniformed Services University of the Health Sciences

Epidemiological studies indicate job stress is associated with symptom severity, functional limitations, and lost work time in individuals with a variety of work-related upper extremity disorders, including carpal tunnel syndrome (CTS). Psychophysiological studies report that individuals with musculoskeletal symptoms in the upper limbs have exhibited increased muscle tension in response to stress. Response to stress has also been associated with increased sympathetic nervous system activity. These physiological correlates of stress may impact the pathophysiology of a range of musculoskeletal disorders. Despite this work, little is known about the specific effects of stress on potential musculoskeletal and sympathetic nervous system mediators of carpal tunnel syndrome. The present study will determine whether workers with electrodiagnostically confirmed CTS demonstrate heightened musculoskeletal and sympathetic nervous system reactivity to job stress. 60 female subjects (30- CTS, 30- matched symptom-free controls- age, ergonomic exposure, and job stress) will be recruited. All subjects will monitor sources of job stress, symptoms, and distress using a standardized diary for a period of two-weeks prior to a laboratory investigation of response to stress. Subjects will then be exposed to job-related, pain-related, and general stressors while continuous, bilateral forearm extensor and upper trapezius electromyographic recordings are obtained. Sympathetic nervous system reactivity will also be collected using a measure of skin conductance. Self-report measures of symptoms (pain, numbness and tingling) and distress will be obtained during baseline, stressor, and recovery periods. Results will be analyzed to determine whether differences in reactivity exist between the CTS and control group. The degree to which relationships exist among self-reported job stress and symptoms will also be examined.

Cross-Sectional Field Investigation of Pointing Device Usage in a Computer Intensive Environment

This study investigated common usage patterns and their roles on upper extremity discomfort in eighty intensive, scientific and technical PC pointing device users at the Lawrence Livermore National Laboratory. The questionnaire used solicited information about work tasks, work practices, gripping styles and conditions in association with PD use. Subjects used visual analogue scales, diagrams or forced choice alternatives to estimate usage pattern. 70% of the participants (45/60) met the inclusion criteria for heavy usage (4hr/day). Within this subgroup, subjects worked 42 hours per week and spent 55% (23 hours per week) of their working time using pointing devices. Pointing devices (PDs) were used with the right hand by 34 (75%) subjects, with the left hand by 6 (13%) subjects and with both hands alternately by 5 (11%) of the subjects. Fifty-six percent (25/45) of the subjects reported switching PDs. Among this group, PD changes were due to upper limb symptoms (63%), poor design/function (28%), equipment failure (8%) and inadequate workspace (4%). Also, 18% (7/40) of the right hand dominant PD users switched to using their non-dominant hand or both hands due to upper limb pain/discomfort. There was a slight trend of greater hand/wrist comfort among those using wrist/forearm support ($p=0.06$). Hand/wrist comfort was also associated with certain gripping styles ($p=0.05$). This study showed that due to upper limb discomfort, many PD users reported having switched devices or operating hand. In addition, there was a trend toward greater hand and wrist comfort with certain gripping styles and working conditions.

Publication:
Oral presentation to the OERC

Static vs. Dynamic Forces Applied to Computer Keyboard Keys
Marklin, R.W. Marquette University

Marquette University conducted a study that quantified the static and dynamic forces required to depress rubber-dome, which is the most common mechanism in commercially available QWERTY keyboards, and

coil-spring computer keyboard keys. In the experiments, a probe on a computer-controlled test rig was used to depress and release a computer key under software control. Contact force and motion data were collected as computer keys were depressed and released at constant velocities up to 80 mm/s. Both rubber-dome and coil-spring keys exhibited damping forces, represented by increased force with speed of travel of the key. Peak contact forces required to depress computer keys were at least 10% greater at 80 mm/s travel speed than at the quasi-static speed (0.5 mm/s) for both rubber-dome and coil-spring keys, indicating a presence of damping forces during the depression stroke. In addition, peak contact forces for non-alphabetic keys, such as "Enter" and "Spacebar", were almost twice as great as alphabetic keys. Quantification of these speed-dependent forces enhances our understanding of the basic mechanical properties of the mechanisms of computer keys, which thus far have been investigated with respect to quasi-static properties only.

Publications:

Nagurka, M.L. and Marklin, R.W., Measurement of impedance characteristics of computer keyboard keys, 7th Mediterranean Conference on Control and Automation - MED99, Sponsored by IEEE, Haifa, Israel,, June 28-30.
Nagurka, M.L., Marklin, R.W., and Liu, C., Design of a test rig for measurement of stiffness and damping characteristics of computer keyboard keys, American Control Conference, Sponsored by ASME, IEEE, AIAA, AICHE, AISE, ASCE, ISA, and SCS, San Diego, CA, July 2-4.
Marklin, R.W. and Nagurka, M.L., Static vs. dynamic application of forces applied to computer keyboard keys, Submitted to American Industrial Hygiene Assoc. J. for review, July 2001

Using Muscle Twitch to Measure Muscle Fatigue in Forearm Extensor Muscles During Typing
Rempel, D. University of California, Berkeley

The aims of this pilot study conducted by the University of California, Berkeley were to determine whether extensor carpi radialis muscle fatigue could be measured in four hours of typing and whether there were differences in the level of wrist fatigue while typing with the wrist in different angles of wrist extension. Fatigue measurements were obtained by measuring twitch force of the muscle after electrical stimulation. The results were that apparent low frequency fatigue did not occur until the end of four hours of keyboard use; although there was a trend toward increasing muscle fatigue with increasing angles of wrist extension the differences were not statistically significant; symptoms of subjective fatigue occurred within one hour of typing; and, subjective fatigue recovered over a time course of hours.

Publication:

Chien-Yi Lu, J., Using Muscle Twitch to Measure Muscle Fatigue in Forearm Extensor Muscles During Typing, Masters Thesis, University of California, Berkeley, 1997

Different Computer Tasks Affect the Exposure of the Upper Extremity to Biomechanical Risk Factors Dennerlein, J. Harvard University

In order to determine differences in biomechanical risk factors across computer tasks, a repeated measures laboratory experiment was completed with 30 touch-typing adults (15 females and 15 males). The participants completed five different computer tasks: typing text, completing an htmlbased form with text fields, editing text within a document, sorting and resizing objects in a graphics task and browsing and navigating a series of intranet web pages. Electrogoniometers and inclinometers measured wrist and upper arm postures, surface electromyography measured muscle activity of four forearm muscles and three shoulder muscles and a force platform under the keyboard and force-sensing computer mouse measured applied forces. Keyboard-intensive tasks were associated with less neutral wrist postures, larger wrist velocities and accelerations and larger dynamic forearm muscle activity. Mouse-intensive tasks (graphics and intranet web page browsing) were associated with less neutral shoulder postures and less variability in forearm muscle activity. Tasks containing a mixture of mouse and keyboard use (form completion and text editing) were associated with higher shoulder muscle activity, larger range of motion and larger velocities and accelerations of the upper arm. Comparing different types of computer work demonstrates that mouse use is prevalent in most computer tasks and is associated with more constrained and non-neutral postures of

the wrist and shoulder compared to keyboarding.

Publications:

Dennerlein, J.T., Johnson, P.W., Different Computer Tasks Affect The Exposure of the Upper Extremity to Biomechanical Risk Factors, Ergonomics, Vol. 49, No. 1, 15 January 2006, 45 - 61

Student Ergonomics

Undergraduate Students' Ergonomic Knowledge of Appropriate Computer Workstation Design and Work Habits: The Emerging Young Knowledge Workforce. Amick, B.C. U. Texas

A participatory approach was used to create a computer ergonomics workshop for college students, incorporating an instructional systems design process and adult learning inquiry perspectives. The primary objective of this participatory ergonomic pilot intervention was to involve students throughout the training design process in solving computer workstation ergonomic problems and adopting healthy computing behaviors. Students' level of participation included becoming part of the training design team, a co-facilitator, or a student trainee. A second objective was to examine the translation of an industrial office ergonomics training program into a college computer ergonomics training program. The long term goal was to reduce upper extremity symptoms and disability. The program was piloted at one private university. The three student trainees significantly increased their knowledge of computer ergonomics from 69% post-training. Trainees were also successful in conducting computer ergonomic evaluations of students' computing work areas. They achieved 100% proposing solutions in five ergonomic workstation assessments in the field. This approach was successful in creating a sense of ownership among the student developers and facilitators as reflected in their self-reports during a post-intervention debriefing. The results of this pilot study justify formal controlled trials of this intervention in university students, who will become tomorrow's workers.

Publication:

Michelle M. Robertson, Benjamin C. Amick, III, Nathaniel Hupert, Mary Pellerin-Dionne, Eugene Cha, Jeffrey N. Katz, Effects of a participatory ergonomics intervention computer workshop for university students: a pilot intervention to prevent disability in tomorrow's workers. Work, 2002;18(3):305-14.

Prevalence of upper extremity musculoskeletal disorders in college students.
Amick, B.C. U. Texas
Recently, researchers have reported high musculoskeletal symptom prevalence at several U.S. colleges. Since ergonomic interventions have been shown to prevent and reduce disability, it is important to identify the risk factors for developing symptoms among college students. A nested case-control study was completed to determine computer-related ergonomic risks associated with musculoskeletal symptoms. A trained observer completed ergonomic assessments on 52 randomly selected cases and controls. More than 75 percent (cases and controls combined) of the population was exposed to nine potential postural strains including: arms not along side during keying or mousing; lower back not supported; not having chair accessories; computer monitor not adjustable; mouse being too high or low; hand/wrist/forearm in contact with the desk edge; lack of wrist support; and keyboard not being adjustable. Cases and controls were equally likely to have substantially elevated risks but because the sample was small and lacked power, no risks were statistically significant. Since many known risk factors were prevalent in cases and controls, more research is required to evaluate and prevent injury in this population.

Publication:

Jessica Tullar, MPH, Benjamin C. Amick III, PhD, Michelle M. Robertson, PhD, CPE, Anne H. Fossel, Chris Coley, MD, Nathaniel Hupert, MD, MPH, Mark Jenkins, MD, Jeffrey N. Katz, MD, MS5, Direct observation of computer workplace risk factors of college students, The American Journal of Medicine, Volume 109, Issue 7, Pages 586-588

2**4/7 Tablet PC Access for Students and Their Teachers in One Columbus High School: How good is their current IT program and how can ergonomics know-how help make it better?** Sommerich, C.M, Ohio State University

Compact Keyboards – Piet van Lingen, TNO, 2007

University Students' Notebook Computer Use: Phase 2 – Karen Jacobs, Boston University, 2007

The prevalence of hand disorders amongst hand held device users and their relationship to patterns of device usage - Wells, R. University of Waterloo, 2008