5 R01 OH00 8781 - 03: Interactions of Biomechanics and Psychosocial Stressors and MSDs

20 November 2013

PI:
Jack T Dennerlein, Ph.D.
Harvard School of Public Health
665 Huntington Avenue
Boston, MA 02115
jax@hsph.harvard.edu

Award Made to:
Harvard School of Public Health
665 Huntington Avenue
Boston, MA 02115

Start date: 1 September 2008
End date 31 August 2013

Co-Investigators
Jennifer Bruno-Garza, Harvard School of Public Health
Peter Johnson, University of Washington, Seattle, WA
Birgette Blatter, VU University Medical Center, Amsterdam, NL
Belinda Eijckelhof, VU University Medical Center, Amsterdam, NL
Maaike Huysmans, VU University Medical Center, Amsterdam, NL
Allard van der Beek, VU University Medical Center, Amsterdam, NL
Jaap van Dieen, VU University Medical Center

Table of Contents

Abstract

Computer related musculoskeletal disorders plague the American office work force. Epidemiological studies have identified physical, psychosocial and individual factors associated with musculoskeletal health outcomes; however, the role of physical factors have been difficult to ascertain due to the difficulty of measuring these factors in the real work environment. For the first aim of the study, we developed a system that measured 22 different biomechanical factors of 120 office workers in their real work environment. The system was untethered allowing workers to freely move in their work environment. For these direct measures of biomechanical factors we tested the hypothesis that (1) physical risk factors and psychosocial factors were highly correlated in the modern office. From these data we built exposure prediction models for these 22 biomechanical parameters that can be applied to larger epidemiological studies. For the second aim of the study, we applied these exposure prediction models to a cohort of office workers to test the hypothesis that (2) these physical risk factors were associated with musculoskeletal disorders (MSD) outcomes.

The first aim created a number of key findings. First, extending our laboratory work, within subject upper extremity biomechanical exposure intensities vary across tasks significantly. Keyboarding activities were associated with neutral postures of the shoulder yet were associated with higher levels wrist extension and acceleration. Mouse activities were associated with non-neutral postures of the right shoulder and the least variability (or most constrained postures). Idle activities were associated with the largest variability. Second, participants who reported high over-commitment and low reward had significantly larger shoulder trapezius muscle activity than those with lower levels of over-commitment and high reward. In addition, work patterns also varied significantly across workers who report different levels of organizational work stress with less breaks and longer continuous bouts of activity for those in higher stress groups. The second aim created two major findings. First, across subjects upper extremity biomechanical exposure intensities vary and can be predicted based on a set of self-reported parameters often collected in epidemiological studies of computer related MSDs. Second, oreliminary univariate analysis indicates in a separate and larger cohort, that predicted values of right shoulder flexion, right forearm muscle activity, and keyboard force are associated with the incidence of new reports of neck, shoulder, arm, wrist, and hand pain.

The impact of these findings includes changing our knowledge about associations between work place psychosocial factors and exposure to computer work identifying biomechanical pathways for computer related musculoskeletal disorders.

SECTION 1: FINAL PROGRESS REPORT

We made significant progress completing the specific aims for this project. There have been no changes in the specific aims since the inception of the project. We called this project, the PROOF Study -- PRedicting Occupational biomechanics in OFfice workers (PROOF) study, which investigated the effects of psychosocial stressors at work on biomechanical loading of office workers in the field

The working hypotheses for the PROOF study were that (1) physical risk factors and psychosocial factors are highly correlated in the modern office and that (2) these physical risk factors are strongly associated with musculoskeletal disorders (MSD) outcomes.

The approach of the PROOF study was to directly measure 22 physical/biomechanical parameters in a representative sample of 120 office workers for a two hour period in their own workstation. These 120 workers were selected and recruited across the four psychosocial factors of the Siegrest model inducing over-commitment and reward. From these data we tested the first hypothesis. In addition we built exposure prediction models from these data. These models predicted biomechanical exposures from self-reportable data for each individual participant. For our second aim we applied these predictions to a two-year longitudinal cohort of 1582 office workers measuring MSD outcomes and many of the self-reported data in the developed prediction models.

Significant (Key) findings

The significant findings from the PROOF Study include:

- Within subject upper extremity biomechanical exposure intensities varied across tasks of keyboard use, mouse use, and idle computer interactions significantly
- Shoulder muscle activity was larger in workers who report higher levels of organizational work stress.
- Work patterns varied significantly across workers who report different levels of organizational work stress.
- Across subjects upper extremity biomechanical exposure intensities varied and could be predicted based on a set of self-reported parameters often collected in epidemiological studies of computer related MSDs
- Preliminary univariate analysis indicates in a separate and larger cohort, that predicted values of right shoulder flexion, right forearm muscle activity, and keyboard force were associated with the incidence of new reports of neck, shoulder, arm, wrist, and hand pain.

Translation of Findings

These findings have direct translation to knowledge, research and practice. In terms of knowledge, these findings provide evidence from a group of real workers in their real work environment that link psychosocial factors and work stressors with increased biomechanical load. This link supports the conceptual injury model that contains biomechanical pathways for psychosocial factors. Such relationships have been hypothesized and documented in the laboratory; however, little data exist for the field using psychosocial factors rather than work stressors. The increased shoulder muscle activity has long been suspected physical risk factor for computer related musculoskeletal disorders of the shoulder and neck, which is also associated with increases psychosocial stress.

Similarly we have increased our knowledge about work patterns and workplace stress. We observed longer duration of exposure among those who report higher levels of stress as well as different break patterns, both which have been associated with MSD outcomes. Again, the different patterns provide further evidence that exposure patterns varied across groups reporting different levels of stress.

In addition, the findings add to the knowledge of potential physical/biomechanical risk factors for computer related MSDs. We are observing relationships in our preliminary analysis between shoulder posture and shoulder and neck symptoms as well as forearm muscle activity and keyboard typing force with arm, wrist, and hand symptoms. These identified factors provide credence to postural interventions and workstation design in this population.

In terms of translating the findings to research and research methodology, the PROOF study has identified new methods for estimating exposure to biomechanical factors in a set of office workers allowing future researchers to examine and create new exposure-dose response relationships. Hence, these findings can be applied to other epidemiological studies of office workers developing prediction models for a specific cohort and testing relationships between biomechanics and MSD outcomes.

In terms of practice, these findings provide evidence that stress can change a worker's exposure to biomechanical factors. Hence, in practice intervention and ergonomic programs can address physical factors through both engineering type of controls (adjustable furniture, for example) and work place organizational factors such as participatory approaches to including workers providing them with more control over their work environment and increasing their job satisfaction, co-worker support, and supervisor support that all affect our measures of psychosocial stress.

In addition, these findings provide the practice with information about work patterns and stress suggesting that intervention for stress should examine break scheduled in terms of both duration and frequency. By focusing on the culture of breaks within an organization, worker health and stress may change working patterns, which in turn can increase the worker's comfort and productivity.

Outputs

- 7 peer reviewed papers published, 2 papers under review, 5 papers in preparation
- 2 Doctoral Student Disserations
- 15 presentations and posters at international conferences
- A system that can measure 22 biomechanical parameters for office workers.
- We have communicated our results to the Office Ergonomics Research Committee (OERC), a group of ergonomists and designers from various industries who are interested in applying the latest research in the field of office ergonomics to their practice, at their annual meeting, the Marconi@Marigold conference in Holland, MI. In addition, we have presented our results to NIOSH Total Worker Health^{TM} Center of Excellence meeting at CPH-NEW – the Center for projecting the health of the New England Work Force.

Outcomes

- We have demonstrated biomechanical injury pathways for psychosocial factors for computer related musculoskeletal disorders in the modern office.
- We have developed prediction models for upper extremity biomechanical exposure intensities during computer use using data from self-report questionnaires.
- We have identified preliminary predicted biomechanical risk factors associated with the development of computer related musculoskeletal disorders.
- Field measures have confirmed the different exposure between keyboarding and mousing activities perhaps explaining some of the injury mechanisms associated with computing driven by extensive mouse usage.

SECTION 2 SCIENTIFIC REPORT

A. Background

Psychosocial factors in the modern work environment of the office have been associated with higher incidences of musculoskeletal disorders (MSDs) [1]. However, when physical workloads are considered for other types of work environments the direct effects of psychosocial factors diminish.[2,3] While several pathways may exist through which psychosocial factors impact the body and influence the onset and development of MSDs, one hypothesis, which is supported by numerous laboratory studies, suggests that increased stress originating from the psychosocial work environment increases one's exposure to biomechanical loads.[4]

Many factors have been proposed to describe different aspects of the psychosocial work environment [Levi et al., 2000; Siegrist, 1996; Siegrist et al., 2004; Karasek et al., 1998]. Most previous studies of neck and upper limb symptoms have looked for associations of these symptoms and the workplace psychosocial factors proposed by Karasek [1998] (eg Hannan et al., 2005; van den Heuvel et al., 2005). However, Siegrist [1996] proposes that conditions of low “status control”, or reward, a work organization factor, may lead to more psychological strain for workers than low “task control”, the aspect of control considered by Karasek [Siegrist, 1996]. Indeed, one study has reported an association of low reward and symptoms in an office worker population [Huysmans et al., 2012], and other studies have observed associations of an imbalance of effort and reward [Siegrist et al., 1996] and symptoms [Bongers et al., 2006]. Hence, reward appears to be a relevant workplace psychosocial factor.

Siegrist [1996; 2004] hypothesizes that the effects of reward may be amplified in the presence of over-commitment. Over-commitment is an individual’s pattern of coping with work demands which involves spending excessive effort at work due to an inability to withdraw from work obligations [Siegrist, 2004]. No previous field or laboratory studies have demonstrated associations of over-commitment and neck and upper limb symptoms, muscle activities, or postures. There is, however, evidence suggesting that similar factors such as an individual’s pattern of Type A behavior and anxiety affect arm movements and spinal loading, respectively, [Glasscock et al., 1999; Marras et al., 2000] suggesting that over-commitment may also affect biomechanical loading (Figure 1).

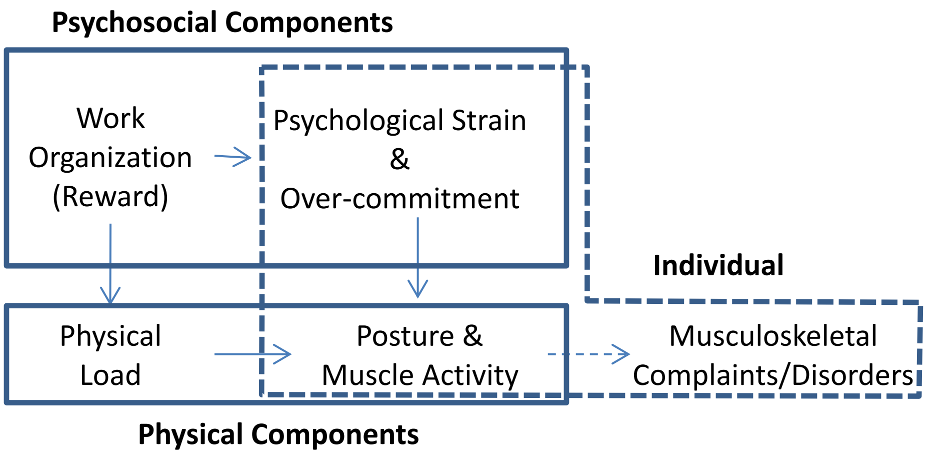


Figure 1, Theroretical Model for the Siegrest model of Over-committment and Reward on biomechanical pathways and MSDs.

Through the proposed measurements we will be able to make conclusions on the effects of hypothesized biomechanical exposures and exposure patterns on long term musculoskeletal health effects. The proposal will take advantage of a large-scale ongoing study and existing proven instrumentation to build innovative biomechanical exposure estimation technologies and provide methods for both engineering and administrative interventions to be readily implemented in modern work environments.

B. STUDIES AND RESULTS

FINDINGS AND RESULTS FOR AIM 1A: *We will directly measure biomechanical exposure intensities (i.e. keyboard and mouse forces, hand, forearm, upper arm and shoulder postural dynamics and EMG of the trapezius and the extensor carpiradialis) in 120 computer workers in the field spanning four different psychosocial environments.*

To complete Aim 1a first developed a system to measure the 22 biomechanical components and second we completed recruitment and data collection of biomechanical exposures and questionnaire data on all 120 participants with the last subject measured in August 2010 (Table 1). For the sconed part we were successfully able to recruit 30 participants from each of four psychosocial environments based on their over-commitment and reward profiles. Of the 12 departments from the VU University approached to participate in the study, 9 agreed. Of all workers approached to participate in the study, 740 filled out our screening questionnaire with information about their over-commitment and reward profiles, and 47% (348 workers) were willing to participate in the study. This work is represented in three publications described here.

Table 1. Participant characteristics of the four groups.

	Age	*(year)*	*Gender*	*Height*	*(cm)*	*Weight*	*(kg)*
	Mean	*Range*		*Mean*	*Range*	*Mean*	*Range*
Low OC, high RW group (N=31)	*37*	*24-62*	*M:10 / F:21*	*177.7*	*163.0-195.0*	*72.2*	*53.0-91.0*
High OC, high RW group (N=29)	*39*	*23-62*	*M:9 / F:20*	*173.3*	*157.0-195.0*	*75.5*	*56.0-112.0*
Low OC, low RW group (N=30)	*40*	*26-60*	*M:8 / F:22*	*175.0*	*153.0-204.0*	*72.9*	*49.0-123.0*
High OC, low RW group(N=30)	*43*	*28-63*	*M:8 / F:22*	*175.2*	*161.0-199.0*	*75.6*	*54.0-103.0*

Bruno JL, Li Z, Trudeau M, Raina SM, & Dennerlein JT. [2012]. A single video camera postural assessment system to measure rotation of the shoulder during computer use. **J Appl Biomech, *28(3), 343-348. PMID: 21908899***

The goal of this study was to evaluate the performance of a single video camera system for measuring shoulder rotation during computer work, and to quantify the work and postural space within which the system performs optimally. Shoulder rotation angles calculated using the video system were compared with angles calculated using an active infrared LED three-dimensional motion analysis system while 10 adult volunteers simulated postures for two different trials: typical of normal computer work (freestyle) and with forced shoulder abduction (constrained) (Figure 2). Average and absolute errors were calculated to determine the accuracy and precision of the system, respectively, for each trial, for each position, and for both the right and left hands. For the right hand, mean values for the average and absolute errors were –1 and 0 degrees, respectively. Only the absolute error increased significantly to 12 degrees for the constrained posture compared with freestyle. During normal computer work, the video system provided shoulder rotation angle values similar to those of a three-dimensional system, thus making it a viable and simple instrument to use in field studies.

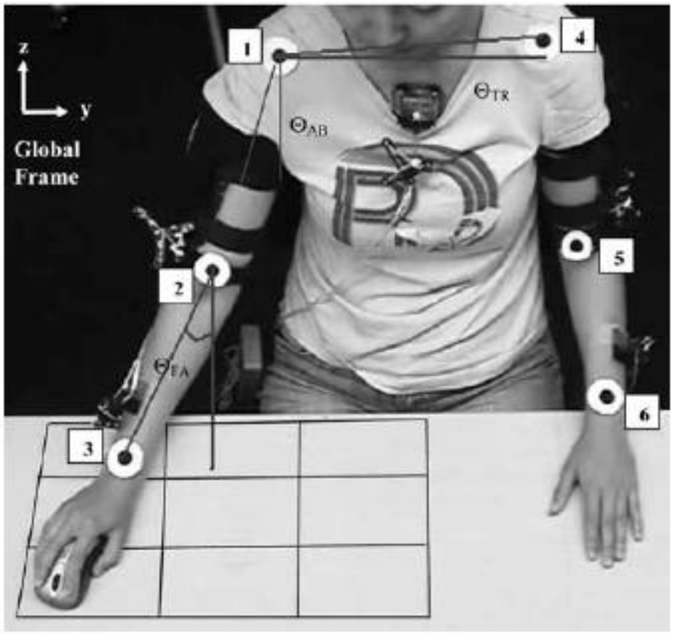


Figure 2: View from the video camera, defining the video marker positions and angles used to calculate shoulder rotation angle. Each participant wore six black and white video markers to be tracked by the video system. Angles of the trunk, shoulder abduction, and shoulder rotation calculated by the video system are also shown. Also shown in the figure is the 3 × 3 grid used to define positions for the mouse and abduction trials. In this figure, the right-hand grid is accentuated for easy viewing. During the experiment, participants were able to see the markings of the grid during each trial without the accentuation. During this mouse trial, the participant is sitting with her left hand in the "neutral" position, which is also the correct positioning of the hand for abduction trials. The participant's right hand demonstrates the correct positioning of the hand for mouse trials.

Asundi K, Johnson PW, & Dennerlein JT. [2012]. Variance in direct exposure measures of typing force and wrist kinematics across hours and days among office computer workers. **Ergonomics,** ***55(8), 874-884. doi: 10.1080/00140139.2012.681807 PMID: 22676481***
An important part of our study was validating our exposure assessment sampling strategy. To determine the number of direct measurements needed to obtain a representative estimate of typing force and wrist kinematics, continuous measures of keyboard reaction force and wrist joint angle were collected at the workstation of 22 office workers while they completed their own work over three days, six hours per day. Typing force and wrist kinematics during keyboard, mouse and idle activities were calculated for each hour of measurement along with variance in measurements between subjects and between day and hour within subjects. Variance in measurements between subjects was significantly greater than variance in measurements between days and hours within subjects. Therefore, we concluded a single, one-hour period of continuous measures is sufficient to identify differences in typing force and wrist kinematics between subjects. Within subjects, day and hour of measurement had a significant effect on some measures and thus should be accounted for when comparing measures within a subject. From this we were able to justify selecting a 2 hour window to capture our biomechanical measurements.

Bruno Garza JL, Eijckelhof BH, Johnson PW, Raina SM, Rynell PW, Huysmans MA, van Dieen JH, van der Beek AJ, Blatter BM, & Dennerlein JT. [2012]. **Observed differences in upper extremity forces, muscle efforts, postures, velocities and accelerations across computer activities in a field study of office workers**. *Ergonomics*, 55(6), 670-681. doi: 10.1080/00140139.2012.657692 PMID: 22455518

This study, a part of the PRedicting Occupational biomechanics in OFfice workers (PROOF) study, investigated whether there are differences in field-measured forces, muscle efforts, postures, velocities and accelerations across computer activities. These parameters were measured continuously for 120 office workers performing their own work for two hours each (Figure 3).

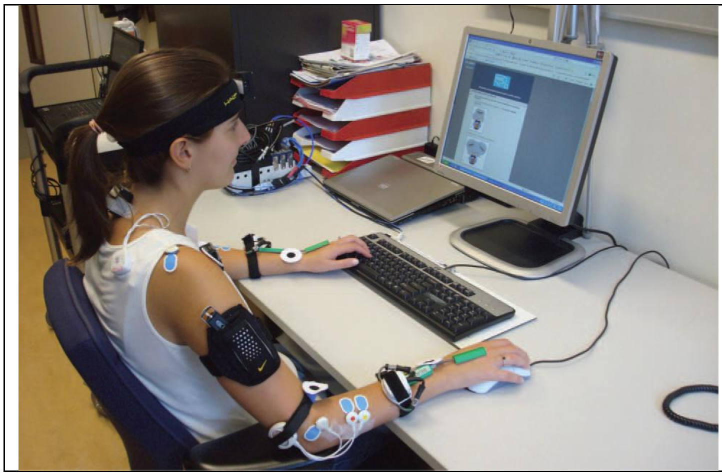


Figure 3: Instrumentation set up on a participant at her workstation. The systems used to measure the biomechanical exposures were chosen to be unobtrusive and allow the participant to perform her regular work without interruption or restriction. Participants were able to move freely at their workstation and to leave the workstation without restraint.

There were differences in nearly all forces, muscle efforts, postures, velocities and accelerations across keyboard, mouse and idle activities. Keyboard activities showed a 50% increase in the median right trapezius muscle effort when compared to mouse activities (Figure 4). Median shoulder rotation changed from 25 degrees internal rotation during keyboard use to 15 degrees external rotation during mouse use. Only keyboard use was associated with median ulnar deviations greater than 5 degrees. Idle activities led to the greatest variability observed in all muscle efforts and postures measured. In future studies, measurements of computer activities could be used to provide information on the physical exposures experienced during computer use.

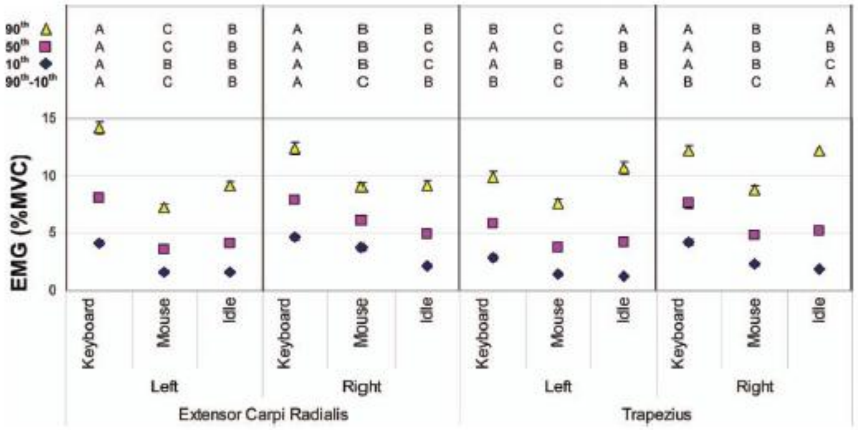
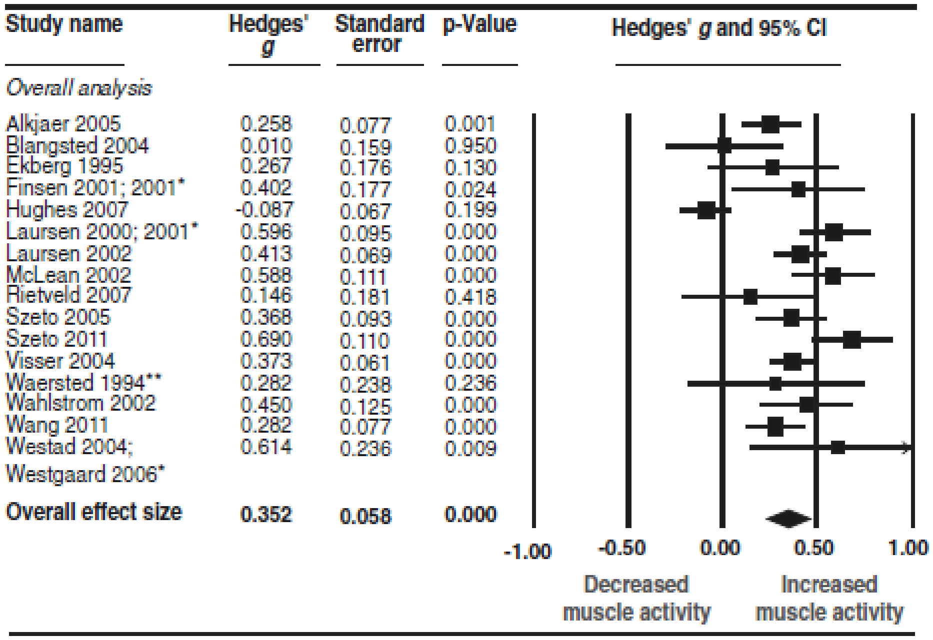


Figure 4: Mean (standard error) 10th (diamond), 50th (square) and 90th (diamond) percentiles of left and right extensor carpi radialis and trapezius muscle effort expressed as a %MVC averaged across all participants (n ¼ 118). Letters (A, B, C) indicate that significant differences across computer activities were found based on an F-test from a repeated measures ANOVA. Different letters indicate which computer activities were different from one another. ‘A’ represents the highest muscle effort values for each muscle effort parameter and muscle, with ‘B’ and ‘C’ indicating smaller values. When no significant differences were found, it is indicated by p-values greater than 0.05.

Eijckelhof BH, Huysmans MA, Bruno Garza JL, Blatter BM, van Dieen JH, Dennerlein JT, & van der Beek AJ. [2013]. The effects of workplace stressors on muscle activity in the neck-shoulder and forearm muscles during computer work: a systematic review and meta-analysis. **Eur J Appl Physiol.** ***doi: 10.1007/s00421-013-2602-2 PMID: 23584278***

Workplace stressors have been indicated to play a role in the development of neck and upper extremity pain possibly through an increase of sustained (low-level) muscle activity. The aim of this review was to study the effects of workplace stressors on muscle activity in the neck-shoulder and forearm muscles. An additional aim was to find out whether the muscles of the neck-shoulder and the forearm are affected differently by different types of workplace stressors. A systematic literature search was conducted on studies investigating the relation between simulated or realistic workplace stressors and neck-shoulder and forearm muscle activity. For studies meeting the inclusion criteria, a risk of bias assessment was performed and data were extracted for synthesis. Results were pooled when possible and otherwise described. Twenty-eight articles met the inclusion criteria, reporting data of 25 different studies. Except for one field study, all included studies were laboratory studies. Data of 19 articles could be included in the meta-analysis and revealed a statistically significant, medium increase in neck-shoulder and forearm muscle activity as a result of workplace stressors (Figure 5). In subgroup analyses, we found an equal effect of different stressor types (i.e. cognitive/emotional stress, work pace, and precision) on muscle activity in both body regions. In conclusion, simulated workplace stressors result in an increase in neck-shoulder and forearm muscle activity. No indications were found that different types of stressors affect these body regions differently. These conclusions are fully based on laboratory studies, since field studies on this topic are currently lacking.



Study name	Hedges' *g*	Standard error	p-Value
Overall analysis			
Alkjaer 2005	0.258	0.077	0.001
Blangsted 2004	0.010	0.159	0.950
Ekberg 1995	0.267	0.176	0.130
Finsen 2001; 2001*	0.402	0.177	0.024
Hughes 2007	-0.087	0.067	0.199
Laursen 2000; 2001*	0.596	0.095	0.000
Laursen 2002	0.413	0.069	0.000
McLean 2002	0.588	0.111	0.000
Rietveld 2007	0.146	0.181	0.418
Szeto 2005	0.368	0.093	0.000
Szeto 2011	0.690	0.110	0.000
Visser 2004	0.373	0.061	0.000
Waersted 1994**	0.282	0.238	0.236
Wahlstrom 2002	0.450	0.125	0.000
Wang 2011	0.282	0.077	0.000
Westad 2004; Westgaard 2006*	0.614	0.236	0.009
Overall effect size	**0.352**	**0.058**	**0.000**

Figure 5: Overall effect of stress on muscle activity of the neckshoulder and forearm muscles, and the effect on the neckshoulder and forearm muscles separately: asterisk denotes data in the two publications concern the same study population and the same experiment and are therefore combined; double asterisk denotes that experiment 1, of four in total, only is included

FINDINGS FOR AIM 1B: *We will evaluate hypothesis 1 (intensity of biomechanical exposures is associated with job strain) and in doing so develop an exposure determinants model for these biomechanical intensities that is adjusted for intrinsic and extrinsic covariates such as individual anthropometry and workstation configuration stratified across the three computer tasks (keyboard, mouse and passive idle activities).*

Bruno Garza JL, Eijckelhof BH, Huysmans MA, Catalano PJ, Katz JN, Johnson PW, van Dieen JH, van der Beek AJ, & Dennerlein JT. [2013]. **The effect of over-commitment and reward on trapezius muscle activity and shoulder, head, neck, and torso postures during computer use in the field**. *Am J Ind Med*, 56(10), 1190-1200. doi: 10.1002/ajim.22192 PMID: 23818000***0***

Background: Because of reported associations of psychosocial factors and computer related musculoskeletal symptoms, we investigated the effects of a workplace psychosocial factor, reward, in the presence of over-commitment, on trapezius muscle activity and shoulder, head, neck, and torso postures during computer use.

Methods: We measured 120 office workers across four groups (lowest/highest reward/over-commitment), performing their own computer work at their own workstations over a 2 hour period.

Results: Median trapezius muscle activity (p=0.04) and median neck flexion (p=0.03) were largest for participants reporting simultaneously low reward and high over-commitment (Figures 6 and 7). No differences were observed for other muscle activities or postures.

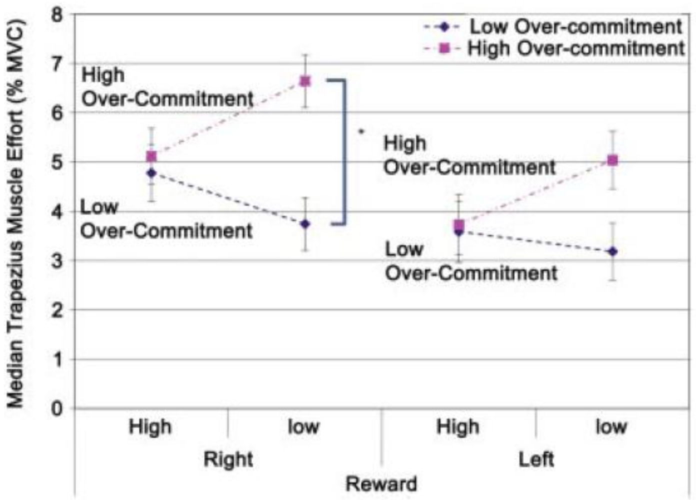


Figure 6: Least-squares means of the trapezius muscle effort median values from the repeated measures ANOVA model adjusted for Percent Mouse, Percent Idle, BMI, Gender, Hand Length, and Years Having Job Requiring Computing (n = 117). The error bars represent one standard error. The starred bracket denotes significant difference between the values based on Tukey's post-hoc analysis. These data demonstrate the significant over-commitment and reward interaction for the right side only.

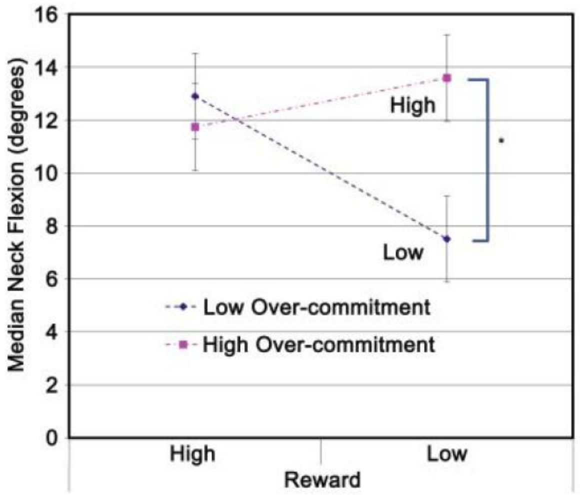


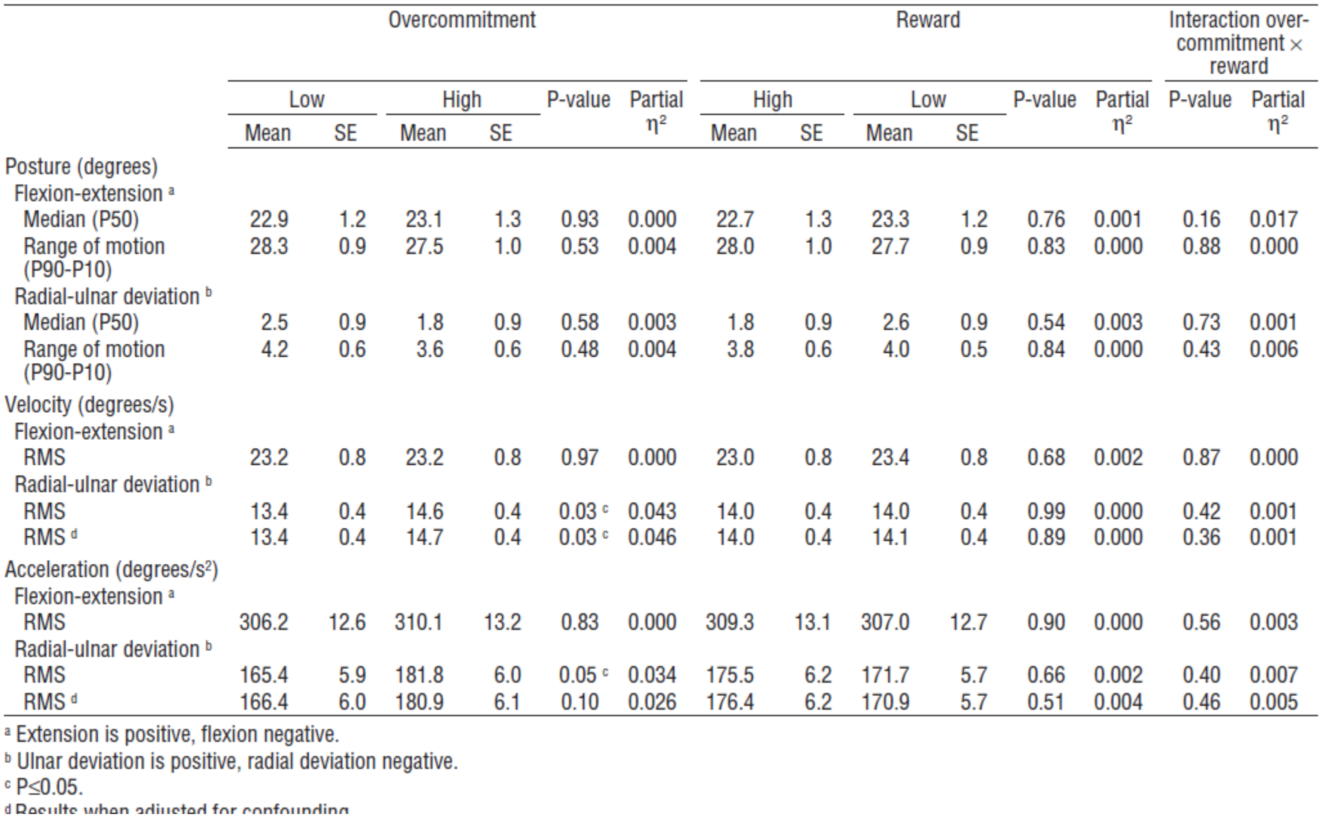
Figure 7: Least-squares mean of neck flexion angle median values from the repeated measures ANOVA model adjusted for Age (n = 117). The error bars represent one standard error. The starred bracket denotes significant difference between the values based on Tukey's post-hoc analysis. These data demonstrate the significant over-commitment and reward interaction. Positive values indicate neck flexion.

Conclusions: These data suggest that the interaction of reward and over-commitment can affect upper extremity muscle activity and postures during computer use in the real work environment. This finding aligns with the hypothesized biomechanical pathway connecting workplace psychosocial factors and musculoskeletal symptoms of the neck and shoulder.

Eijckelhof BH, Bruno Garza JL, Huysmans MA, Blatter BM, Johnson PW, van Dieen JH, van der Beek AJ, & Dennerlein JT. [2013]. **The effect of overcommitment and reward on muscle activity, posture, and forces in the arm-wrist-hand region - a field study among computer workers.** *Scand J Work Environ Health*, 39(4), 379-389. doi: 10.5271/sjweh.3346 PMID: 23377125 . Open Access

Objective Office workers with high levels of overcommitment and low levels of reward are thought to be more prone to arm-wrist-hand symptoms, possibly through a higher internal physical exposure. The aim of this study was to examine the effects of high overcommitment and low reward on (i) forearm muscle activity, (ii) wrist posture and kinematics, and (iii) forces applied to computer input devices during computer work in an actual work setting. Methods We continuously measured wrist extensor muscle activity, wrist posture and kinematics, and forces applied to the keyboard and mouse for two hours during the daily work of 120 office workers with four different levels of overcommitment and reward (low–high, high–high, low–low, and high–low). Results Wrist velocities and accelerations in radial-ulnar direction were higher for workers with high compared to low overcommitment, while their wrist range of motion was similar, possibly indicating a higher work pace (Table 2). Wrist extensor muscle activity and forces applied to the keyboard and mouse were not increased by high overcommitment and/or low reward. Conclusion Overall, our findings provide little support for the proposed pathway of high overcommitment and low reward in the development of arm-wrist-hand symptoms through a higher internal physical exposure.

Table 2: Results of median wrist posture and kinematics of the left and right sides (n=117 for posture and n=116 for velocity and acceleration) and results of adjusted models in case relevant confounding was indicated: age, body height, and body weight were included as covariates for velocity, and work history, body height, and body weight were included as covariates for acceleration. [RMS=root mean square; SE=standard error.]



	Overcommitment						Reward						Interaction over-commitment × reward	
	Low		High		P-value	Partial η^2	High		Low		P-value	Partial η^2	P-value	Partial η^2
	Mean	SE	Mean	SE			Mean	SE	Mean	SE				
Posture (degrees)														
Flexion-extension [a]														
Median (P50)	22.9	1.2	23.1	1.3	0.93	0.000	22.7	1.3	23.3	1.2	0.76	0.001	0.16	0.017
Range of motion (P90-P10)	28.3	0.9	27.5	1.0	0.53	0.004	28.0	1.0	27.7	0.9	0.83	0.000	0.88	0.000
Radial-ulnar deviation [b]														
Median (P50)	2.5	0.9	1.8	0.9	0.58	0.003	1.8	0.9	2.6	0.9	0.54	0.003	0.73	0.001
Range of motion (P90-P10)	4.2	0.6	3.6	0.6	0.48	0.004	3.8	0.6	4.0	0.5	0.84	0.000	0.43	0.006
Velocity (degrees/s)														
Flexion-extension [a]														
RMS	23.2	0.8	23.2	0.8	0.97	0.000	23.0	0.8	23.4	0.8	0.68	0.002	0.87	0.000
Radial-ulnar deviation [b]														
RMS	13.4	0.4	14.6	0.4	0.03 [c]	0.043	14.0	0.4	14.0	0.4	0.99	0.000	0.42	0.001
RMS [d]	13.4	0.4	14.7	0.4	0.03 [c]	0.046	14.0	0.4	14.1	0.4	0.89	0.000	0.36	0.001
Acceleration (degrees/s^2)														
Flexion-extension [a]														
RMS	306.2	12.6	310.1	13.2	0.83	0.000	309.3	13.1	307.0	12.7	0.90	0.000	0.56	0.003
Radial-ulnar deviation [b]														
RMS	165.4	5.9	181.8	6.0	0.05 [c]	0.034	175.5	6.2	171.7	5.7	0.66	0.002	0.40	0.007
RMS [d]	166.4	6.0	180.9	6.1	0.10	0.026	176.4	6.2	170.9	5.7	0.51	0.004	0.46	0.005

[a] Extension is positive, flexion negative.

[b] Ulnar deviation is positive, radial deviation negative.

[c] P≤0.05.

[d] Results when adjusted for confounding

Eijckelhof BH, Huysmans MA, Blatter BM, Leiden P, Johnson PW, van dieen JH, Dennerlein JT, & van der Beek AJ. [Submitted]. **Office workers' exposure patterns are associated with workplace stressors.** ***Applied Ergonomics*.**

Objective. This field study examined associations between workplace stressors and office workers' computer exposure patterns. Methods. We collected keyboard and mouse activities of 93 office workers (68F, 25M) for approximately two work weeks. Linear regression analyses examined the associations between self-reported effort, reward, overcommitment, and perceived stress and software-recorded computer use duration, number of short and long computer breaks, and pace of input device usage. Results. Daily duration of computer use was longer by 30 minutes on average for workers with high compared to low levels of overcommitment and perceived stress. The number of short computer breaks was smaller by about 20% for those with high compared to low effort and for those with low compared to high reward (Table 3). Conclusion. These outcomes support the hypothesis that office workers' computer exposure patterns vary across individuals with different levels of workplace stressors.

TABLE 3		Confounder(s) corrected for	Regression coefficient		*p*-value	
			Low–Medium[a]	Low-High[b]	Low–Medium[a]	Low-High[b]
Computer duration						
Total computer interaction (min/day)	Over-commi	work history	13.59	32.19	0.31	**0.03**[c]
	Perceived stress	history of symptoms	19.54	25.12	0.11	**0.05**[c]
8-hour Frequency of computer breaks						
≥2-30s	Effort	educational level, work history	-74.59	-77.29	0.22	0.22
≥30s-5min	Effort	work history, touch typing skill, history of symptoms	1.26	-5.19	0.78	0.29
	Reward	job title, work history, touch typing skill, history of symptoms	-7.91	-11.88	0.06	**0.01**[c]
≥15min	Effort	educational level, work history	0.17	0.16	0.60	0.64

Bruno Garza JL, Cavallari JM, Eijckelhof BH, Huysmans MA, Johnson PW, Dennerlein JT, et al. [In Preparation]. **High effort in the workplace decreases workers' heart rate variability**.

We investigated the chronic and acute effects of workplace psychosocial factors on heart rate variability (HRV) in 120 office workers. - During a two hour data collection period, we measured heart rate using a Polar heart rate monitor both while participants completed a 15 minute questionnaire and while they completed their own work at their own computer workstation. -We used the heart rate data to calculate heart rate variability in the time (SDNN, RMSSD, pNN50) and frequency (low frequency power, high frequency power, low/high frequency power ratio) domains in five minute epochs. We observed that participants that reported high effort were associated with reductions in the acute HRV parameters of SDNN, RMSSD, HF Power, and LF/HF ratio (Table 4). These observations were not affected when adjusting for confounders. There were no differences in acute HRV parameters across workers reporting different levels of reward or decision authority observed in this study. There was a significant (p=0.04) association between Decision Authority and chronic HRV as characterized by RMSSD, only after adjusting for confounding (Table 1). There were no other associations between Decision Authority, Effort, or Reward and chronic HRV parameters observed in this study. Exposure to adverse psychosocial factors in the workplace can have negative consequences for the cardiovascular system.

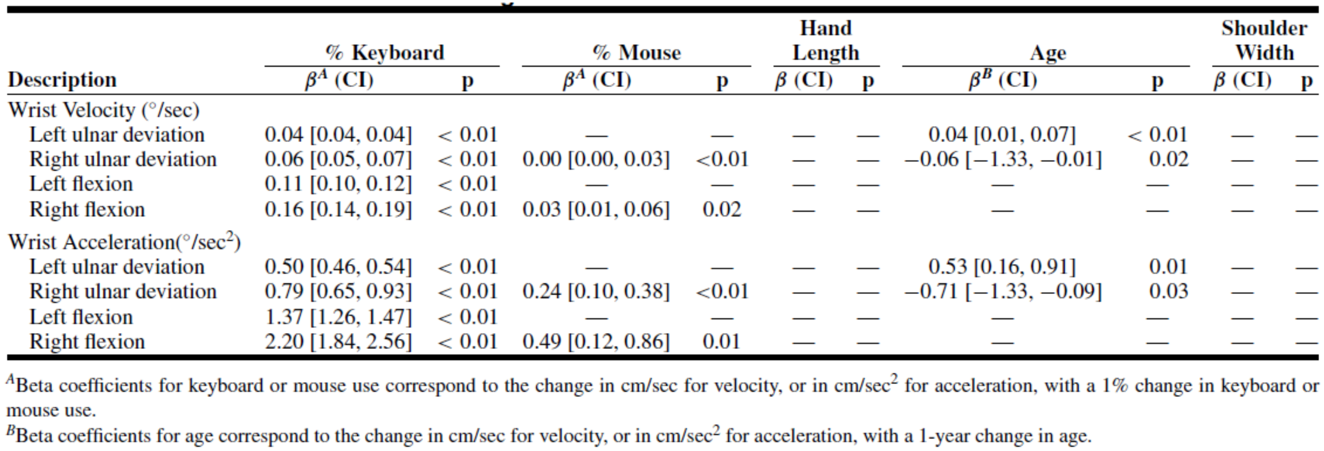
Table 4: P-values for the independent variables in each unadjusted and adjusted (for age, gender, BMI, time of day, and exercise level) ANOVA model for each HRV parameter during the measurement period while participants performed computer work.

	SDNN		RMSSD		HF power		LF/HF Power Ratio	
	Un	Adjusted*	Unadjusted	Adjusted*	Unadjusted	Adjusted*	Unadjusted	Adjusted*
Effort	0.35	0.89	0.19	0.61	0.24	0.73	0.56	0.68
Time	0.06	0.06	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Effort*Time	**0.02**	**0.02**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Reward	0.21	0.6	0.29	0.71	0.32	0.82	0.94	0.66
Time	0.03	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Reward*Time	0.90	0.90	0.49	0.48	0.77	0.75	0.36	0.36
Decision Authority	0.49	0.43	0.64	0.19	0.7	0.29	0.97	0.34
Time	0.02	0.02	<0.01	<0.1	<0.1	<0.1	<0.1	<0.01
Decision*Time	0.49	0.50	0.36	0.36	0.61	0.61	0.72	0.75

Progress for Aim 1c: *Using the exposure determinants models, we will estimate the average and cumulative exposures based on the duration of keyboard, mouse and idle tasks for each of the 120 members and evaluate the performance fo these estimates by comparing them to the directly measured average and cumulative exposure parameters of Aim 1a.*

Bruno Garza JL, Catalano PJ, Katz JN, Huysmans MA, & Dennerlein JT. [2012]. **Developing a framework for predicting upper extremity muscle activities, postures, velocities, and accelerations during computer use: the effect of keyboard use, mouse use, and individual factors on physical exposures**. *J Occup Environ Hyg*, 9(12), 691-698. doi: 10.1080/15459624.2012.728927 PMID: 23066993

Prediction models were developed based on keyboard and mouse use in combination with individual factors that could be used to predict median upper extremity muscle activities, postures, velocities, and accelerations experienced during computer use. In the laboratory, 25 participants performed five simulated computer trials with different amounts of keyboard and mouse use ranging from a highly keyboard-intensive trial to a highly mouse-intensive trial. During each trial, muscle activity and postures of the shoulder and wrist and velocities and accelerations of the wrists, along with percentage keyboard and mouse use, were measured. Four individual factors (hand length, shoulder width, age, and gender) were also measured on the day of data collection. Percentage keyboard and mouse use explained a large amount of the variability in wrist velocities and accelerations (Table 5). Although hand length, shoulder width, and age were each significant predictors of at least one median muscle activity, posture, velocity, or acceleration exposure, these individual factors explained very little variability in addition to percentage keyboard and mouse use in any of the physical exposures investigated. The amounts of variability explained for models predicting median wrist velocities and accelerations ranged from 75 to 84% but were much lower for median muscle activities and postures (0–50%). RMS errors ranged between 8 to 13% of the range observed.While the predictions for wrist velocities and accelerations may be able to be used to improve exposure assessment for future epidemiologic studies, more research is needed to identify other factors that may improve the predictions formuscle activities and postures.



	% Keyboard		% Mouse		Hand Length		Age		Shoulder Width	
Description	β^A (CI)	p	β^A (CI)	p	β (CI)	p	β^B (CI)	p	β (CI)	p
Wrist Velocity (°/sec)										
Left ulnar deviation	0.04 [0.04, 0.04]	< 0.01	—	—	—	—	0.04 [0.01, 0.07]	< 0.01	—	—
Right ulnar deviation	0.06 [0.05, 0.07]	< 0.01	0.00 [0.00, 0.03]	<0.01	—	—	−0.06 [−1.33, −0.01]	0.02	—	—
Left flexion	0.11 [0.10, 0.12]	< 0.01	—	—	—	—	—	—	—	—
Right flexion	0.16 [0.14, 0.19]	< 0.01	0.03 [0.01, 0.06]	0.02	—	—	—	—	—	—
Wrist Acceleration(°/sec^2)										
Left ulnar deviation	0.50 [0.46, 0.54]	< 0.01	—	—	—	—	0.53 [0.16, 0.91]	0.01	—	—
Right ulnar deviation	0.79 [0.65, 0.93]	< 0.01	0.24 [0.10, 0.38]	<0.01	—	—	−0.71 [−1.33, −0.09]	0.03	—	—
Left flexion	1.37 [1.26, 1.47]	< 0.01	—	—	—	—	—	—	—	—
Right flexion	2.20 [1.84, 2.56]	< 0.01	0.49 [0.12, 0.86]	0.01	—	—	—	—	—	—

[A] Beta coefficients for keyboard or mouse use correspond to the change in cm/sec for velocity, or in cm/sec^2 for acceleration, with a 1% change in keyboard or mouse use.

[B] Beta coefficients for age correspond to the change in cm/sec for velocity, or in cm/sec^2 for acceleration, with a 1-year change in age.

Table 5: Results of Prediction Modeling for Median Wrist Velocities and Accelerations

Bruno Garza JL, Eijckelhof BH, Huysmans MA, Johnson PW, van Dieen JH, Catalano PJ, Katz JN, van der Beek AJ, & Dennerlein JT. [Under Re-review]. **Predicting individuals' median and range of amplitude of upper extremity trapezius muscle activity and median and range of motion of shoulder, head, neck, and torso postures during computer use: results of a field study**. *BMC Musculoskeletal Disorders*.

Background Due to difficulties in performing direct measurements as an exposure assessment technique, evidence supporting an association between physical exposures such as neck and shoulder muscle activities and postures and musculoskeletal disorders during computer use is limited. Alternative exposure assessment techniques are needed.

Methods We predicted the median and range of amplitude (90th-10th percentiles) of trapezius muscle activity and the median and range of motion (90th-10th percentiles) of shoulder, head, neck, and torso postures based on two sets of parameters: the distribution of keyboard/mouse/idle activities only (task-based predictions), and a comprehensive set of task, questionnaire, workstation, and anthropometric parameters (comprehensive predictions). We compared the task based and comprehensive predictions based on R^2 values, root mean squared (RMS) errors (the square root of the squared observed minus predicted values averaged over all participants), and relative RMS errors (RMS errors divided by the full range of values across all participants) calculated compared to direct measurements.

Results R^2 values ranged from 0.01 to 0.10 (except right shoulder internal rotation, R^2=0.35) for the task-based predictions, and from 0.19 to 0.57 for the comprehensive predictions. RMS errors (relative RMS errors) from comprehensive predictions for muscle activity ranged from 3-4% maximum voluntary contraction (MVC) (for muscle activity) (16-19%)/3-21 degrees (for posture) (13-42%) for the task-based predictions, and from 2-3% MVC (for muscle activity) (11-15%)/2-13 degrees (for posture) (9-19%). (able 6)

Conclusions The comprehensive predictions of the median and range of amplitude of trapezius muscle activity and median and range of motion of all postures had consistently better R^2 values, RMS errors and relative RMS errors than the task based predictions

Table 6 Predictions of range of amplitude of trapezius muscle activity and range of motion shoulder, head, neck, and torso postures: Comparison of task based and comprehensive predictions based on R^2 values, RMS errors, relative RMS errors.

Range of Amplitude/ Range of Motion	**Task based predictions**			**Comprehensive predictions**		
	R^2	RMS	Relative RMS	R^2	RMS	Relative RMS
Right Trapezius	0.00	4%MVC	18%	0.50	3%MVC	11%
Left Trapezius	0.00	4%MVC	16%	0.52	3%MVC	11%
Right Abduction	0.02	9°	16%	0.48	7°	11%
Left Abduction	0.02	8°	17%	0.44	6°	13%
Right Flexion	0.02	8°	16%	0.31	7°	14%
Left Flexion	0.01	10°	19%	0.29	8°	17%
Right Internal Rotation	0.00	21°	30%	0.27	10°	15%
Left Internal Rotation	0.04	15°	23%	0.35	12°	18%
Head Tilt	0.00	10°	14%	0.30	7°	9%
Head Flexion	0.03	22°	35%	0.37	9°	14%
NeckTilt	0.01	3°	16%	0.34	2°	14%
NeckFlexion	0.05	7°	16%	0.29	6°	13%
TorsoTilt	0.01	16°	42%	0.32	4°	10%
Torso Flexion	0.02	11°	29%	0.33	7°	19%

Eijckelhof BH, Huysmans MA, Bruno Garza JL, Blatter BM, Johnson PW, van Dieen JH, van der Beek AJ, & Dennerlein JT. [In Preparation]. **Predicting forearm physical exposures during computer work using self-reported factors, measurement of anthropometry and workstation dimensions, and software-recorded usage patterns**.

Background. Alternative techniques to assess physical exposures during computer use could facilitate the performance of future large cohort studies. Such studies are need to fill the gaps in the scientific literature connecting physical exposures to the development of work-related musculoskeletal symptoms.

Objective. The aim of this study was to evaluate models that predict arm-wrist-hand physical exposures (i.e. muscle activity, wrist postures and kinematics, and keyboard and mouse forces) during computer use based on self-report factors and software-recorded usage patterns alone, and with additional - measurements of anthropometric and workstation dimensions.

Methods. We predicted median extensor carpi radialis muscle activity, wrist postures and kinematics, and keyboard and mouse forces, treated as continuous and categorical outcomes, using the following predictors i) self-reported individual factors, job characteristics, computer work behaviours, psychosocial factors, workstation set-up characteristics, health and pain characteristics, and leisure time activities, ii) tape-measurements of anthropometry and workstation set-up, and iii) software-recorded computer use. We evaluated the quality of the predictions with R^2 values and percentage of agreement scores for models with continuous and categorical outcomes, respectively.

Results. R^2 values of the models based on self-reported, tape-measured, and software-recorded data ranged from 0.19 to 0.80. When tape-measured data were excluded, R^2 values were lower, especially regarding wrist acceleration and keyboard and mouse force predictions, and ranged from 0.09 to 0.40. When exposure outcomes of these models were classified into “low”, “medium”, and “high” exposure groups, agreement between observed and predicted values revealed highest percentage correctly predicted low and high exposures, with percentages of agreement between 33% and 72%. Most misclassification appeared between adjacent low-medium and medium-high categories and on average only 9% for the low and high categories.

Conclusion. Prediction models based on data collected through self-report and software-recordings and additional tape-measurements, showed the best predictive quality, but results varied largely across different arm-wrist-hand exposure parameters. When exposure parameters were classified into “low”, “medium”, and “high” groups, agreement between observed and predicted outcomes were satisfactory for the most contrasting (low and high) groups, but the amount of misclassification would result in considerable lower risk estimates, when using these models in future research.

FINDINGS for AIM 2 *We will estimate average and cumulative biomechanical exposures for each participant of a two-year prospective cohort of office workers. The intensities will be determined by the biomechanical exposure determinants model developed above and the duration of keyboard, mouse and idle times that were measured by computer usage monitors.*

Eijckelhof BH, Bruno Garza JL, Huysmans MA, van der Beek A, Dennerlein JT, van Dieen JH, & Blatter BM et al. [In Preparation]. **Linking symptoms with predictions of biomechanical parameters.**

This final analysis is being finalized as this report is being written and any results here are strictly preliminary. Overall we're applying the prediction models developed in Aim 1c and applying them to a cohort of 1582 office workers where MSD data were collected quarterly (Figure 8) We have defined cases as newly developed cases at T5 and T9 at the 1 and 2 year follow times.

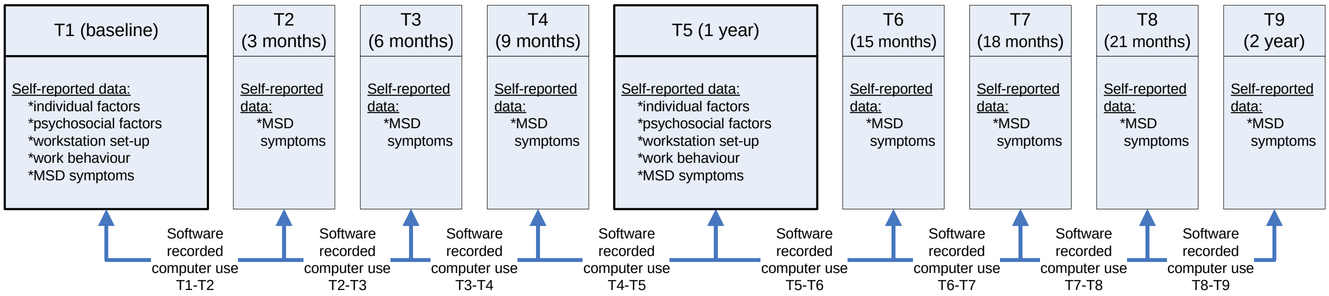


Figure 8 – The longitudinal study of 1582 Office workers as part of the PROMO Cohort.

From the prediction models we have classified workers' exposure to the biomechanical factors as low, medium and high base on the cohort's tertials. To date we have completed univariate analysis examining odds ratios across the three categories. Based on these preliminary results, the only significant variable was high right flexion was associated with higher risk of reporting a neck and shoulder pain (Table 7). There were several parameters that were approaching significance. Those variables include Right arm abduction, which was protective of neck-shoulder symptoms and Head Abduction (or lateral flexion). For the arm-wrist-hand symptoms, the Right wrist extensor highest category and highest keyboard force approached significance (Table 8).

C. Plans

As we completed the PROOF study in September 2013, we will continue to disseminate our results and analyzing data through other funding sources. We have several manuscript still in preparation and the final analysis for Aim 2. We expect Linda Eijcklehof to complete the analysis by the end of 2013 and submit a manuscript in early 2014.

Table 7. Effect of neck-shoulder biomechanics on the development of neck-shoulder symptoms; univariate relations: Biomechanical exposures were grouped into low, medium and high based on the cohort's tertials

Neck-shoulder exposures	N	OR		95% CI of OR	
		Low-Med	Low-High	Low-Med	Low-High
Muscle activity					
Left Trapezius	770	0.98	1.14	0.62-1.54	0.74-1.75
Right Trapezius	342	1.10	0.74	0.55-2.20	0.37-1.50
Posture					
Left arm abduction	820	0.95	1.30	0.60-1.48	0.85-1.99
Left arm flexion	844	0.93	0.68	0.61-1.41	0.44-1.05
Left arm rotation	331	0.95	1.00	0.46-1.97	0.49-2.03
Right arm abduction	*208*	*0.44*	*0.44*	*0.17-1.13*	*0.19-1.04*
Right arm flexion	908	1.43	**1.81***	0.92-2.20	**1.23-2.66***
Right arm rotation	342	0.78	1.03	0.38-1.61	0.53-1.99
Torso flexion	907	0.96	0.69	0.64-1.43	0.46-1.05
Torso abduction	844	0.84	1.16	0.54-1.29	0.77-1.75
Neck adduction	908	0.90	0.75	0.53-1.54	0.43-1.32
Neck flexion	772	1.14	0.75	0.74-1.77	0.48-1.17
Head flexion	908	1.29	1.04	0.86-1.93	0.69-1.58
Head adduction	*506*	*1.33*	*1.46*	*0.76-2.34*	*0.87-2.46*

Table 8 Effect of arm-wrist-hand exposures on the development of arm-wrist-hand symptoms; univariate relations: Biomechanical exposures were grouped into low, medium and high based on the cohort's tertials

Arm-wrist-hand exposures	N	OR		95% CI of OR	
		Dummy1	Dummy2	Dummy1	Dummy2
Muscle activity					
Left ECR	378	0.71	0.76	0.38-1.31	0.42-1.39
Right ECR	*745*	*1.43*	*1.28*	*0.90-2.27*	*0.80-2.06*
Posture					
L wrist flexion-extension	923	1.07	1.03	0.71-1.62	0.68-1.56
L wrist radial-ulnar	289	0.96	0.78	0.49-1.89	0.39-1.54
R wrist flexion-extension	378	1.10	0.82	0.60-2.03	0.44-1.56
R wrist radial-ulnar dev	746	1.04	1.08	0.65-1.65	0.69-1.69
Velocity					
L wrist flexion-extension	931	0.83	1.03	0.58-1.18	0.56-1.91
L wrist radial-ulnar deviation	829	1.13	1.15	0.24-5.22	0.24-5.51
R wrist flexion-extension	378	1.18	0.91	0.64-2.15	0.49-1.72
R wrist radial-ulnar deviation	375	1.39	1.00	0.77-2.52	0.52-1.89
Acceleration					
Left wrist flexion-extension	932	0.89	1.13	0.59-1.36	0.75-1.70
L wrist radial-ulnar dev	302	1.08	0.85	0.55-2.12	0.43-1.69
R wrist flexion-extension	378	1.10	1.38	0.60-2.03	0.75-2.55
R wrist radial-ulnar dev	374	1.30	1.06	0.71-2.36	0.56-1.99
Force					
Keyboard	*1007*	*0.67*	*1.45*	*0.44-1.01*	*0.99-2.11*
Mouse	375	1.05	0.87	0.57-1.94	0.46-1.62

Inclusion Enrollment Report

This report format should NOT be used for data collection from study participants.

Study Title: Interactions of biomechanics & psychosocial stressors & MSDs in the modern office

Total Enrollment: 120 **Protocol Number:** P15609-101

Grant Number: R01 OH008781

PART A. TOTAL ENROLLMENT REPORT: Number of Subjects Enrolled to Date (Cumulative) by Ethnicity and Race

Ethnic Category	Sex/Gender			
	Females	**Males**	**Unknown or**	**Total**
Hispanic or Latino	1	0	0	1 **
Not Hispanic or Latino	76	33	0	109
Unknown (individuals not reporting ethnicity)	9	1	0	10
Ethnic Category: Total of All Subjects*	86	34	0	120 *
Racial Categories				
American Indian/Alaska Native				
Asian	4	1		5
Native Hawaiian or Other Pacific Islander				
Black or African American	3			3
White	76	33		109
More Than One Race				
Unknown or Not Reported	3	0		3
Racial Categories: Total of All Subjects*	86	34		120 *

PART B. HISPANIC ENROLLMENT REPORT: Number of Hispanics or Latinos Enrolled to Date (Cumulative)

Racial Categories	Females	Males	Unknown or	Total
American Indian or Alaska Native	0	0	0	0
Asian	4	1	0	5
Native Hawaiian or Other Pacific Islander	0	0	0	0
Black or African American	3	0	0	3
White	76	33	0	109
More Than One Race	0	0	0	0
Unknown or Not Reported	3	0	0	3
Racial Categories: Total of Hispanics or Latinos**	1	0	0	1 **

* These totals must agree.
** These totals must agree.

PUBLICATIONS
Published Peer Reviewed Publications:

- Bruno JL, Li Z, Trudeau M, Raina SM, & Dennerlein JT. [2012]. A single video camera postural assessment system to measure rotation of the shoulder during computer use. *J Appl Biomech*, 28(3), 343-348. PMID: 21908899
- Bruno Garza JL, Eijckelhof BH, Johnson PW, Raina SM, Rynell PW, Huysmans MA, van Dieen JH, van der Beek AJ, Blatter BM, & Dennerlein JT. [2012]. Observed differences in upper extremity forces, muscle efforts, postures, velocities and accelerations across computer activities in a field study of office workers. Ergonomics, 55(6), 670-681. doi: 10.1080/00140139.2012.657692 PMID: 22455518
- Asundi K, Johnson PW, & Dennerlein JT. [2012]. Variance in direct exposure measures of typing force and wrist kinematics across hours and days among office computer workers. *Ergonomics*, 55(8), 874-884. doi: 10.1080/00140139.2012.681807 PMID: 22676481
- Bruno Garza JL, Catalano PJ, Katz JN, Huysmans MA, & Dennerlein JT. [2012]. Developing a framework for predicting upper extremity muscle activities, postures, velocities, and accelerations during computer use: the effect of keyboard use, mouse use, and individual factors on physical exposures. *J Occup Environ Hyg*, 9(12), 691-698. doi: 10.1080/15459624.2012.728927 PMID: 23066993
- Bruno Garza JL, Eijckelhof BH, Huysmans MA, Catalano PJ, Katz JN, Johnson PW, van Dieen JH, van der Beek AJ, & Dennerlein JT. [2013]. The effect of over-commitment and reward on trapezius muscle activity and shoulder, head, neck, and torso postures during computer use in the field. *Am J Ind Med, 56*(10), 1190-1200. doi: 10.1002/ajim.22192 PMID: 23818000
- Eijckelhof BH, Huysmans MA, Bruno Garza JL, Blatter BM, van Dieen JH, Dennerlein JT, & van der Beek AJ. [2013]. The effects of workplace stressors on muscle activity in the neck-shoulder and forearm muscles during computer work: a systematic review and meta-analysis. Eur J Appl Physiol. doi: 10.1007/s00421-013-2602-2 PMID: 23584278
- Eijckelhof BH, Bruno Garza JL, Huysmans MA, Blatter BM, Johnson PW, van Dieen JH, van der Beek AJ, & Dennerlein JT. [2013]. The effect of overcommitment and reward on muscle activity, posture, and forces in the arm-wrist-hand region - a field study among computer workers. *Scand J Work Environ Health*, 39(4), 379-389. doi: 10.5271/sjweh.3346 PMID: 23377125 . Open Access

Under Review:

- Eijckelhof BH, Huysmans MA, Blatter BM, Leiden P, Johnson PW, van dieen JH, Dennerlein JT, & van der Beek AJ. [Submitted]. Office workers' exposure patterns are associated with workplace stressors. Applied Ergonomics.
- Bruno Garza JL, Eijckelhof BH, Huysmans MA, Johnson PW, van Dieen JH, Catalano PJ, Katz JN, van der Beek AJ, & Dennerlein JT. [Under Re-review]. Predicting individuals' median and range of amplitude of upper extremity trapezius muscle activity and median and range of motion of shoulder, head, neck, and torso postures during computer use: results of a field study. *BMC Musculoskeletal Disorders*.

In Preparation

- Bruno Garza JL, Cavallari JM, Eijckelhof BH, Huysmans MA, Johnson PW, Dennerlein JT, et al. [In Preparation]. High effort in the workplace decreases workers' heart rate variability.
- Dennerlein JT, Manjourides J, & van Dieen JH et al. [In preparation]. Correlation and Principle Component Analysis of some 22 Biomechanical Parameters of 120 computer workers
- Eijckelhof BH, Bruno Garza JL, Huysmans MA, van der Beek A, Dennerlein JT, van Dieen JH, & Blatter BM et al. [In Preparation]. Linking symptoms with predictions of biomechanical parameters.
- Eijckelhof BH, Huysmans MA, Bruno Garza JL, Blatter BM, Johnson PW, van Dieen JH, van der Beek AJ, & Dennerlein JT. [In Preparation]. Predicting forearm physical exposures during computer work using self-reported factors, measurement of anthropometry and workstation dimensions, and software-recorded usage patterns.
- Huysmans MA, van Dieën JH, Dennerlein JT, Johnson PW,. van der Beek AJ. Perceived muscular tension in relation to trapezius and forearm extensor muscle activity as measured with EMG – a field study

Related Conference Proceedings and Presentations

1. Bruno Garza JL, Eijckelhof BHW, Huysmans MA, Johnson PW, van Dieen JH, van der Beek AJ, Dennerlein JT. The effects of psychosocial factors on trapezius muscle activity levels during computer use. HFES Conference 2012, Boston, USA *accepted for oral presentation*
2. Bruno Garza JL, Eijckelhof BHW, Johnson PW, Raina SM, Rynell P, Huysmans MA, van Dieen JH, van der Beek AJ, Blatter BM, Dennerlein JT. Developing a framework for assessing muscle effort and postures during computer work in the field: The effect of computer activities on neck/shoulder muscle effort and postures. IEA 2012, Recife, Brazil *accepted for oral presentation*
3. Bruno Garza JL. The effect of psychosocial stress on upper exremity biomechanical loading during computer work in the real work environment. *Presented at:* Marconi at Marigold2012; Holland, Michigan
4. Bruno JL, Huysmans MA, Dennerlein JT. Accounting for individual variability improves estimates of biomechanical parameters in computer workers. Conference proceedings of Seventh International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders 2010; Angers, France,.
5. Dennerlein JT, Bruno J, Johnson P. Building better risk models for computer users, integrating anthropometry to work patterns, Proceedings of X2009. The Sixth International Conference on Innovations in Exposure Assessment, Boston, MA 2009
6. Eijckelhof BHW, Huysmans MA, Blatter BM, Bruno JL, Johnson PW, van der Beek AJ, van Dieën JH, Dennerlein JT. Interactions of biomechanics and psychosocial stressors in the relation to the development of MSDs in the modern office: the 'PROOF' study protocol. Conference proceedings of Seventh International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders 2010; Angers, France, *accepted for poster presentation*.
7. Huysmans MA, Blatter B, van der Beek AJ. Perceived muscular tension is a risk factor for future neck-shoulder symptoms. Conference proceedings of Seventh International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders 2010; Angers, France,
8. Huysmans MA. Neck-shoulder and hand-arm symptoms: Consequences of symptoms and identifying workers at risk. *Presented at:* Marconi at Marigold2012; Office Ergonomics Research Committee, Holland, Michigan

9. Bruno Garza JL, Eickelhof BHW, Huysmans MA, Johnson PW, van Dieen JH, van der Beek AJ, Dennerlein JT. The Effects of Psychosocial Factors on Trapezius Muscle Activity Levels During Computer Use *Proc. Of the 56th Annual Meeting of the Human Factors and Ergonomics Society*, Boston, MA, 2012
10. Bruno Garza J.L., Eijckelhof B.H.W., Johnson P.W., Raina S.M., Rynell, P., Huysmans, M.A., van Dieën J.H., van der Beek A.J., Blatter B.M. and Dennerlein J.T. Developing a framework for assessing muscle effort and postures during computer work in the field: The effect of computer activities on neck/shoulder muscle effort and postures. *Proceedings of 18th World Congress of Ergonomics*, IEA 2012, Recife, Brazil
11. Bruno Garza JL, Eijckelhof BHW, Huysmans MA, van der Beek AJ, Dennerlein JT The psychosocial factor of reward affects shoulder muscles in a real office work environment . *Proceedings of Work, Stress and Health 2013: Protecting and Promoting Total Worker Health*. http://www.apa.org/wsh/ Los Angeles, CA 2013
12. Huysmans MA van der Beek AJ, van Dieen JH, Dennerlein JT. Perceived muscular tension in relation to trapezius muscle activity. *Proceedings of the Eighth International Conference on Prevention of Work-related Musculoskeletal Disorders PREMUS 2013*, www.premus2013.org, Busan, Korea, 2013.
13. Bruno Garza JL, Eijckelhof BHW, Huysmans MA, van der Beek AJ, Dennerlein JT. Building better prediction models for exposure assessment of trapezius muscle activity during computer use. *Proceedings of the Eighth International Conference on Prevention of Work-related Musculoskeletal Disorders PREMUS 2013*, www.premus2013.org, Busan, Korea, 2013.
14. Eijckelhof BHW, Bruno Garza JL, Huysmans MA, van Dieen JH, Dennerlein JT, van der Beek AJ. The effects of workplace stressors on muscle activity in the neck-shoulder and forearm muscles during computer work: a systematic review and meta-analysis. *Proceedings of the Eighth International Conference on Prevention of Work-related Musculoskeletal Disorders PREMUS 2013*, www.premus2013.org, Busan, Korea, 2013.
15. Huysmans MA, Bruno Garza JL, Eijckelhof BHW, van der Beek AJ, Dennerlein JT. The effects of overcommitment and reward on muscle activity in the trapezius and forearm extensor muscles during computer work in a real work setting. *Proceedings of the Eighth International Conference on Prevention of Work-related Musculoskeletal Disorders PREMUS 2013*, www.premus2013.org, Busan, Korea, 2013.

Dissertation/Thesis

1. Bruno Garza JL. (2013). *New tools for the assessment of office workers' muscle activity, force, and posture exposures during computer use, and their applications.* (ScD), Harvard School of Public Health, Boston, MA.
2. Eijckelhof BH. (2014 – In preparation). The PROOF Study: Measuring, predicting, and testing assocations biomechanical factors and computer workers. (Ph.D.), VU University Medical Center, Amsterdam, NL.