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The effect of over-commitment and reward on trapezius muscle activity and shoulder, head, neck, and torso postures during computer use in the field

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Abstract

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. No differences were observed for other muscle activities or postures.

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

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environment. This finding aligns with the hypothesized biomechanical pathway connecting workplace psychosocial factors and musculoskeletal symptoms of the neck and shoulder.

Keywords

Psychosocial; VDT; MSDs; exposure assessment; office ergonomics

INTRODUCTION

Workplace psychosocial factors have long been recognized for their associations with work-related neck and upper limb disorders and their symptoms in the general working population and among office workers [NRC/IOM Report, 2001; Bongers, 2006]. Causal pathways between workplace psychosocial factors and neck and upper extremity symptoms have been hypothesized, but the literature has not yet provided strong evidence for these pathways.

One pathway that has been suggested to connect workplace psychosocial factors and neck and upper limb symptoms is a biomechanical pathway, where increased psychosocial components such as work organization and psychological strain affect the physical demands of the job and the internal biomechanical loading of tissues [Figure 1; Wahlstrom, 2005; Sauter and Swanson, 1996]. Increased biomechanical loading may result from changes to the physical demands of the job, increases in muscle effort (e.g. increased co-contraction) or effort associated with different postures [Feuerstein, 1996]. An increased exposure to biomechanical loading is thought to lead to increased neck and upper limb symptoms by causing damage to muscle tissues, which can contribute to chronic, harmful inflammation [NRC/IOM, 2001; Visser and van Dieen, 2006; Barbe and Barr, 2006].

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).

The goal of this study was to investigate the effects of one workplace psychosocial factor, reward, in the presence of over-commitment, on trapezius muscle activities and shoulder, head, neck, and torso postures of 120 computer workers with contrasting reward and over-commitment profiles while they performed their own computer work in their real work environments. Previously, we developed several sensor systems utilizing current technology to make measurements within a real work environment [Johnson et al., 2000; Bruno et al., 2011; Bruno Garza et al., 2012; Asundi et al., 2012]. Using these methods we tested the hypothesis that workers reporting simultaneously low reward and high over-commitment will have increased and less variable trapezius muscle activity, more non-neutral shoulder, head, neck, and torso postures and decreased ranges of motion of postures of the neck and upper limbs during computer use.

METHODS

Experimental Design and Setup

Muscle activity of the right and left trapezius as well as shoulder, head, neck, and torso postures from 120 office workers performing computer work were measured across four profiles of reward and over-commitment. Muscle activities and postures of the lower extremity were also measured, and this data was presented in another paper [Eijckelhof et al., 2012]. Each worker completed approximately two hours of their regular work at their own workstations. All participants (34 male and 86 female) recruited for this study were free from musculoskeletal pain symptoms one week prior to the measurement. The participants ranged from 23 to 63 (mean=40) years of age and worked a minimum of 20 hours a week at the VU University or the VU University Medical Center. This project was approved by the applicable Institutional Review Boards for protection of human subjects and all participants signed written consent forms before beginning the study.

Recruitment Procedure

The 120 participants were recruited based on their self-reported reward and over-commitment scores from a pre-screening survey. Reward and over-commitment were chosen for this study because a previous study involving a very similar cohort of office workers reported that these factors were associated with musculoskeletal symptoms [Huysmans et al., 2012]. Reward and over-commitment were defined as in Siegrist [2004], and the questions used to define each concept are also displayed in table I.

Participant recruitment was performed one department at a time on a rolling basis throughout the eight month data collection period, until the 120 participants were acquired from 9 departments of the VU University and the VU University Medical Center. This rolling recruitment was utilized due to feasibility of collecting the physical data and to limit the amount of time between when workers filled out the pre-screening survey and when they were measured. At the beginning of the study, the heads of all of the departments at the VU University and VU University Medical Center were contacted by a member of the research staff to identify departments that would be interested in participating in the study. After all data collection on all eligible participants was completed in one department, the recruitment procedure was repeated in the next interested department until we had a total of 30 workers from each of the four reward and over-commitment profiles for a total of 120 participants. We chose 30 participants per group based on preliminary power calculations which determined that this number would provide 80% power to detect a 25% difference in effect size between groups (alpha=0.05), as well as on the recommendations of a previous study of power/sample size for studies of muscle activity during occupational work [Mathiassen et al., 2012].

All workers from each department were notified and informed of the study through an email with a participant information flyer attached to it that a study was being conducted on why some office workers develop musculoskeletal pain and requesting them to complete a short online survey determining their reward via an11-question scale and over-commitment via a 6-question scale [Siegrist et al., 2004; Table I]. Scores for reward and over-commitment were calculated by summing the responses across all questions. The possible reward scores could range from 11–55, and the possible over-commitment scores could range from 6–24. Workers were not informed of their scores. Workers within each department who were also willing to participate in the data collection portion of the study were classified into tertiles for reward (lowest/medium/highest) and over-commitment (lowest/medium/highest), creating nine different groups.

Workers within each department meeting the inclusion criteria and from the four groups that represented lowest and highest tertiles for both reward and over-commitment (lowest reward/over-commitment, highest reward/over-commitment, lowest reward/highest over-commitment, highest reward/lowest over-commitment) in that department were invited by phone to participate in the data collection. The inclusion criteria were: worked more than 20 hours per week, free of musculoskeletal pain the week prior to measurement, could work the mouse with their right hand during the measurement period, and could use a desktop computer during the measurement period. Recruitment within each department aimed to balance age and gender across reward and over-commitment profiles to minimize potential confounding. 854 workers filled out the screening questionnaire, and 348 workers were willing to participate in the study. There were no differences in the reward or over-commitment scores for workers who were willing to participate in the study compared to workers who were not willing to participate in the study.

Since we assigned participants to the reward/over-commitment groups at the departmental level, the ranges of “low” and “high” reward and over-commitment scores in the overall study population for participants assigned each group varied by department (Table II). However, since we used tertiles for recruiting within each department, separation was still achieved between participants classified as “low” or “high” reward/over-commitment in the overall study population. The group assignments would not have been any different if we had, before assigning group membership, pooled participants across all departments and then made assignments based on an individual’s score being above (“high”) or below (“low”) the median score for the overall study population. There were a small number of participants from both high and low groups that had as their own reward (n=12) and over-commitment (n=12) score the median score from the overall study population. These individuals remained assigned to “high” or “low” based on their original assignment within their department.

Once recruited, a 3.5 hour period (1.5 hours of setup and 2 hours of data collection) was scheduled with participants for a time representative of their normal computer work with minimal meetings. A two hour collection has been shown to be representative for several biomechanical factors [Johnson et al., 2000; Asundi et al., 2012; Ortiz et al., 1997]. Of the 120 participants recruited and measured in this study, 117 were included in the data analysis because of technical failure of the measurement equipment (n=2) or because the participant spent less than 5 minutes interacting with the computer during the measurement period (n=1).

To quantify potential confounders participants completed a brief survey and we recorded several anthropometric measures [Pheasant and Haselgrave, 2005] for each participant (Table III). Each participant’s height, weight and anthropometry including right arm length (acromion to radiale), shoulder breadth (acromion to acromion), hand length (distal wrist crease to dactylion), and hand breadth (between the metacarpale II and V), were also measured and each participant’s body mass index (BMI) was calculated from the measured weight and height. We treated gender, years having a job requiring computing, and job title as categorical variables, and all others as continuous variables, and used ANOVA (continuous) or Chi-squared (categorical) tests to determine whether there were statistical differences in our potential confounders across the four groups ($p<0.05$, Table III).

Trapezius muscle activity and shoulder, head, neck and torso posture

Muscle activity of the right and left trapezius was measured using surface electrodes mounted in accordance with published guidelines for the surface EMG of the trapezius and a wireless logger system (Mega WBA, Mega Electronics LTD, Kupio, Finland) [Jensen et al., 1993]. Data were recorded at 1000 samples per second after amplification (bandwidth of 10–500 Hz), and were then rectified and smoothed through a 3Hz second-order, zero phase, low–pass Butterworth filter. To match the postural data collection rates and reduce file storage size, the muscle activity data were then down-sampled to 40 samples per second using a mean filtering procedure.

The trapezius EMG data were normalized to each participant’s maximum voluntary contractions (MVCs), collected while participants attempted to elevate their shoulders upwards against resistance applied by the experimenter. Each muscle’s MVC was the highest 1-second average of the EMG amplitudes collected from the three measurements with approximately 1 minute of rest in between each MVC.

Summary statistics for the trapezius muscle activity included the median value and the variability of the signal during periods of computer interaction. Variability was defined as the difference between the 90^{th} and 10^{th} percentile of the values observed during computer interaction. Median and variability were chosen to describe trapezius muscle activity because these values have both been associated with occupational musculoskeletal symptoms [Srinivasan and Mathiassen, 2012; Marcus et al., 2002; van den Heuvel et al., 2006].

Shoulder abduction and flexion, and head, neck, and torso flexion and lateral tilt, were measured using five data-loggers containing triaxial accelerometers (G-Link Data Loggers; Microstrain, Inc; Williston, VT). To measure shoulder posture, sensors were placed in stretchable bands on each participant's right and left arm as close to the shoulder joint as possible. To measure torso posture, the sensor was attached with tape centered below the acromial notch. To measure neck posture, the sensor was attached with tape centered above the C7 vertebrae. To measure head posture, the sensor was centered on the participant's forehead using a stretchable band. Data were logged at a frequency of 25 samples per second, downloaded to a personal computer, and filtered using a 5Hz second order, zero-phase, low-pass Butterworth filter. The acceleration vector data were transformed from the sensor's coordinate system to the anatomic coordinate system defined by a reference posture (standing erect looking straight ahead with arms resting at the sides) aligned with flexion and extension by a pure bowing motion (flexion at the hips only). The vector data were then converted to degrees using Euler angle transformations [Winter, 2005].

Shoulder rotation was measured using a custom video system that calculated angles based on the projected position of black and white markers [Bruno et al., 2011]. Markers were taped at the dorsal side of the wrist, the lower biceps brachii and on the acromion at the shoulder. Video images were collected at 30 frames per second, downloaded to a personal computer, converted to position data, and filtered using a 5Hz fourth-order, low-pass filter.

Summary statistics for the postural variables included the median value and the range of motion during periods of computer interaction. The range of motion of the joint was defined as the difference between the 90^{th} and 10^{th} percentile of the postural values observed during computer interaction.

Computer use

To identify the periods of computer use that were utilized to calculate the summary statistics for trapezius muscle activity, shoulder, head, neck, and torso postures, computer interaction monitoring software recorded the beginning and end times of keyboard and mouse events captured by either the Windows operating system or through an external USB tracker (Model 110b, Ellisys Inc., Geneva, Switzerland). From these data we defined periods of computer use as any time within 30 seconds of activating a key on the keyboard, pressing the button on the mouse, or moving the mouse [Blangsted et al., 2004; Chang et al., 2008; Bruno Garza et al., 2012]. All data collection systems were aligned with and parsed by computer use by having participants perform specific movements that would be noticeable in both the muscle activity/posture signals and the computer use signal simultaneously [Bruno Garza et al., 2012]. We further used the data from the computer interaction monitoring software to identify the distribution of tasks, which we represented as the percentage of the total computer use time where participants were actively using the keyboard (percent key), actively using the mouse (percent mouse), or passively engaged (percent idle) [Blangsted et al., 2004; Chang et al., 2008; Bruno Garza et al., 2012].

Statistical Analysis

Unadjusted repeated-measures analysis of variance (RMANOVA) and analysis of variance (ANOVA) models were used to test the hypothesis that workers reporting simultaneously low reward and high over-commitment will have increased and less variable trapezius muscle activity, more non-neutral shoulder, head, neck, and torso postures and decreased ranges of motion of postures during computer use. Each model contained three between-subject independent variables: over-commitment (low/high), reward (high/low), and the interaction between over-commitment and reward. The interaction was calculated as the product of reward (1=high, 0=low) multiplied by over-commitment (1=high, 0=low). When the interaction term was not significant, it was removed from the model, the analysis was run again, and new p-values were recalculated for the main effects model only. RMANOVA models were used for trapezius muscle activity and shoulder abduction, flexion, and rotation postures based on the assumption that each participant's right and left side muscle activity/ posture were dependent and correlated. The RMANOVA model is a robust and unbiased approach to account for data correlation. Each RMANOVA model included the three between-subject independent variables described above, along with an additional within-subject indicator variable for right/left side and the interactions between side and over-commitment and side and reward. The dependent variables for the RMANOVA models were the median or variability/range of motion values for shoulder posture and trapezius muscle activities for both the right and left side. The dependent variables for the ANOVA models were the median or range of motion values for head, neck, and torso postures.

In addition, adjusted RMANOVA and ANOVA models were used to confirm observed effects in the presence of confounders. Any of the fourteen potential confounders described in table III that changed the partial eta squared by at least 10% when: over-commitment, reward, or the over-commitment-by-reward interaction were significant in the unadjusted models; or, over-commitment, reward, or the over-commitment-by-reward interaction became significant with the addition of the potential confounder, were added to the adjusted models. When two or more variables were highly correlated (Spearman coefficient greater than 0.6), only the variable with the largest effect on the partial eta squared was chosen. When interaction terms were significant, a Tukey's post hoc analysis was performed to determine which values differed from others. Significance was defined as $p < 0.05$.

RESULTS

After adjusting for BMI, Gender, Hand Length, and Years Having Job Requiring Computing, there was a significant reward-by-over-commitment interaction for median trapezius muscle activity (Table IV). Median trapezius muscle activities during computer use were significantly different and approximately 2%MVC larger for participants reporting simultaneously low reward and high over-commitment compared to participants reporting simultaneously low reward and low over-commitment, with no difference for participants with high reward, for the right hand only (Figure 2).

The variability of trapezius muscle activity was significantly larger for participants reporting high compared to participants reporting low over-commitment for the unadjusted model only (Table V). There were no significant effects of reward on the variability of trapezius muscle activity and there was no significant reward-by-over-commitment interaction.

There was no significant effect of reward, over-commitment, or the reward-by-over-commitment interaction on the median values for shoulder flexion, abduction, or rotation postures (Table IV). After controlling for percent idle, the effect of reward on the median shoulder rotation posture was borderline-significant, but a Tukey's post hoc analysis did not reveal any significant differences between low/high reward for either the right or left hand. There was no significant effect of reward, over-commitment, or the reward-by-over-commitment interaction on the range of motion for shoulder flexion, abduction, or rotation postures.

There was no significant effect of reward or over-commitment on any median head, neck, or torso angles; however, the reward-by-over-commitment interaction was significant for both the unadjusted and adjusted models of neck flexion (Table V). Neck flexion for low reward was significantly different and approximately 5 degrees larger for participants reporting simultaneously low reward and high over-commitment compared to participants reporting simultaneously low reward and low over-commitment, with no difference for participants with high reward (Figure 3).

The range of motion for torso flexion was significantly lower for participants reporting high over-commitment compared to participants reporting low over-commitment; however, after adjusting for confounders the effect was no longer significant (Table V). There was no significant effect of over-commitment on any other range of motion value for head, neck, or torso posture variability. There was also no significant effect of reward or the reward-by-over-commitment interaction on head, neck, or torso posture variability.

DISCUSSION

The goal of this study was to determine if workers reporting simultaneously low reward and high over-commitment had increased and less variable trapezius muscle activity, more non-neutral shoulder, head, neck, and torso postures and decreased ranges of motion of postures of the neck and upper limbs during computer use. We observed that median trapezius muscle activity and median neck flexion during computer use were largest for participants reporting simultaneously low reward and high over-commitment. Few differences in median shoulder, head, and torso postures, variability of muscle activity, or range of motion of postures were observed for participants reporting different levels of reward and over-commitment.

The findings of increased trapezius muscle activity in participants reporting simultaneously low reward and high over-commitment provided the first field evidence that could be used to support the biomechanical pathway hypothesis (Figure 1). There have been numerous laboratory studies that have demonstrated an association of psychosocial stressors and increased trapezius muscle activity, supporting the hypothesized relationship (e.g. Rietveld et al., 2007; Wang et al., 2011). Additionally, since other studies have demonstrated that increased and non-variable trapezius muscle activity is associated with neck and upper limb symptoms among office workers [Srinivasan and Mathiassen, 2012; Marcus et al., 2002; van den Heuvel et al., 2006], it is possible that the findings may help to explain the association that has been identified for psychosocial factors and musculoskeletal disorders (e.g. Hannan et al., 2005; van den Heuvel et al., 2005; Huysmans et al., 2012).

The main results of increased trapezius muscle activity and neck flexion reported in this study could be due tithe different physical demands associated with differences in computer tasks performed by participants indifferent reward/over-commitment groups [Bruno Garza et al., 2012]. The ecological model of Sauter and Swanson [1996] portrays two pathways through which psychosocial components can increase muscle activities and postures, one through psychological strain and one through physical load (Figure 1). However, when controlling for task distribution in our analysis the relationships of psychosocial factors and the muscle activity and postures remained. In addition, job title, another variable that could influence physical demands, was not identified as a confounder for trapezius muscle activity or any of the postures considered and did not affect any of our results; however, it should be noted that the classification of job titles was limited to three categories with a large majority selecting “other”.

Based on our findings, over-commitment was a relevant and essential predictor of both of our significant results. Increased trapezius muscle activity and neck flexion were only observed for participants with simultaneously high over-commitment and low reward. Over-commitment may influence muscle activity and posture through several pathways (Figure 1). First, since the items in the over-commitment scale describe workers’ reactions to or efforts to cope with stressful working conditions, differences in over-commitment scores, similarly to differences in reward scores, could reflect differences in work organization [Belkic et al., 2000]. Second, over-commitment is alternatively thought of as a “psychological risk factor in its own, even in the absence of structural conditions of imbalance at work,” and thus could affect psychological strain independently of work organization [Siegrist, 2004]. Finally, increased over-commitment may directly influence biomechanical loading. For example, over-committed individuals might be more greatly affected by pressures at work, exerting greater efforts than are required to complete a work-task [Siegrist, 1996].

Whether the differences in overall muscle activity reported in this study are substantial enough to actually cause symptoms remains to be determined. We observed an approximately 2%MVC increase in trapezius muscle activity (figure 2) and 5 degree increase in neck flexion (figure 3) for workers in the low reward/high over-commitment group compared to workers in the low reward/low over-commitment group, both of which are objectively small. While the current literature does not have a definitive answer on how large of an increase in muscle activity or posture might be required to cause injury, it is generally believed that even small increases could be significant over the long duration of computer use experienced by office workers, especially for small muscle fibers which may remain continuously active [Visser and van Dieen, 2006; Hagg, 1991]. Several studies have suggested that changes to the work environment resulting in reductions of median trapezius muscle activity similar to the differences reported in our study would be beneficial in the reduction of symptoms [Cole et al., 2012; Lintula et al., 2001; Konarska et al., 2005]. Since participants within the current study were free of symptoms at the time of the measurements, testing of associations of musculoskeletal symptoms, muscle activities, and postures is not possible here. Future longitudinal studies incorporating measures of reward, over-commitment, muscle activities, postures, and neck and upper limb symptoms are needed to answer these questions.

We only considered the effects of one workplace psychosocial factor, reward, for this study. The concept of reward is actually derived from a larger model used to describe the psychosocial work environment, the effort-reward imbalance model [Siegrist, 1996]. The full effort-reward imbalance model theorizes that it is actually a combination of low reward and high effort that produces the most stressful response, with high over-commitment amplifying that response. Our decision to use reward independently of effort was made a priori based on the results of a previous study in a similar cohort of office workers, which reported an association of reward, but not effort, and musculoskeletal symptoms [Huysmans et al., 2012]. We acknowledge that there are many ways to characterize the psychosocial environment, and any of the parameters measured in this study may be associated with other psychosocial factors or models of psychosocial stress not investigated here.

This study has some additional limitations that should also be considered. First, because data collection was quite involved, taking place over eight months, we assigned participants to their low/high reward/over-commitment groups based on their scores relative to others in their department rather than relative to the entire study population. However, our approach of recruiting participants within the highest and lowest tertiles of their department allowed there to be adequate differences in scores between the low/high groups in the overall study population, with almost no overlap for the final cohort. Second, we were unable to recruit participants with very low reward scores (<24) or very high over-commitment scores (>23) from any department. The reduced variability in reward and over-commitment scores in this study may lead to estimates of the effects of reward and over-commitment that are smaller than in a population with more diverse scores. However, there were no differences in the reward or over-commitment scores of the workers who filled out the survey and were willing to participate compare to those who were not willing to participate in the study. Third, because this was an observational study, we cannot conclude that psychosocial stress caused the increases that we observed in trapezius muscle activity or neck flexion. However, this finding corroborated the results of prospective laboratory studies (e.g. Rietveld et al., 2007; Wang et al., 2011), lending credence to our results. Fourth, our measurements due to technical and feasibility aspects were only two hours and only examined muscle activity and postures during computer interactions. For example, wireless systems were chosen to allow participants to move freely and to leave their workstations, but for this reason data was only collected while participants were close to their computers. Thus, questions regarding exposure during non-computer interaction times and variance of the data from day to day remain unanswered [Asundi et al., 2012]. Additionally, we were limited in the number of muscles that we could measure using EMG. We chose to prioritize the trapezius muscle because many previous laboratory studies have focused on the effects of psychosocial stressors on the trapezius (e.g. Rietveld et al., 2007; Wang et al., 2011). Finally, because we performed a large number of significance tests for the interaction (28 adjusted models) and main effects (26 adjusted models), few of which produced significant results (2/28 for interaction and 1/26 for main effects), we cannot rule out the possibility that our significant findings occurred by chance. However, we do feel that the results presented here for the trapezius muscle activity and neck flexion posture are plausible, as they were in line with our hypothesis and may help to explain the large number of neck and shoulder musculoskeletal complaints observed among office workers [NRC/IOM Report, 2001; Bongers, 2006]. Regardless of the limitations, this was the first study to measure psychosocial stress and neck and upper limb muscle activities and postures directly in a large population of office workers performing their own computer work, and to report a positive association amongst these factors.

In conclusion, the interaction of low reward and high over-commitment was associated with increased median trapezius muscle activity and increased median neck flexion posture among office workers performing computer work. Other postures, muscle activity variability, and posture ranges of motion were largely similar across these constructs. These findings add some evidence to the plausibility of a pathway connecting psychosocial stress and musculoskeletal symptoms that goes through muscle activity or postures. Additionally, these findings support the idea that there can be large differences in individuals' physiological responses to similar work environment factors across the workforce. Workers' psychosocial factors, and their personal traits, can influence their physical exposures. Thus, prevention efforts need to consider multiple aspects of the work environment, as well as the individual, in order to reduce physical exposures, such as through multiple component program approaches [Kennedy et al., 2010; Wahlstrom, 2005].

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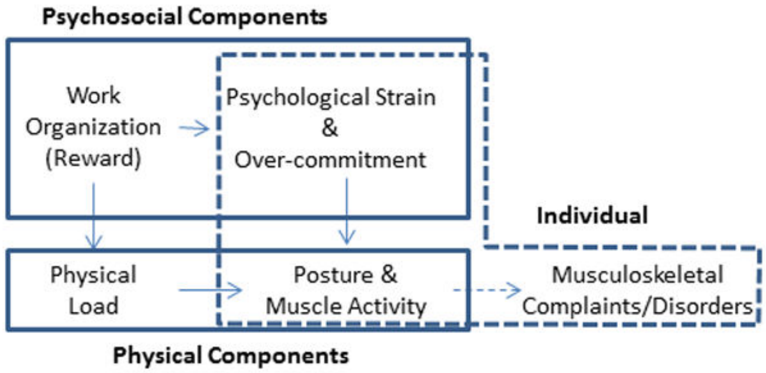

Figure 1.

The hypothesized biomechanical pathway based on the model of Sauter and Swanson [1996] incorporating psychosocial, physical, and individual components. Both reward and over-commitment [Siegrist, 1996; Siegrist, 2004] are part of the psychosocial component, with reward being considered a reflection of work-organization and over-commitment being considered as both a psychosocial and individual component that could also be influenced by work organization. Posture and muscle activity are the measures of the individual's internal biomechanical loading.

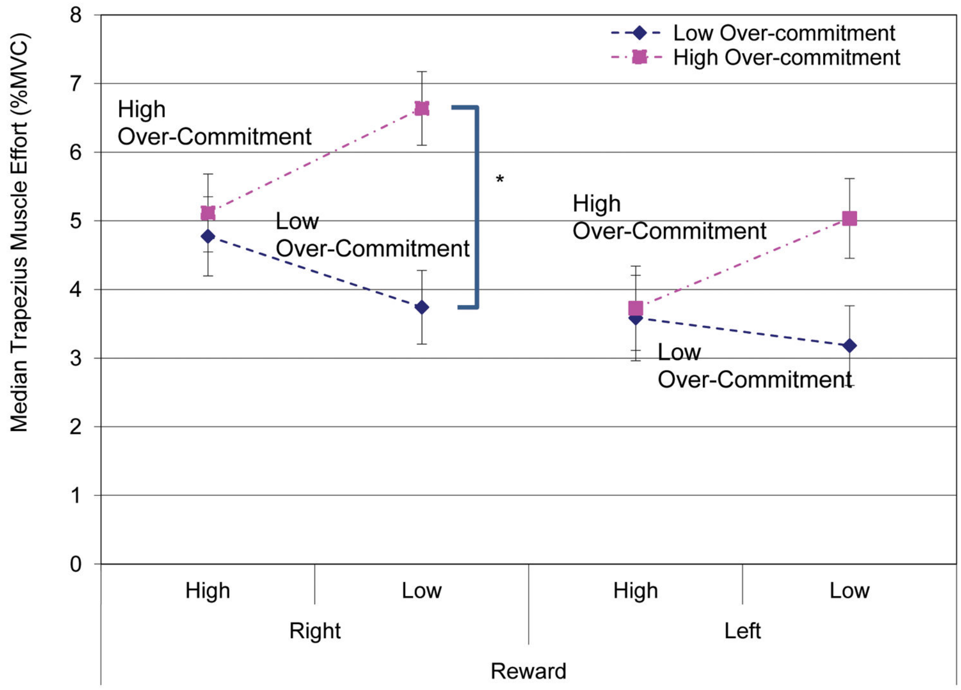

FIGURE 2.

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.

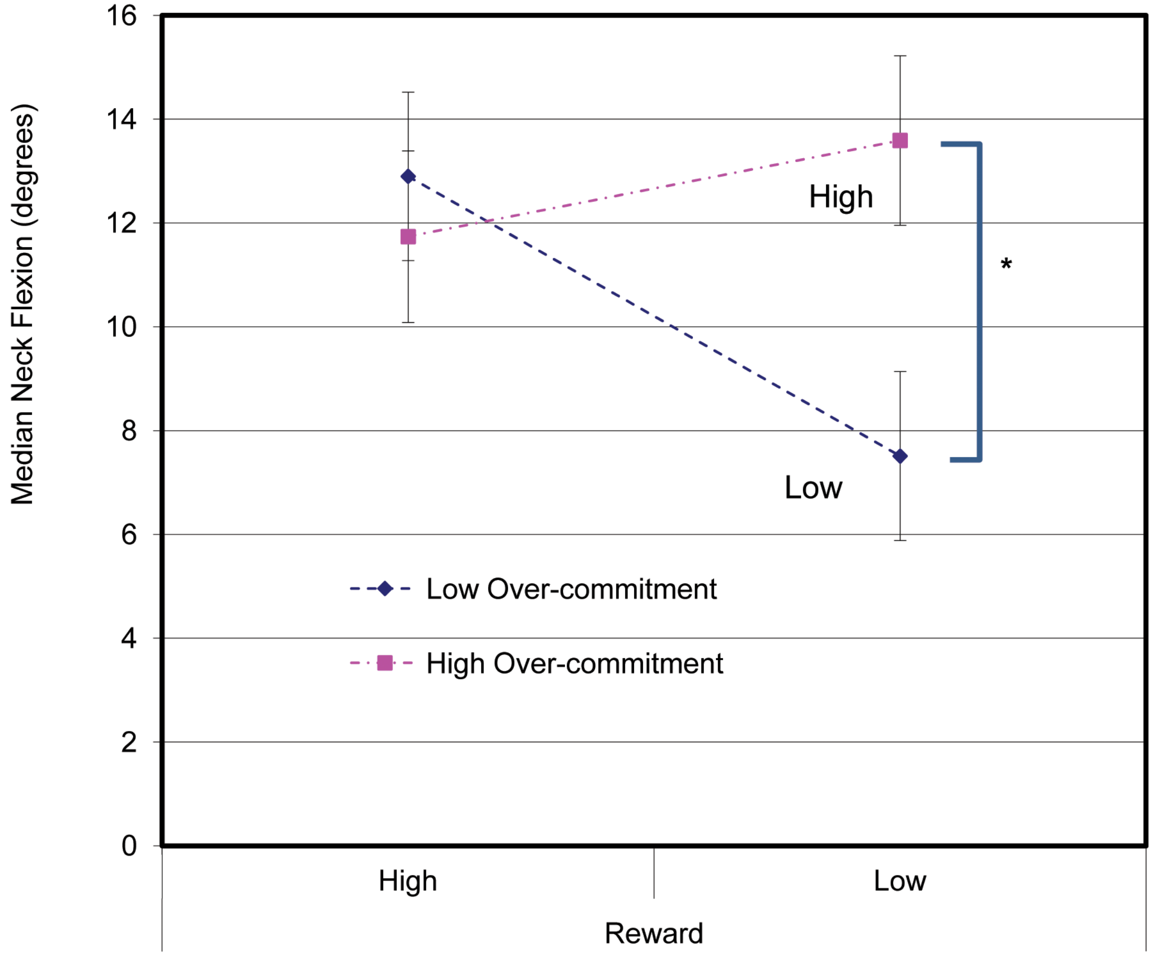

FIGURE 3.

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.

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TABLE I

Questions used to define "reward" and "over-commitment", based on Siegrist's (2004) definitions.

Reward	Over-commitment
• I receive the respect I deserve from my superiors. • I receive the respect I deserve from my colleagues. • I experience adequate support in difficult situations. • I am treated unfairly at work. • Considering all my efforts and achievements, I receive the respect and prestige I deserve at work. • My job promotion prospects are poor. • My current occupational position adequately reflects my education and training. • Considering all my efforts and achievements, my salary/ income is adequate. • I have experienced or I expect to experience an undesirable change in my work situation. • My job security is poor.	• I get easily overwhelmed by time pressures at work. • As soon as I get up in the morning I start thinking about work problems. • When I get home I can easily relax and 'switch off' work. • People close to me say I sacrifice too much for my job. • Work rarely lets me go, it is still on my mind when I go to bed. • If I postpone something that I was supposed to do today I'll have trouble sleeping at night.

TABLE II

Range (number of participants in each department) of over-commitment and reward scores for each department, and for all participants.

	Reward (11–55)		***Over-commitment (6–24)***	
Department	**High**	**Low**	**Low**	**High**
A (n = 11)	53–55	26–46	10–13	14–16
B (n = 15)	51–55	31–46	6–13	15–20
C (n = 9)	48–55	31–37	7–14	16–18
D (n = 7)	51–55	24–48	10–13	14–19
E (n = 11)	53–55	24–44	8–12	14–23
F (n = 13)	51–55	35–48	7–14	17–18
G (n = 7)	55–55	37–48	9–13	15–20
H (n = 14)	53–55	37–48	6–13	16–20
I (n = 30)	51–55	29–48	7–13	14–23
All participants (n=117)	48–55	24–48	6–14	14–23

TABLE III

Distribution of potential confounders across the four reward/over-commitment groups: mean values (and standard deviations) for continuous variables or number (and percentage) for categorical variables separated by group are presented.

Reward	HIGH	HIGH	LOW	LOW	
Over-Commitment	**LOW**	**HIGH**	**LOW**	**HIGH**	**p-value**[1]
N	30	27	30	30	
Age – years	37 (13)	39 (12)	40 (11)	43 (10)	0.04
Gender – n					
Female (%)	21 (70)	20 (74)	22 (73)	22 (73)	0.98
Male (%)	9 (30)	7 (26)	8 (27)	8 (27)	
Height – cm	178 (9)	174 (10)	175 (11)	175 (9)	0.30
Weight – kg	72 (11)	76 (14)	73 (15)	76 (13)	0.39
BMI – kg/m^2	23 (7)	24 (5)	26 (10)	25 (5)	0.08
Arm Length – cm	57 (8)	55 (4)	55 (4)	56 (5)	0.61
Shoulder Breadth – cm	37 (3)	38 (3)	37 (3)	37 (3)	0.86
Hand Length – cm	18(2)	18 (1)	18 (1)	18 (1)	0.38
Hand Breadth – cm	7 (1)	8 (1)	8 (1)	8 (1)	0.51
Task Distribution					
Percent Idle	35 (9)	35 (7)	39 (10)	37 (8)	0.63
Percent Keyboard	22 (11)	23 (9)	19 (10)	24 (12)	0.33
Percent Mouse	41 (12)	42 (11)	45 (11)	39 (11)	0.23
Job Title – n					0.09
Secretary (%)	2 (7)	2 (7)	3 (10)	2 (7)	
Other support (%)	4 (13)	7 (26)	7 (23)	4 (13)	
Other (%)	24 (80)	18 (67)	20 (67)	24 (80)	
Computer job experience					0.02
<1 year	5 (17)	2 (7)	2 (7)	0 (0)	
1–2 years	7 (23)	1 (4)	2 (7)	2 (7)	
2–5 years	2 (7)	9 (33)	9 (30)	5 (17)	
5–10 years	6 (20)	5 (19)	7 (23)	6 (20)	

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Reward	**HIGH**	**HIGH**	**LOW**	**LOW**	
Over-Commitment	**LOW**	**HIGH**	**LOW**	**HIGH**	**p-value**[1]
>10 years	10 (33)	10 (37)	10 (33)	17 (57)	

[1] P-value calculated from an ANOVA for continuous variables or a Chi-squared test for categorical variables.

TABLE IV

Trapezius Muscle Activities and Shoulder Postures: Least-square means (and standard error) from unadjusted and adjusted repeated-measures ANOVA models for the trapezius median and variability and shoulder median and range of motion (ROM) values (n=117).

Description		*Reward* High (Reference)	Low	p-value	*Over-commitment* Low (Reference)	High	p-value	*Interaction* p-value
Trapezius muscle activity (%MVC)								
Median	Right	5.1 (0.4)	5.7 (0.4)	0.17[5]	**4.4 (0.4)**	**6.4 (0.4)**	**<0.01**[5]	0.06
Unadjusted	Left	3.8 (0.4)	4.7 (0.4)		**3.5 (0.4)**	**5.1 (0.4)**		
Median	Right	4.9 (0.4)	5.2 (0.4)	0.42[5]	**4.3 (0.4)**	**5.8 (0.4)**	**0.02**[5]	**0.03**
Adjusted[2]	Left	4.1 (0.4)	3.6 (0.4)		**3.4 (0.4)**	**4.3 (0.4)**		
Variability	Right	8.6 (0.4)	9.0 (0.5)	0.26	**7.9 (0.4)**	**9.7 (0.5)**	**0.03**	0.34
Unadjusted	Left	7.4 (0.6)	8.4 (0.6)		**7.3 (0.6)**	**8.5 (0.6)**		
Variability	Right	8.7 (0.4)	8.9 (0.4)	0.50	8.1 (0.4)	9.6 (0.5)	0.10	0.36
Adjusted[3]	Left	7.5 (0.6)	8.3 (0.5)		7.5 (0.6)	8.3 (0.6)		
Shoulder Flexion (°)								
Median	Right	11.4 (1.9)	12.7 (1.8)	0.33	12.9 (1.9)	11.3 (1.9)	0.10	0.62
Unadjusted[1]	Left	11.1 (1.7)	14.3 (1.7)		15.5 (1.6)	9.9 (1.6)		
ROM	Right	25.9 (1.1)	22.7 (1.0)	0.35	25.2 (1.1)	23.4 (1.1)	0.44	0.46
Unadjusted[1]	Left	26.3 (1.4)	26.9 (1.3)		26.8 (1.3)	26.4 (1.3)		
ShoulderAbduction (°)								
Median	Right	12.9 (1.4)	13.3 (1.4)	0.78	13.8 (1.4)	12.4 (1.4)	0.90	0.39
Unadjusted[1]	Left	7.8 (1.3)	6.6 (1.1)		6.7 (1.2)	7.8 (1.2)		
ROM	Right	15.8 (1.3)	14.9 (1.2)	0.87	15.2 (1.3)	15.5 (1.3)	0.70	0.34
Unadjusted[1]	Left	16.3 (1.1)	16.8 (1.1)		17.2 (1.1)	15.9 (1.1)		
Shoulder Internal Rotation (°)								
Median	Right	0.3 (2.3)	4.2 (2.2)	0.08	1.8 (2.3)	2.7 (2.3)	0.94	0.22
Unadjusted[1]	Left	24.5 (1.7)	20.4 (1.6)		21.8 (1.6)	23.0 (1.6)		
Median	Right	**0.4 (1.8)**	**4.0 (1.8)**	**0.05**	0.3 (1.9)	4.2 (1.9)	0.34	0.60
Adjusted[4]	Left	**24.4 (1.6)**	**20.4 (1.5)**		22.3 (1.6)	22.5 (1.6)		
ROM	Right	44.1 (1.7)	44.8 (1.6)	0.62	44.2 (1.7)	44.7 (1.7)	0.51	0.50

Description		*Reward*			*Over-commitment*			*Interaction*
		High (Reference)	**Low**	**p-value**	**Low (Reference)**	**High**	**p-value**	**p-value**
Unadjusted[1]	Left	30.0 (2.2)	27.2 (2.1)		27.5 (2.1)	29.7 (2.1)		

The interaction was calculated as the product of reward (1=high, 0=low) multiplied by over-commitment (1=high, 0=low)

[1] Since the unadjusted model was not significant, the adjusted model was not presented.

[2] Adjusted for Percent Mouse, Percent Idle, BMI, Gender, Hand Length, and Years Having Job Requiring Computing

[3] Adjusted for Age, Weight, BMI and Years Having Job Requiring Computing

[4] Adjusted for Percent Key

[5] P-values for Over-commitment and Reward in this model were calculated from models with the over-commitment-by-reward interaction included.

Bolded values indicate significance (p<0.05)

TABLE V

Head, Neck and Torso Postures: Least-squares means (and standard errors) from unadjusted and adjusted repeated-measures ANOVA models for the head, neck, and torso angles' medain and range of motion values (n=117).

Description	Model	*Reward*			*Over-commitment*			*Interaction*
		High (Reference)	**Low**	**p-value**	**Low (Reference)**	**High**	**p-value**	**p-value**
Head (°)								
Flexion	Median							
	Unadjusted[1]	12.4 (1.2)	11.9 (1.2)	0.53	11.6 (1.2)	12.7 (1.2)	0.78	0.64
	ROM							
	Unadjusted[1]	26.5 (1.5)	27.4 (1.4)	0.64	25.8 (1.4)	28.1 (1.4)	0.27	0.85
Lateral Tilt	Median							
	Unadjusted[1]	0.9 (0.5)	1.0 (0.5)	0.96	1.0 (0.5)	0.9 (.05)	0.92	0.74
	ROM							
	Unadjusted[1]	11.5 (1.1)	10.6 (1.1)	0.17	12.1 (1.1)	10.0 (1.1)	0.59	0.44
Neck (°)								
Flexion	Median							
	Unadjusted	12.5 (1.2)	10.5 (1.1)	0.23[4]	10.3 (1.1)	12.8 (1.2)	0.13[4]	**0.04**
	Adjusted[2]	12.7 (1.2)	10.3 (1.1)	0.15[4]	10.4 (1.1)	12.6 (1.2)	0.17[4]	**0.04**
	ROM							
	Unadjusted[1]	15.4 (0.9)	15.8 (0.9)	0.37	16.2 (0.9)	15.0 (0.9)	0.72	0.52
Lateral Tilt	Median							
	Unadjusted[1]	0.6 (0.5)	1.2 (0.4)	0.38	0.6 (0.4)	1.1 (0.5)	0.46	0.59
	ROM							
	Unadjusted[1]	8.1 (0.4)	8.9 (0.4)	0.15	8.6 (0.4)	8.3 (0.4)	0.56	0.35
Torso (°)								
Flexion	Median							
	Unadjusted[1]	15.6 (1.4)	12.4 (1.4)	0.11	13.5 (1.4)	14.5 (1.4)	0.60	0.16
	ROM							
	Unadjusted	18.3 (1.1)	17.1 (1.2)	0.46	**19.7 (1.2)**	**15.6 (1.2)**	**0.01**	0.48
	Adjusted[3]	17.6 (1.1)	17.7 (1.1)	0.99	18.8 (1.1)	16.5 (1.1)	0.16	0.51

Description	Model	*Reward*			*Over-commitment*			*Interaction*
		High (Reference)	**Low**	**p-value**	**Low (Reference)**	**High**	**p-value**	**p-value**
Lateral Tilt	Median							
	Unadjusted[1]	2.2 (0.5)	1.6 (0.4)	0.31	1.9 (0.4)	2.0 (0.4)	0.90	0.54
	ROM							
	Unadjusted[1]	7.9 (0.6)	7.3 (0.6)	0.42	7.5 (0.6)	7.7 (0.6)	0.80	0.87

The interaction was calculated as the product of reward (1=high, 0=low) multiplied by over-commitment (1=high, 0=low)

[1]Since the unadjusted model was not significant, the adjusted model was not presented.

[2]Adjusted for Age

[3]Adjusted for Percent Key, Percent Idle, Age, Height, Body Mass Index, and Years Having a Job Requiring Computing

[4]P-values for Over-commitment and Reward in this model were calculated from models with the over-commitment-by-reward interaction included.

Bolded values indicate a significance (p<0.05)

Positive values indicate head, neck, and torso flexion and right lateral tilt.