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# The effectiveness of a training method using self-modeling webcam photos for reducing musculoskeletal risk among office workers using computers

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ABSTRACT

An intervention study was conducted to examine the effectiveness of an innovative self-modeling photo-training method for reducing musculoskeletal risk among office workers using computers. Sixty workers were randomly assigned to either: 1) a control group; 2) an office training group that received personal, ergonomic training and workstation adjustments or 3) a photo-training group that received both office training and an automatic frequent-feedback system that displayed on the computer screen a photo of the worker's current sitting posture together with the correct posture photo taken earlier during office training. Musculoskeletal risk was evaluated using the Rapid Upper Limb Assessment (RULA) method before, during and after the six weeks intervention. Both training methods provided effective short-term posture improvement; however, sustained improvement was only attained with the photo-training method. Both interventions had a greater effect on older workers and on workers suffering more musculoskeletal pain. The photo-training method had a greater positive effect on women than on men.


## 1. Introduction

Computer work stations are common in many places of employment, such as universities, hospitals, government offices and industry. Recent research reviews have confirmed the dose response association between the number of hours working at a computer workstation and the risk of musculoskeletal symptoms (MSS) and disorders (MSD) which include pain and symptoms in the shoulder-neck, back and upper limbs particularly (Brewer et al., 2006; Gerr et al., 2004; Gerr et al., 2006; Hoogendoorn et al., 2000; IJmker et al., 2007). The prevalence of MSS among persons with frequent computer use (3–5 h a day) ranges from 40% among college students (Menendez et al., 2009), 50% among new workers in the first year on the job (Gerr et al., 2002) to over 70% of university staff and students (Berner and Jacobs, 2002).

MSS are also associated with loss of work time and occupational injuries, generating workers' compensation claims that are costly to employers and the economy in general (Aptel et al., 2002). Fang and colleagues showed that in 2004, over 50% of US adults used a computer at work, the rate is increasing yearly, MSD accounted for approximately one-third of all the injuries and sick days away from work in the US workforce and that 74% of the MSD injured applied for workers' compensation (Fang et al., 2007).

There is a consensus that the development of MSD is multifactorial and is best explained by an interaction between personal characteristics of the worker such as age, gender, experience and work-family conflicts, the nature of the occupational exposure (e.g., exposure to different working conditions such as working with time pressure, flexible breaks from work, number of working hours, low pay and the presence of supportive work colleagues) and ergonomic features of the workstation such as the type of keyboard and mouse being used regularly at work (Ariens et al., 2001; Bergqvist et al., 1995; Berner and Jacobs, 2002; Nelson and Silverstein, 1998; Pillastrini et al., 2010; Pransky et al., 2002). Following the multivariate etiology of MSD, interventions for the primary or secondary prevention of work-related MSD among computer workers typically emphasize engineering, organizational, personal/behavioral and ergonomic interventions or a combination of these types of interventions (Bongers et al., 2006; Brewer et al., 2006; Gerr et al., 2005; Kennedy et al., 2010; Lincoln et al., 2000; Tullar et al., 2010). Engineering interventions include, for example, changes in keyboard or mouse designs or wrist supports. Personal/behavioral interventions include wearing of arm splints, back braces, exercise programs and electromyographic biofeedback. Ergonomic interventions generally include both ergonomic adjustments to the workstation to tailor the physical conditions to the worker's physiology and working patterns as well as educational components about correct sitting posture.

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Organizational options for prevention include workstation rotation, alternative seating and lighting conditions, pay adjustments and changes in workplace regulations. Reviews have found that combined interventions including more than one element are most consistently found to be effective in MSD prevention, despite the fact that multiple interventions complicate understanding precisely which element has the greatest relative ameliorative effect (Brewer et al., 2006; Kennedy et al., 2010; Lincoln et al., 2000; Norman and Wells, 1998; Pransky et al., 2002; Tullar et al., 2010; Westgaard and Winkel, 1996).

Recent reviews of randomized controlled trials have demonstrated only limited effectiveness of ergonomic interventions in the workplace to prevent MSD. The pooled evidence suggests that exercise programs are an effective intervention (Tullar et al., 2010) but the evidence for other types of interventions is mixed (Bongers et al., 2006; Brewer et al., 2006; Kennedy et al., 2010; Proper et al., 2003; Tullar et al., 2010; Westgaard and Winkel, 1996). Furthermore there is a dearth of studies that have followed workers over time to assess the impact of the intervention (Brewer et al., 2006; Gerr et al., 1996; Pillastrini et al., 2007). Two recent studies are exceptions. A cross-over intervention trial conducted by Pillastrini and colleagues with follow-ups at 5, 12, 30 months from baseline and at 6 months after cross-over compared an ergonomic intervention with a control group who received an informative brochure (Pillastrini et al., 2010). In the intervention conducted by Amick and colleagues with 2, 6, and 12 months post-intervention follow-ups, a group received an adjustable office chair together with office ergonomics training which was compared with a training-only group and a control group (Amick et al., 2003; Robertson et al., 2009).

The use of photography or video as a teaching mechanism is well known from the education of teachers and the teaching of parenting skills to parents of small children (Bakermans, 1998; Paillotet, 1995; Weiner et al., 1994) as well as in the education of teen drivers (Carney et al., 2010; McGehee et al., 2007). A small but growing body of literature has made use of still photography or video to quantify ergonomic measures (e.g., Jamjumrus and Nanthavanij, 2008; Juul-Kristensen et al., 2001; Spielholz et al., 2001), however the use of photography or video feedback to enhance workers' learning of postures that may reduce MSD has been less widely used. Rosen and colleagues reviewed the use of video exposure monitoring (VEM) in the workplace which is an established method of training workers in areas such as workplace safety and occupational hygiene. The video and other methods such as still photography enhance the visualization of the work process, aiding in behavioral change (Rosen et al., 2005). Kadefors & Forsman evaluated the utility of an interactive program of video recordings which recorded incidents of pain or discomfort among automotive workers which were stored in a personal library for later analysis (Kadefors and Forsman, 2000).

One focus of research is the oft-reported difference between men and women in the workforce and the impact of gender on the development of MSD among workers in general and among computer users specifically (Hellerstedt and Jeffery, 1997; Punnett and Herbert, 2000; Strazdins and Bammer, 2004). Research shows that women in community samples report more musculoskeletal pain in general without any relation to work (Wijnhoven et al., 2006b) and that pain complaints are not explained by physical activity, overweight, education, smoking and how pain is subjectively evaluated (Wijnhoven et al., 2006a). Among workers, psychosocial factors such as low educational attainment, divorced family status, job insecurity, having children at home appear to more negatively affect women's reporting of MSS than men (Hagberg et al., 2002; Hooftman et al., 2004; Huisstede et al., 2008; Marcus and Gerr, 1996; Strazdins and Bammer, 2004). For example, a matched sample of cases and controls retrospectively analyzed risk factors for neck/shoulder disorders among the Stockholm workforce and found that psychosocial factors affect women more and that the physical strain of work affects men more. The only common exposure factor that affected both men and women was repetitive hand movements, such as what is done on the computer (Fredriksson et al., 2000). However, because women are concentrated in low-paying jobs with little decision-making latitude, often doing repetitive computer work such as data entry, there is a significant interaction between psychosocial factors in the workplace and the type of occupational exposures that women have (Hooftman et al., 2004; Jensen, 2003; Jensen et al., 1998; Juul-Kristensen et al., 2004; Marcus and Gerr, 1996; Strazdins and Bammer, 2004).

The "objectification theory" proposed by Barbara Fredrickson & Tomi-Ann Roberts attempts to explain how men and women react differently to social situations (Fredrickson and Roberts, 1997). Research on objectification theory has shown that women are gazed at more than men and women are more likely to report that they feel "checked out" visually in social encounters, which in turn promotes a feeling of "objectification" of women's bodies. As a result, Western women have internalized this frequent observation and adopt an observer's perspective on their physical selves resulting in frequent monitoring of how they look (Fredrickson and Roberts, 1997; Fredrickson et al., 1998; Rodin et al., 1984; Striegel-Moore et al., 1986; Tiggemann and Lynch, 2001; Wolf, 1992).

In this study we present a self-modeling training method using webcam photos, which are presented on the workers' computer screens, in order to improve their workplace posture. We compare the photo-training intervention with a conventional office ergonomic intervention group and with a control group and evaluate their effectiveness in reducing musculoskeletal risk, both between the genders and over time. We propose the following hypotheses:

**Hypothesis 1**. There will be a reduction in musculoskeletal risk for both intervention groups compared to the control group with a greater reduction in risk in the photo-training group compared to the office training group.

**Hypothesis 2**. There will be a greater reduction in musculoskeletal risk as a result of the photo training intervention among women than among men.

## 2. Methods

### *2.1. Participants*

Study participants were employees at either a major research university or a university hospital whose jobs were in the following sectors: administration (42 participants), computer programmers (8 participants), or research (10 participants). Participants worked an average of at least 4 h per day, five days a week working at an office computer station and had been employed at this position for at least a year. The participants signed an informed consent form and the study's procedures were approved by the Institutional Review Board for the protection of human subjects in both experimental sites. Participants included 38 women and 22 men whose ages ranged from 23 to 66 years. Participants received a sum equivalent to 15$ for participation in the study.

### *2.2. Workplace settings*

Most of the participants worked in private offices, with work stations that included adjustable office chairs, adjustable computer screens, and variable lighting conditions including natural light from windows and from overhead florescent lighting fixtures. Some

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workers worked in cubicles in a long hallway and some worked in large rooms with several work stations around the perimeter of the room.

### 2.3. Study design

A modified randomized experimental design was used in which participants were equally divided into three study groups: (1) a control group; (2) office training group that received personal ergonomic training and workstation adjustments; (3) a photo-training group that received both office training and self-modeling photos that capitalize on the innate ability of workers to compare images of themselves and use it to improve their workplace posture. In order to prevent contamination of the intervention, when two people agreed to participate in the experiment and shared a physical work space, they were both assigned to the same group based on the first volunteer's randomization. This disproportion was then corrected in the assignment of the next participants, who were assigned, in turn, to both remaining groups, in order to preserve approximately equal numbers in each group.

### 2.4. Procedure

Following written informed consent, demographic, physical status about current symptoms including musculoskeletal pain and work-related personal data (e.g., job description and experience, hours of computer use) on all three groups were collected before randomization using a specially designed questionnaire.

The experiment ranged over six weeks for each participant. The study consisted of four phases: baseline (week one), intervention (weeks two-four), post-intervention phase during which we had a one week break (week five) and a final follow-up data collection phase (week six). The four stages were executed following the randomization procedure.

During the baseline phase, we photographed all the participants using a specially installed webcam in order to characterize their normal work-time posture without any intervention. The webcam was positioned at a 90° angle relative to the side where the worker held the mouse while using the computer. During this week, no participant received any training, feedback on their sitting posture or ergonomic intervention. During the intervention phase, we trained the subjects according to their group assignment and collected data using photographs. The three weeks of intervention allowed time for habituation to the intervention and minimized the possibility that random changes in work-related tasks would affect the results. During the fifth week there were no interventions or photos taken. During the follow-up week we again monitored their sitting postures using the webcam without any additional training. The specific interventions are detailed below.

### 2.5. Interventions

#### 2.5.1. Office ergonomic training

The intervention given the office ergonomic training group by an ergonomist included two aspects: 1) personal training (approximately 20 min) on how to improve their posture while working on the computer including recommendations on how to minimize strain on forearms, back and neck by adjusting angles and work postures, taking breaks and doing exercises while in the office 2) practical instruction on how to modify their workstation by changing chair and desk height, backrest inclination, keyboard inclination and location, screen height, inclination and orientation, forearm supports and foot rests as needed. In some cases the workplace was reorganized, altering the position of the desks and the chair (or replacing them if necessary), the screen, keyboard and mouse according to the lighting conditions, and to improve the fit between the workers and their computer workplace. These modifications are supported by the current literature on work space ergonomics (e.g., Aaras et al., 1997; Aaras et al., 1998; Dumas et al., 2008; Jamjumrus and Nanthavanij, 2008; Ketola et al., 2002; Kilroy and Dockrell, 2000; Robertson et al., 2009; Williams et al., 1991).

#### 2.5.2. Self-modeling photo-training

This group received the office ergonomic training as detailed above and in addition also received self-modeling photo-training feedback. After receiving the office ergonomic training, the participant was asked to sit correctly according to the training. The ergonomist verified that this posture was the optimal working posture. A photograph of this correct posture was taken using the webcam.

Using a specially designed software package, Photonom© that was developed for this purpose, the webcam was used throughout the three intervention weeks to display two photographs: a photo of the worker's current sitting posture together with the correct posture photo taken earlier during office training for comparison. The photographs were displayed on the participant's computer screen approximately once every 20 min (randomly displayed between 20 and 25 min). This time interval was selected to replicate the suggested ergonomic advice on when to break, stretch and or change position. This automatic frequent-feedback system was used as a personal reminder to reinforce the physical feeling and to mirror the appearance of the participant when sitting correctly during ergonomic office training (as ratified by the ergonomist).

#### 2.5.3. Control group

The control group did not receive any training regarding work-related posture during the experimental period. At the end of six weeks they received a 20 min meeting during which an ergonomist gave them personal advice on how to improve their workstation posture as discussed in the office intervention above.

### 2.6. Instruments and outcome measures

#### 2.6.1. Photonom© – Photo ergonomic training system

We developed a Client Server system that runs on Windows Operating System and enables operation and control of all interventions. The system consists of a central server and a client application that is installed locally at each user's computer. After the first installation, the system is uploaded automatically upon the computer's restart. A Webcam is attached to each user's computer and the system is able to send a command to the camera to take a picture of the user, capture the photo, and send it to the central server. The central server maintains a database that stores all the photos taken of all users along with their relevant background information, to enable later analysis of the photos.

Photonom© provides the following functions:

- Camera activation – the client application sends an activation signal to the camera to take a still picture of the user. The time interval between the camera activation messages is controlled by a parameter that the administrator can set. The interval defined with low and upper limits (e.g., 20–25 min), and the system randomly selects an interval between these limits in order to prevent user's biased behavior during expected pictures taking intervals. The picture taken is focused only on the user's workstation posture without capturing the environment, the material displayed on the screen, or any motion or sound around in order to preserve user's privacy. Pictures are taken for all three experimental groups during the experiment to enable comparison of the effect of the intervention type on workstation postures between the groups.

- Information storing – the system sends the picture taken along with the relevant information (e.g., time picture was taken and camera ID) to the central server where it is stored for later analysis.
- Image display – the system is able to display to the user as a pop-up screen his/her current position and his/her ideal position as shown on Fig. 1. The ideal position for each user is pictured and saved at the end of the personal training session with the ergonomist. The pop-up is displayed only to participants that are members of the self-modeling photo-training intervention group.
- Experiment administration – the system provides the administrator (the experiment manager) a GUI to fill the user's demographic details and the experiment's settings (e.g., period, type of intervention, etc.), and to take and save a picture of the user's ideal position.

Initially, a pilot study was conducted to test the reliability of the measurements, the stability of the software, to test the user's acceptance of the interventions, and to finally infer the best settings of the experiments accordingly. Ten users participated in the pilot experiment for a few days; they used the system, and were later interviewed about their experiences. Some operative conclusions were drawn, for example: the time interval between photo displays was set to 20–25 min; the size of the pop-up screen was made smaller and its position was moved to the center of the screen. It was also decided to automatically start the system upon the computer's restart to avoid the situation that the user forgot to activate the software.

### 2.6.2. Rapid Upper Limb Assessment (RULA) measuring tool

In order to analyze the sitting postures, we used the RULA measure for computer users (Lueder, 1996), which quantifies the grade of musculoskeletal risk of the sitting posture in a 1–7 scale. Higher RULA scores indicate greater levels of risk factors causing load on the structures of body segments. The grade is calculated based on the degree of angles between various body segments and their recommended postures according to criteria derived through interpretation of previous relevant studies (McAtamney and Corlett, 1993). RULA provides one overall grade that is an estimation of the user's risk while seated at a computer station, which is calculated from the grade given to each of the measured angles and recommended postures. A RULA grade is calculated after measuring the angles *in vivo* or based on a worker's photo. We developed a semi-automated software (measuring tool) that can access the database of stored photos and computes a RULA grade for each photo. The ergonomist who analyzed the photos needed only to mark the different organs with a special marker provided by the system. The software then calculated the required angles and the overall RULA score.

### 2.6.3. Self-reported symptoms at baseline

We used a validated ergonomic questionnaire developed by Gillen et al. for use in the workplace to evaluate MSS (Gillen et al., 2007; Rugulies et al., 2004). We used three components for this study: 1) The Roland Morris scale for low back symptoms (23 items) which assess back pain-related restrictions in daily life (Cronbach's $\acute{\alpha} = 0.97$) (Roland, 1983). 2) We analyzed two questions from the Von Korff neck pain assessment procedure: severity of neck pain now and severity of neck pain in the past year (10 point scales) (Cronbach's $\acute{\alpha} = 0.80$) (Von Korff et al., 1990; Von Korff et al., 1992). 3) DASH – disability of arm, shoulder and hand. The shortened version was used (11 items) which assess upper extremity symptoms. Two items measure pain while the remainder assesses functional limitations due to symptoms (Beaton et al., 2005) (Cronbach's $\acute{\alpha} = 0.84$).

In addition, we asked participants to rate their global musculoskeletal discomfort on a scale which assesses the level of pain currently felt (scale ranged from 0 = no pain whatsoever to 10 = very high level of pain).

## 2.7. Reliability procedures

The RULA assessment procedures were tested by two qualified ergonomists who were hired especially to evaluate the interventions. Initially they evaluated the first 10 participants separately and discussed their procedures until they achieved a 95% agreement rate. The adherence was monitored to the three groups.

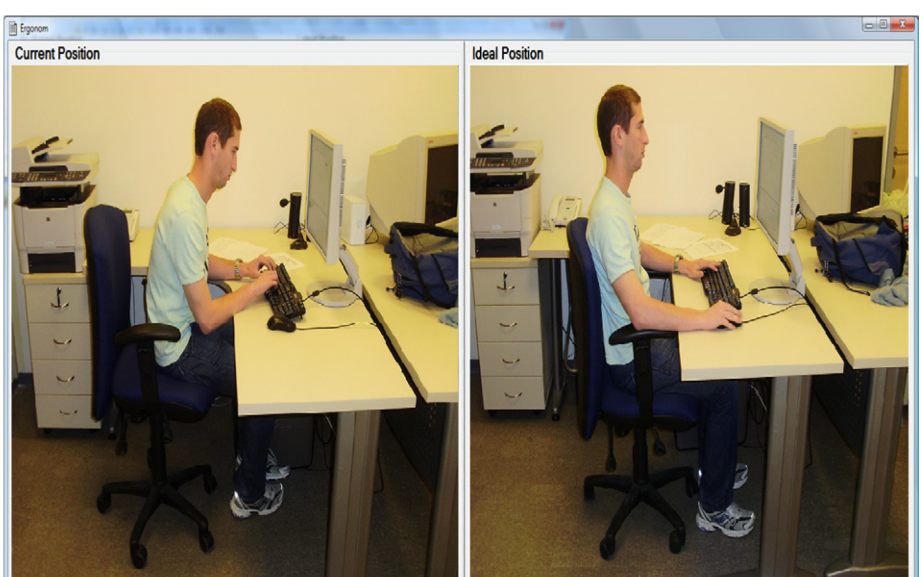


**Fig. 1.** Screen shots of the pop-up screen.

### 2.8. Data preparation

Over the five weeks of data collection (photos were not taken during the fifth week, as previously stated), all 60 participants were photographed during each work day at random intervals ranging from 20 to 25 min apart. Some of the photos were not suitable for analysis for various reasons; i.e., the participant was absent or busy at another activity that did not involve working at a computer (such as answering the phone or dealing with the public) when the photo was taken. Following deletion of photos unsuitable for analysis, 10–14 suitable photos of each work day remained for each participant. Each week comprised five work days; thus, there were at least 50 suitable photos of each participant for each of the five weeks of data collection.

Each photo was analyzed by an ergonomist using the semi-automated measuring-tool, which provided a RULA score. A daily RULA score was calculated for each participant based on the photos that were analyzed for that day. A total of 25 averaged observations were obtained for each participant over the course of the experiment. The first five observations comprised the baseline phase. The following 15 observations were collected during the intervention phase. The final five observations comprised the follow-up phase.

### 2.9. Statistical analyses

A three-way ANOVA with repeated measures analysis was conducted in order to examine the effects of group assignment (Group), day of experiment (Day) and participant's gender (Gender) on the participants' average RULA scores per day. The average daily RULA score was the dependent variable. Day of photo collection was a within-participant independent variable, while Gender and Group were between-participants independent variables. Duncan's Multiple Range Test for homogenous groups was used to test the significance of the differences among RULA scores on the different experiment days, among groups and between genders. We also performed an effect size analysis, using Cohen's $d$ statistic, to quantify the magnitude of the treatment effects that were obtained.

A one-way Anova was conducted to examine whether there was a significant difference between the reported global musculoskeletal pain levels of the three experimental groups before the experiment. The bi-variate relationships among participant's age, reported global musculoskeletal pain level before the experiment and the initial improvement in RULA score were examined using regression analyses. We also performed a regression analysis between the initial improvement in RULA score as a dependent variable and the reported global musculoskeletal pain level before the experiment, while controlling for age.

SPSS version 15 (Author, 2006) was used for all statistical analyses, with significance set at $p < 0.05$.

## 3. Results

### 3.1. Baseline musculoskeletal pain levels

We analyzed the three symptom scales for their correlation with the global pain measure. Back symptoms and arm symptoms showed significant correlations ($r = 0.48$, $p = 0.002$; $r = 0.38$, $p = 0.03$, respectively), while neck severity as a combined measure did not ($r = 0.24$, NS). However, the single item of neck pain severity in the past year approached significance ($r = 0.30$, $p = 0.09$). Due to the fact that there was missing data on some of these items, we preferred to use the global measure as a proxy of arm, back and neck discomfort where we had full data over the experiment.

The results of the one-way Anova showed that there was no significant difference between the reported global musculoskeletal pain levels of the three groups (mean ± SD of 3.13 ± 2.02) before the experiment ($F(2,57) = 0.004$, $p = 0.99$).

### 3.2. Differences among groups and between genders over days of experiment

The three-way ANOVA results showed that the main effects of Group ($F(2,54) = 36.39$, $p < 0.001$) and Day ($F(24,1296) = 19.40$, $p < 0.001$), were significant. The two-way interactions of Group × Day ($F(48,1296) = 12.75$, $p < 0.001$), and Gender × Day ($F(24,1296) = 1.81$, $p < 0.05$) were also significant as was the three-way interaction of Group × Gender × Day ($F(48,1296) = 1.38$, $p < 0.05$). The effects that were not significant were the main effect of Gender ($F(1,54) = 0.04$, $p = 0.84$) and the two-way interaction of Group × Gender ($F(2,54) = 1.58$, $p = 0.21$).

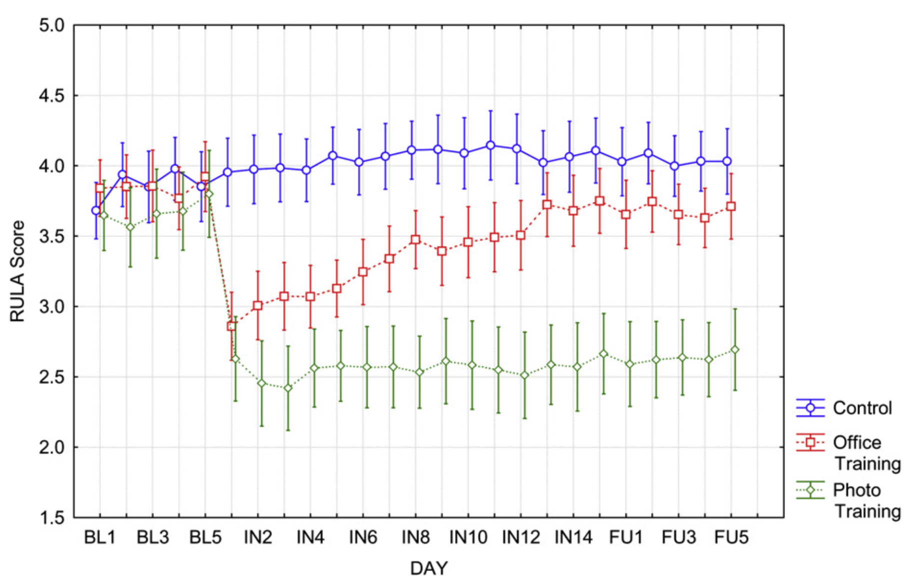


**Fig. 2.** Average daily RULA scores by experimental group over the days of the experiment. The three phases are denoted with abbreviations: BL-Baseline, IN-Intervention, FU-Follow-up. Vertical bars denote 0.95 confidence intervals.

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Fig. 2 shows performance curves for the participants in the three experimental groups. The results demonstrate that during the baseline phase, the RULA scores of all three groups were similar. The control group showed no improvement in RULA scores throughout the experiment. At the beginning of the intervention phase (IN1) the office training group and the photo-training group showed a marked improvement in posture (i.e., a significant reduction in RULA scores). The RULA scores of the photo-training group remained steady throughout the intervention and the follow-up phases, during which the improvement in this group, relative to the baseline, was maintained. The office training group showed a gradual increase in RULA scores (i.e., deterioration of recommended posture) during the intervention phase. By the middle of the third week of the intervention and photo data collection, the RULA scores of the office training group nearly risen back to the level of the baseline phase, approaching those of the control group who received no training.

### *3.2.1. RULA-score differences among groups on different experiment days*

The results of the post-hoc Duncan test showed that the RULA scores of the three groups were not significantly different from each other during the five days of the baseline phase. The RULA scores of the control group did not differ significantly throughout the experiment (mean $\pm$ SD of 4.02 $\pm$ 0.52).

Immediately following training, there was a significant drop in the RULA scores of the two intervention groups relative to the baseline phase, indicating significantly improved posture (see point IN1 in Fig. 2). The average RULA scores of the office training and photo-training groups dropped from an initial mean $\pm$ SD of 3.85 $\pm$ 0.47; 3.70 $\pm$ 0.52 during the baseline phase to mean $\pm$ SD of 2.85 $\pm$ 0.54; 2.50 $\pm$ 0.47, respectively. This drop yielded significant differences between the RULA scores of the photo-training and the office training intervention groups and the control group already on the first day of the intervention. Effect size analyses using Cohen's $d$ statistic indicated large effect sizes for both interventions, relative to the control group at this time point ($d = -1.96$, 95% CI [−2.72, −1.21]; $d = -2.74$, 95% CI [−3.59, −1.87] for the office training and photo-training groups respectively).

For the photo-training group, the significant improvement was maintained throughout the intervention and follow-up phases, during which there were no significant changes in this group's RULA scores. These scores were significantly lower than those of the control group throughout the intervention and the follow-up phases. Cohen's $d$ statistic that was calculated to evaluate the magnitude of the effect size of the photo-training intervention group relative to the control group at the mid-point of the follow-up phase indicated a large effect size ($d = -2.94$, 95% CI [−3.85, −2.05]).

By contrast, with the office training group there was a gradual increase (deterioration in posture) in RULA scores during the intervention phase. The RULA scores of the office training group were significantly lower than those of the control group during days 1–12 of the intervention phase (IN1–IN12). Fig. 2 shows that the differences in RULA scores between these two experimental groups decreased over time so that by day 13 of the intervention phase (IN13) there was no longer a significant difference between them. This lack of difference was carried over into the follow-up phase, yielding a medium effect size at the mid-point of the follow-up phase according to Cohen's convention ($d = -0.52$, 95% CI [−1.15, −0.11]).

Comparison between the photo-training group and the office training group during these phases revealed that on the first day (IN1) of the intervention phase (immediately following instruction) there were no significant differences in the average RULA scores of the two intervention groups. However, starting on the second day of the intervention-phase (IN2) and continuing over the course of the experiment, there was an increasing statistically significant difference between the RULA scores of these two groups as the photo-training group continued to maintain lower RULA scores.

### *3.2.2. RULA score – gender differences*

Fig. 3 presents average RULA scores of men and women (Gender) as a function of experimental group and day of experiment. Duncan's Multiple Range Test for homogenous groups showed no significant differences in the RULA scores during the five-day baseline phase of the experiment; not within groups of men and women (between experimental groups) and not within each experimental group (between these two gender groups). The control group participants,

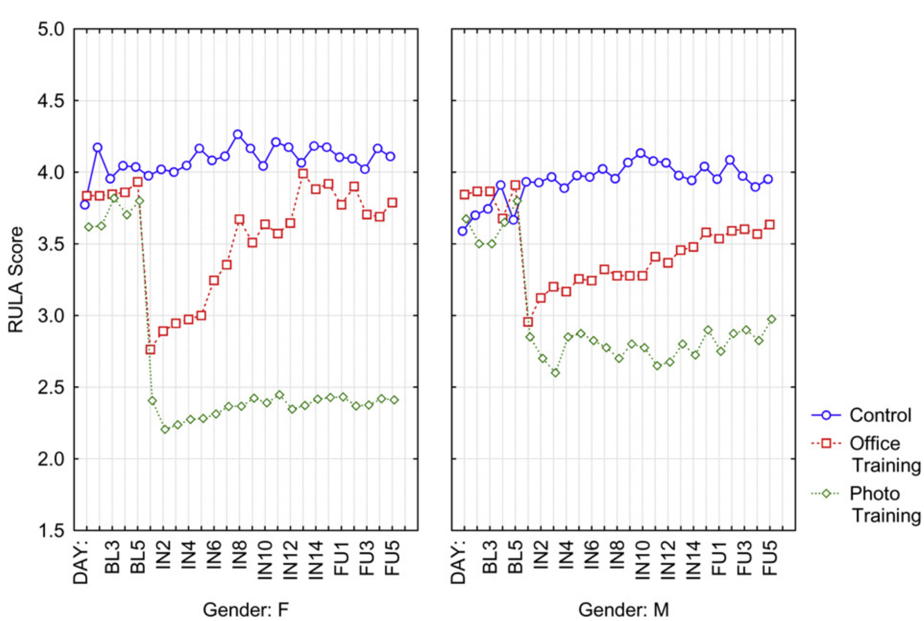


**Fig. 3.** RULA scores by gender, experimental group and day of experiment.

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both women and men, maintained stable RULA scores, similar to the baseline scores, throughout all phases of the experiment.

The photo-training groups – both men and women – showed significant improvement in RULA scores after training, relative to the baseline phase. This improvement was maintained throughout the remainder of the experiment. However, a *t*-test showed that the improvement (the difference between the average RULA scores of the baseline phase and the average RULA scores of the first five days (IN1–IN5) of the intervention phase), was significantly larger ($t(18) = 2.31$, $p = 0.03$, Cohen's $d = 1.1$, 95% CI [0.11, 2.06]) among women (an average decrease of 1.43) than among men (an average decrease of 0.85). This difference in effect between men and women is considered large according to Cohen's convention.

The office training group showed a significant improvement in average RULA scores during the first five days (IN1–IN5) of the intervention phase, relative to the baseline phase. This improvement did not differ significantly between men and women ($t(18) = 1.51$, $p = 0.15$). The office training group showed an increase in RULA scores among both genders during the intervention phase. However, this increase was earlier and sharper among women than among men. Already by the eighth day (IN8) of the intervention phase, the average RULA scores of the women, became significantly different from the RULA scores during the first five days (IN1–IN5) of the intervention phase, and were no longer significantly different from either the baseline RULA scores or from the control-group RULA scores. It was only on day 13 (IN13) that the RULA scores for the men in the office training group increased to the point that they were no longer significantly different from both the RULA scores of the baseline phase and the RULA scores of the control group.

Comparing the women in the office training group with women in the photo-training group shows that there were differences in RULA scores between the two intervention groups (significantly lower RULA scores among the photo-training group) already by the second day of the intervention phase (IN2) – a difference that grew larger over time. Among men, however, there was no difference in RULA scores between the two intervention groups during the first days of the intervention phase. Only on day 11 did the scores reached a statistically significant difference (due to the gradual deterioration among the office training group).

### 3.3. *Relationships between worker's age, reported musculoskeletal pain level and the improvement in RULA score*

We examined the relationship between participant's age, reported global musculoskeletal pain level before the experiment and the initial improvement in RULA score, within each intervention group, using regression analyses. The initial improvement was defined as the difference between the average RULA scores of the baseline phase and the average RULA scores of the first five days (IN1–IN5) of the intervention phase within each group, during which the RULA scores were stable.

The correlations between participant's age and reported musculoskeletal pain level were positive and significant for the whole sample ($r = 0.48$, $p < 0.0001$) and within each intervention group ($r = 0.56$, $p = 0.01$; $r = 0.46$, $p = 0.04$ for the office training and photo-training groups, respectively). This indicates that older workers reported higher musculoskeletal pain levels.

Significant positive correlation was also found between participant's age and the improvement in RULA score within each intervention group ($r = 0.48$, $p = 0.03$; $r = 0.50$, $p = 0.02$ for office training and photo-training group, respectively), showing that older workers tended to have a greater improvement in their sitting posture after the intervention.

There were also significant positive correlations between reported musculoskeletal pain level and the improvement in RULA score for both intervention groups ($r = 0.63$, $p = 0.03$; $r = 0.66$, $p = 0.002$ for office training and photo-training group, respectively).

When controlling for age in the regression, workers suffering from more musculoskeletal pain levels still showed greater improvement in their sitting posture after the intervention than those suffering from less pain levels (partial $r = 0.49$, $p = 0.03$; partial $r = 0.55$, $p = 0.01$ for office training and photo-training group, respectively).

## 4. Discussion

This research evaluated the effectiveness of a specially-designed self-modeling photo-training method on improving the posture of computer users in the workplace in order to prevent work-related MSD. This method was evaluated using comparisons between this new method, conventional office ergonomic training and a control group who did not receive any intervention. To the best of our knowledge, this is the first workplace trial to test the utility of self-modeling photos taken over time to illustrate the acquisition of knowledge regarding recommended work-posture at a computer. While photographs have been used to evaluate work-related posture (e.g., Pillastrini et al., 2010), this is the first trial we are aware of that the photographs that recorded changes in posture over time were actually an integral part of the intervention. The innovation in this method is that the worker will more readily adopt the correct sitting posture when viewing his/her own correct posture using his personal kinesthetic memory and when comparing the physical feeling and appearance of current posture to the recommended correct posture.

Our findings suggest that this self-modeling photo-training method has distinct advantages over the conventional office ergonomic training (e.g., Robertson et al., 2009). The traditional office ergonomic training does have positive and immediate effects on work-related posture. However, this type of intervention was not successful in bringing about a lasting change in work-posture and eroded over the period of the intervention, reaching the level of the baseline assessment by the end of the intervention phase. In addition, the photographs revealed that some of the participants in the traditional office training reorganized their workstation after the training and returned it to its original pre-intervention state. This degeneration of the practical intervention did not occur in the photo-training group.

These results regarding the minimal effectiveness of ergonomic instruction over time are congruent with findings of Walsh and Schwartz (1990) in a study of male warehouse workers who received a 1-h educational training program to teach appropriate lifting techniques compared with a group who received both education and lumbosacral corsets. The educational only group did not show any decrease in absenteeism over six months compared to the control group despite improvements in back strain knowledge immediately following the training. Moreover, the combined intervention group did not show any significant treatment effect over time in parameters such as abdominal strength, productivity and work accident incidence although there was a decrease in absenteeism. Similar results were shown by Daltroy et al. (1993) who found that while education increased knowledge levels, this was not translated into behavioral changes in posture in a large randomized controlled trial of postal workers who attended "back school". A long-term follow up of 5.5 years showed that there was no decrease in low back or related musculoskeletal injuries or rate of absenteeism (Daltroy et al., 1997).

By contrast, Robertson et al. (2009) who used ergonomic training with chair adjustment to address musculoskeletal risk found that the effects of the training were retained over a period of months. This training lasted 90 min and included practice sessions,

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performance feedback, group discussions and problem-solving. However, these interventions were bolstered by e-mail feedback messages at one and three months post-intervention on the results of their acquired knowledge and evaluations of observed behaviors and suggestions for healthy computing habits. The results of Pillastrini et al. (2010) showed retention of positive ergonomic changes after 30 months of follow-up. This intervention consisted of an ergonomic adjustment to the workstation and evaluation by a physiotherapist while performing computer tasks (30 min). However, these changes were reinforced by on-going consultation with the physiotherapist for 5–10 min twice a month during the study period. The findings of both of these recent studies strongly suggests that in order to maintain the desired change in work-related posture over time, there is a need for on-going reminders and cues in order to maintain the behavior change. Furthermore, the greater exposure to more comprehensive and extensive training, particularly when coupled with workstation adjustments, also suggests that this helps to retain positive work-related posture learning.

Photo-training in our study was effective and brought about a clear and immediate improvement in the sitting posture of the workers; an improvement that was maintained over time. Immediately following training there was a definite improvement in the sitting position of the subjects in the photo-trained group. On the first day that photographic feedback was provided, there was an equivalence of sitting-posture risk among the members of the two groups – those who were conventionally trained and those who were photo-trained. On that day the subjects of both groups knew how to sit correctly, after their personal understanding was confirmed by the research team, meaning that, on that day, their sitting postures were optimal for them. However, over the next few days the RULA scores among the office training group began to increase, until the subjects in this group reached the same level of risk as during the baseline phase and very similar to the subjects in the control group, who had not undergone any training at all. By comparison, the subjects in the photo-training group maintained their improved RULA scores throughout the rest of the experiment.

An important issue in this context, then, is whether correct posture principles were truly internalized by the photo-training group. One might argue that the mere reminder given the subjects using photographic feedback was what contributed to maintaining their improved postures. It should be noted that the research team visited the subjects' work stations frequently to ensure that the experiment was proceeding properly. The presence of the cameras and visitors were themselves reminders of the experiment and its purpose for all of the groups. Moreover, it should be emphasized that the effectiveness of the method was retained even during the follow-up phase; i.e., following a period of time during which there was no photographic feedback. This fact supports the conclusion that the habit of sitting correctly had been internalized. It may be concluded that employing this training method for reducing the risk of MSD associated with sitting in front of a computer is preferable to using the conventional training method exclusively.

The photo-training method was more effective among women than among men. During the first days after training, the RULA scores significantly decreased among both men and women, relative to the baseline scores among both the office training group and the photo-training groups. However, while the office training group showed an initial improvement in the RULA scores that was similar for men and women, the average improvement in the RULA scores in the photo-training group during the intervention phase was significantly greater among the women than among the men. This may be due to women responding differently when they know they are being photographed, a response that was reflected by a sharper improvement in their sitting posture at first. Moreover, the women tended to quickly forget their office training when their photos were not displayed, as sitting posture deterioration was more significant and took place faster among the women in the conventionally trained group than among the men in this group.

The different response of women to the displaying of their photos is consistent with the objectification theory which stresses that women exhibit a physical or mental reaction to being watched (Fredrickson and Roberts, 1997; Hill, 2010). Among men, however, extreme fluctuations deviating far from the overall experimental results were not observed. Therefore, we can conclude that there is a difference in response to training with photos between the two genders, and that the impact of this intervention is greater among women than among men.

The results of the experiment indicated a significant positive correlation between age of subject and degree of improvement in sitting posture, no matter which intervention was used (office training or office training combined with pop-up photos). According to this finding, the use of any ergonomic intervention helped middle-aged adults improve their sitting posture more significantly than it helped younger adults. This phenomenon can be explained by the greater musculoskeletal problems adults suffer, due to prolonged exposure to long-term cumulative risk factors; thus, their level of motivation to improve their sitting posture is higher. This conclusion is supported by findings of a significantly positive correlation between the severity of the complaints of musculoskeletal pain and the degree of improvement in sitting posture that resulted from carrying out any intervention. Even young workers with prior complaints were more motivated to participate in the study and showed greater improvements following the interventions in their posture than young people without complaints. It should be recalled that there is a relatively high rate of reported MSS among groups of young people who work predominantly at a computer workstation (e.g., Jamjumrus and Nanthavanij, 2008; Menendez et al., 2009).

In light of all the above, conventional training (training and ergonomic changes in the work environment) are effective for the short term. To sustain the effectiveness of ergonomic intervention over time, the intervention should be a long-term process accompanied by frequent feedback. One possible method, very efficient in terms of cost-and-effect, is the photo-training method we examined in this study. Feedback through self-modeling (self demonstration of the habits the learner desires to gain) was shown to be effective. This method was found to be best at improving working posture, for both genders, with greater efficiency among women. For further study, a possible improvement in the interface could be examined so that the degree of disturbance of the pop-up photos during the regular course of the employee's work could be minimized. For example, the option of reducing the frequency of feedback, once the desired habits have been internalized, could be explored. In addition, different types of feedback could be tested, such as more detailed feedback that called attention to deviations from the desired pose for each of the body segments.

### *4.1. Study limitations*

While this experiment followed the participants for two weeks after the intervention, it would be worthwhile conducting a longer term follow-up to test whether the intervention had long-term effects on posture and risk of musculoskeletal symptoms. In future studies, it would be advisable to have the ergonomist blinded to the intervention group. Our research group did not have the resources to hire additional staff members and thus we were unable to "blind" the ergonomists to the study allocation of participants. Nevertheless, we believe that this bias had at most a negligible effect on the results since the ergonomists were not a part of the research team,

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but were hired for the purpose of evaluating the RULA scores. Furthermore, they used semi-automated software to compute the RULA score and in cases of disagreement discussed their procedures until they achieved a 95% agreement rate for each group.

## 5. Conclusions

In this research, we concluded that our new method using self-modeling webcam photos is effective for improving sitting posture of workers at computer work stations. It performed better than the traditional training method, since the improvement in the sitting posture when using this method sustained over time. The training using photos is more effective among women than men. The effect of the ergonomic interventions in this research was more significant for older computer workers than younger ones and for workers suffering more musculoskeletal pain than those suffering from less pain.

In order to maintain the effectiveness of an ergonomic intervention for the long term, the intervention should be a continuous process, which includes frequent feedback. The method of frequent and continuous feedback using photos was found to be effective in improving the sitting posture of computer workers over time. These conclusions have direct implications for many workers in industry and services. It is recommended that such self-modeling photo-training software would be installed on the workers computer, to provide a frequent and long-term feedback. This should be implemented in addition to the conventional office ergonomic intervention which combines specialized ergonomic training and workstation adjustments. We believe this new ergonomic method can also result in preventing MSD among workers and reduce financial loss to their employers.

In light of the differences in effect between men and women, combining supplementary feedback targeted to different audiences should be considered. For example, it is recommended to consider adding a more detailed feedback that called attention to deviations from the desired pose for each of the body segments, and evaluate its deferential effect on both genders and over the longer term.

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