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Can biofeedback training in combination with ergonomic information reduce pain among young adult computer users with neck and upper extremity symptoms? - A randomized controlled intervention study

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ABSTRACT

The aim of this randomized controlled study was to explore if an intervention with biofeedback training in combination with ergonomic discussions, could improve working technique and work postures, and reduce pain intensity and perceived exertion in young adult computer users with ongoing neck and upper extremity symptoms.

39 participants were divided into an intervention group and a control group. The intervention consisted of 4 sessions during a three-month period. Working technique, working postures, rated perceived exertion, pain intensity, and duration of computer use were measured at baseline and follow ups after 6 and 12 months.

The intervention did not significantly improve working technique and working postures, nor reduce pain intensity and perceived exertion in the intervention group compared to the control group. However, there was a statistically significant reduction in reported pain intensity in the neck/shoulder for the whole group. Also, there was a trend that time spent with computer work without breaks was more reduced in the intervention group than in the control group.

1. Introduction

Computers in form of laptops, stationary computers, and smart phones are today indispensable tools of communication all over the world. The use of ICT (information and communication technology) has become included in modern lifestyle, especially among young people and many young adults spend considerable time in front of computers both at school and in leisure time (Gustafsson et al., 2017; Statistics Sweden, 2022; Eurostat, 2022). Several studies have shown relationships between computer use and development of musculoskeletal disorders.

It is well established that prolonged time spent with computer use without natural breaks, intensive computer mouse use per se, and non-optimal working postures especially in the neck and upper extremities are risk factors for developing musculoskeletal disorders from the neck and upper extremities connected to this use (Tornqvist et al., 2009; Waersted et al., 2010; Andersen et al., 2011; Rodrigues et al., 2017).

Furthermore, one study performed on workers exposed to extensive computer work (the editorial department of a newspaper) has shown an association between poor working technique and increased muscular load (Lindegard et al., 2003). Another study with young mobile phone users found that poor working technique was more common in the group with musculoskeletal symptoms compared with the group without symptoms (Gustafsson et al., 2011). In concordance, work style has been found to predict future pain and functional limitations in office workers with neck and upper extremity symptoms (Nicholas et al., 2005).

Finally, earlier studies have revealed associations between perceived muscle tension and/or perceived exertion and the risk of developing neck and upper extremity symptoms (Wahlstrom et al., 2004; Lindegard et al., 2012).

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Many intervention studies have been conducted to decrease the prevalence of musculoskeletal disorders connected to computer use. A review of intervention studies among computer users from 2011 found no effective interventions in the included studies (Andersen et al., 2011). However, later intervention studies have found reduced pain in the neck and upper extremities after individual adjustments in the workplaces (Frutiger and Borotkanics, 2021; Lee et al., 2021).

Biofeedback training has been used for many years in clinical practice to reduce muscular load, improve working technique and reduce muscular pain among workers with repetitive work tasks and has been shown to be effective to reduce muscle activity in different conditions and tasks (Madeleine et al., 2006; Voerman et al., 2006, 2007). The training involves feedback of the muscle activity in real time through sound or light signals or by accelerometers measuring for example upper arm posture which gives feedback when you pass certain posture intervals. However, the result of such biofeedback training is inconclusive. One study on female computer workers found reduced pain intensity and disability after a combination of myofeedback training and ergonomic counselling at a 6-month follow up (Voerman et al., 2007) but no unique contribution for myofeedback training, while another,study, in contrast showed reduced muscle activity and increased rest time in the trapezius muscle with biofeedback training during computer work (Holtermann et al., 2008).

Nearly all the above studies have been performed on adults with working experiences. A young population, without prior experiences from working life, are likely to perform computer work and other computer related tasks in a different manner with respect to working technique and working postures compared to older and more experienced workers.

To our knowledge, no ergonomic interventions have until now focused on a combination of biofeedback training and ergonomic discussions, to prevent the development of work-related neck and upper extremity symptoms/disorders among unexperienced young adults.

The underlaying hypothesis for doing this study was that a combination of individually tailored ergonomic discussions and biofeedback-training might be effective to raise an awareness of the impact of working technique and working postures on muscular load caused by a certain working posture or working technique.

Thus, the overall aim of this study was to explore if an intervention with biofeedback training in combination with ergonomic discussions, could improve working technique and work postures, and moreover, reduce pain intensity and perceived exertion in young adult computer users with ongoing neck and upper extremity symptoms.

2. Subjects and methods

2.1. Subjects

The study population was based on a cohort of young ICT users recruited from medical and computer-related educations at colleges and universities in the southwest part of Sweden. A web-based questionnaire concerning use of ICT (Information Communication Technology), different exposures in connection with ICT, musculoskeletal symptoms, and psychosocial factors were answered among 3531 young students aged 18–24 years. The study group in the present study consisted of a subgroup of 45 subjects from the cohort study who reported ongoing symptoms from the neck, shoulder, or upper extremities in the last 7 days which they connected to computer use. They reported an average level of computer use of 3.5 h/day.

2.2. Study design

Approximately two weeks prior to the baseline data collection, the subjects were interviewed over the phone to ascertain they still had ongoing symptoms in the neck, shoulder, or upper extremities and "willing" to participate in the present intervention study.

All subjects who volunteered were invited to a clinical examination by an occupational physician following a pre-defined protocol (Hagberg et al., 2007). The examination aimed to identify subjects suffering from systematic disorders affecting the musculoskeletal system (e.g., rheumatoid arthritis). Three subjects were excluded based on the clinical examination due to other disorders that might interfere with or lead to symptoms from the musculoskeletal system and another three subjects denied further participation due to lack of time.

The remaining 39 subjects were then randomized, women and men separately, into two groups. One intervention group with 20 subjects (11 women and 9 men, 22–27 years; Md 24 y) and one control group with 19 subjects (10 women and 9 men, 20–26 years; Md 23 y).

Within seven days after the clinical examination each subject performed a standardized writing and editing task on a computer in a lab environment using both the keyboard and the computer mouse for 15 min while working technique, work postures, and perceived exertion were measured. The subjects were instructed to sit in front of the computer using the same positions and working techniques that matched how they sat in front of their computers in real life. The chair used had a backrest, and armrests and no wheels.

Follow ups were made 6 and 12 months after the baseline data collection described above with the same data collection protocol. In some cases, the time frame between the two follow ups was extended (usually not more than 1–2 month) due to circumstances like vacations, lack of time and an arduous studying situation for the subjects.

2.3. Measurement methods

2.3.1. Measuring of working technique

Working technique, defined as the way the participants performed a certain work task with respect to physical factors like use of forearm support, moving the computer mouse with arm or hand movements etc., was observed and evaluated by an experienced ergonomist (who was not the interventionist) according to an observation protocol. A sum score for working technique was calculated comprising 9 of the evaluated items (forearm support when using the keyboard, forearm support when using the computer mouse, sitting in a tense position, frequent lifting of the computer mouse, fast or jerky movements with the computer mouse, range of movement using the computer mouse, type of arm/hand movements used when operating the computer mouse and elevation of the shoulders during keyboard work and computer mouse work). This protocol for observations of working technique is frequently used by ergonomists in occupational health organizations. The total score ranged from 1 to 25 (the higher the score the better the working technique). A more detailed description and evaluation of the method has been published previously (Lindegard et al., 2003). Hence, the method was found to be useful and valid for the purpose of observing working technique during computer use both in clinical practice and in reaserch.

2.3.2. Measuring of working postures

Working postures, as angles (degrees) from neutral position, were measured according to Greene and Heckman (1994) in the shoulder (abduction) and wrist (extension and ulnar deviation) on the mouse operating side with a plastic 31 cm manual goniometer (Brodin; Medema Physio AB, Solna, Sweden) while performing the standardized computer task. The neck flexion was measured as the angle between ear and C7 and the vertical line through C7.

2.3.3. Rated perceived exertion

Ratings of perceived exertion were performed with Borg CR-10 scale (Borg, 1990) in 11 different body regions immediate before and after the end of the standardized computer task. The difference between the rated perceived exertion before and after the standardized computer task was calculated for every rated body area.

A score of perceived exertion was calculated for 3 different body areas. For the neck/scapular area a score comprising exertion in the neck and the scapular area on both sides were calculated. For the shoulder area, perceived exertion from the right and left shoulders were calculated, and for the arm/hand/fingers a score comprising ratings from the forearm, wrist and fingers on both sides were calculated.

2.3.4. Pain intensity

Pain intensity for the body areas neck/shoulder and arms/hands/fingers was measured at the medical examination by an instrument developed by Von Korff et al. (Von Korff et al., 1992). The subjects rated their mean pain intensity during the last month on a 0–10 pain scale where 0 represented no pain at all and 10 represented worst possible pain.

2.3.5. Duration of computer use and changes in working technique

Data regarding duration of computer use were obtained through a diary where the subjects wrote down the duration of computer use for each day for one week. If one of these days contained computer use for more than 4 h without a break the subject was considered as exposed.

Data concerning made changes regarding working technique and workplace layout due to symptoms/pain were obtained by interviews.

2.4. Intervention

The intervention was conducted by an experienced ergonomist and consisted of four different individual sessions during a three-month period with approximately one month between each session. Every session consisted of an equal amount of information, discussions, and training. The first session lasted1.5 h due to additional information about the aims of the intervention, primarily to improve the motivation of the subjects and furthermore to introduce the biofeedback technique while the last three sessions lasted for 1 h. Every session contained a discussion concerning workplace layout, working postures, and working technique at school/work and at home. Moreover, a discussion concerning behavior patterns i.e., total time spent with computers, break patterns, and the benefits of variation in exposure were initiated during each session. The discussions were structured according to a manual.

A SEMG (surface electromyography) biofeedback equipment (Myo-Trac 60 Hz - Home Trainer 1 Channel sEMG - T4000P, Thought Technology Ltd) was used during the intervention sessions. Electrodes were applied on the wrist extensors (extensor digitorum on the dominant side), and on the pars descendens of both trapezius muscles. The subject than performed a standardized editing task using both the keyboard and the computer mouse. Both the subject's own working technique and other working techniques proposed by the interventionist were used. The subjects got feedback in real time through a sound signal and the frequency of the sound signal increased when the muscular activity increased, and the frequency decreased when the muscle activity decreased. The feedback pattern was monitored by the interventionist by a light signal indicating increased (red light) or decreased muscle activity (green light). Working postures and working technique were discussed and the most preferable working positions and different aspects concerning working technique e.g., forearm support, degree of neck flexion and wrist extension, and actions to reduce muscular load was discussed and tested with the biofeedback equipment. The intervention also included a personal goal-document for each subject where both the overall aim and intermediate aims with the training sessions were specified. At the next sessions, these aims were discussed concerning whether they had been able to reach the previously formulated goals or not.

2.5. Data analysis and statistics

Differences between control and intervention group at baseline concerning working technique were analyzed in JMP version 5.0 using Wilcoxon/Kruskal Wallis test and repeated measurements over time were analyzed in SPSS version13.0 using Sign Test.

Descriptive data at baseline concerning perceived exertion were presented by mean values and standard deviations (Sd). Differences between groups at baseline were tested using *t*-test, p-values and 95% confidence intervals (CI) were presented.

When analyzing changes over time a mixed effects linear regression model (software program SAS version 9.0) proposed for analyzing repeated measurements were used. In the model the outcome was the perceived exertion after performing the standardized computer task. Explanatory variables included in the model were group (control, intervention), time (baseline, 6 month and 12 month) and the interaction between group and time.

Working postures at baseline were presented as mean values with standard deviations (Sd) and differences at baseline were analyzed using *t*-test with 95% (CI). In each of the groups changes over time are presented as mean values of the differences (baseline-6 month and baseline −12 month). These differences were analyzed using pare wise t-tests.

Results concerning pain intensity were analyzed in JMP version 5 using Wilcoxon/Kruskal Wallis test and repeated measurements were analyzed in SPSS using Sign Test.

Finally, data regarding self-made changes in workplace layout, working technique and duration of computer use were analyzed in JMP version 5 using Fisher's exact test with a significance level set to $p = 0.05$.

3. Results

3.1. Working technique

No major differences were seen between the two groups at baseline regarding working technique though the variation within the group was greater in the intervention group than in the control group (Fig. 1). Median value 14 (range 5–18) for the control group and 13 (range 5–20) for the intervention group. Control group 25th percentile = 11, 75th percentile = 16. Intervention group 25th percentile = 7, 75th percentile = 17.

No significant changes in working technique could be detected neither at the 6 month nor the 12-month follow-up in either of the two groups ($p = 0.8$–1.0) (Table 1). Moreover, there were no significant difference between the two groups neither at the 6 month follow up nor at the 12 month follow up ($p = 0.23$ and $p = 0.26$).

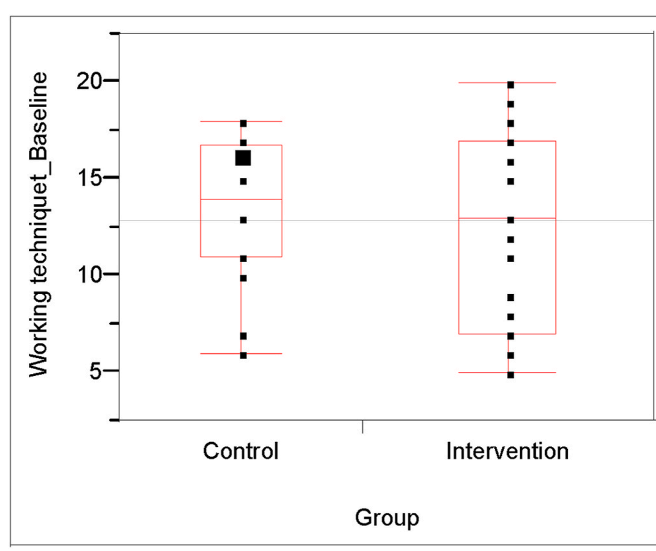

Fig. 1. Differences between the two groups regarding working technique at baseline. Median, range (min, max) and 25th- 75th percentile is presented. The bigger "square" for the control group indicate an accumulation of data at a specific value.

Table 1
Changes in working technique score for the control group and the intervention group respectively from baseline to the 6-month follow up and from baseline to the 12-month follow up.

Working technique	Control		Intervention	
	n	%	n	%
Baseline - 6-month *follow up*				
Improved	8	44	7	39
Unchanged	2	11	2	11
Impaired	8	44	9	50
Baseline - 12-month *follow up*				
Improved	7	41	6	38
Unchanged	3	18	2	13
Impaired	7	41	8	50

3.2. Working postures

No differences in working postures were found between the two groups at baseline (Table 2).

No differences were found between the groups at either the 6 month follow up or the 12 month follow up for any of the measured angles (neck flexion $p = 0.47$ and $p = 0.46$, shoulder abduction $p = 0.34$ and $p = 0.99$, wrist extension $p = 0.55$ and $p = 0.74$, wrist ulnar deviation $p = 0.65$ and $p = 0.39$ respectively). Differences over time were small in both groups (Table 3).

A decrease in measured angles was found for shoulder abduction, wrist extension, and ulnar deviation in both groups at both follow-ups. However, there was an increase in neck flexion for the control group at both follow-ups and for the intervention group only at the 6-month follow up.

3.3. Perceived exertion

There were no differences in perceived exertion between the groups at baseline in any of the body regions explored (Table 4).

There were significant differences regarding influence of time and interaction between intervention and time on perceived exertion in the neck and scapular area (Table 5). There is a decrease in perceived exertion over time in both groups. Between baseline and the 6-month follow up, the rated perceived exertion for the intervention group decreased more than for the control group, but the rating of perceived exertion in the intervention group increased between the 6-month follow up and the 12-month follow up while the rated perceived exertion for the controls continued to decrease (Fig. 2). The same patterns were present regarding perceived exertion in the shoulders and in the arm/hand/fingers.

Table 2
Working postures as angles (degrees) from neutral position for the control group and the intervention group respectively at baseline. Mean and standard deviation (Sd) for each group and differences, and p-values (p) and 95% confidence intervals (95% CI) for the differences are given.

Working posture	Control n = 19	Intervention n = 20	Differences		
	Mean (Sd)	Mean (Sd)	Diff	p	95% CI
Neck flexion	15.5 (7.2)	16.5 (7.0)	1.0	0.67	−5.62-3.67
Shoulder abduction	25.2 (3.0)	25.7 (2.9)	0.5	0.71	−6.95-10.01
Wrist extension	21.0 (1.6)	22.8 (1.7)	1.8	0.44	−6.57-2.94
Ulnar deviation	11.1 (1.8)	9.3 (1.9)	−1.8	0.49	−3.55-7.24

Diff = difference.

3.4. Pain intensity

The ratings of pain intensity in the neck/shoulder area at baseline (average pain during the preceding month) were low in both groups and there was no statistically significant difference between the groups ($p = 0.84$) (Fig. 3).

Within the intervention group there were no statistically significant effect of the intervention on pain intensity in the neck/shoulder neither between baseline and 6-month follow up ($p = 0.34$) nor between baseline and 12-month follow up ($p = 0.14$) (Table 6).

Regarding pain intensity in the arm/hand/fingers the same pattern was present, no major differences were seen between the groups at baseline ($p = 0.25$) and both groups rated low intensity of the pain both at baseline and at the follow-ups. Within the intervention group no statistically significant effects of the intervention in arm/hand and finger pain intensity could be detected although a small trend towards a gradual decrease in pain was noticeable (baseline-6-month $p = 0.11$; baseline-12-month $p = 0.07$).

For the whole study group (both the intervention group and the controls) there was a statistically significant reduction in reported pain intensity between baseline and the 12 month follow up regarding neck and shoulder pain intensity ($p = 0.001$) but not in arm/hand/finger pain intensity ($p = 0.31$).

3.5. Duration of computer use without breaks

At baseline no statistically significant differences could be detected between the groups ($p = 0.55$). In the intervention group, 50% of the subjects used the computer for more than 4 h without a break at least once a week compared to the control group where 47% reported the same exposure. At the 6 month follow up 24% of the subjects in the intervention group were exposed compared to 47% in the control group ($p = 0.16$). At the 12 month follow up the difference between the groups had increased further and 14% of the subjects in the intervention group compared to 44% in the control group were exposed to computer use more than 4 h without breaks ($p = 0.06$) (Table 7).

3.6. Self-reported changes in workplace layout and working technique

Changes regarding workplace layout and working technique to reduce symptoms/pain have been made in both groups but there were no statistically significant differences between the groups neither at baseline nor at the follow-ups (Table 8).

4. Discussion

This randomized controlled intervention study on young adult computer users with neck and upper extremity symptoms aimed to explore the influence of an intervention with biofeedback training in combination with ergonomic discussions on working technique, work postures, pain intensity, and perceived exertion found no statistically significant differences between the intervention group and the control group at follow-ups. Earlier studies (Voerman et al., 2007; Van Eerd et al., 2016) on adult computer workers, have found no benefit for biofeedback-training in interventions aimed to prevent musculoskeletal symptoms. The present study found that a combination of biofeedback-training and semi-structured ergonomic discussions did not contribute to a decrease in perceived exertion and pain.

However, this study found a trend that the intervention group decreased their duration of computer time without breaks over time more compared to the control group (p 0.06). The importance of breaks for prevention or decreasing neck and upper extremity symptoms among office workers have been studied before. A systematic review from 2018 found very low-quality evidence for supplementary breaks and perceived discomfort in preventing musculoskeletal disorders in the neck and upper limb (Hoe et al., 2018). However, a randomized

Table 3
Differences in working postures (angles in degrees from neutral position) at 6-month follow up and 12-month follow up compared to baseline (0) measurements for the control group and the intervention group respectively. Differences in degrees and p-values for the differences are given.

Working posture	Control				Intervention			
	0–6 month n = 15		0–12 month n = 18		0–6 month n = 18		0–12 month n = 16	
	Diff	p	Diff	p	Diff	p	Diff	p
Neck flexion	6.2	0.004	6.2	0.03	4.2	0.05	3.1	0.32
Shoulder abduction	−7.5	0.04	−3.0	0.58	−2.0	0.65	−3.1	0.48
Wrist extension	−5.2	0.02	−4.5	0.05	−3.5	0.08	−3.5	0.11
Ulnardeviation	−2.2	0.27	−1.4	0.61	−3.8	0.24	−5.0	0.09

Diff = difference; p = p-value.

Table 4
Perceived exertion (Borg CR-10 scale) in the different body areas after performing the standardized editing task at baseline in the two groups. Mean and standard deviation (Sd) for each group and p-values (p) and 95% confidence interval (95% CI) of the differences between the groups are given.

	Control n = 19		Intervention n = 20		Differences		
	mean	Sd	mean	Sd	Diff	p	95% CI
Neck/Scapular area	5.9	1.0	5.8	1.0	−0.1	0.93	−2.74-2.98
Shoulders	2.0	0.4	1.9	0.4	−0.1	0.90	−1.19-1.33
Arm/Wrist/hand	8.9	1.8	8.4	1.7	−0.5	0.83	−4.45-5.49

Table 5
Influence of group (control, intervention) and time (baseline, 6-month and 12-month follow-ups) and the interaction between group and time on perceived exertion in the different body areas. P-values from the mixed effects regression models are given.

	Group	Time	Group* time
Neck/scapular area	0.87	0.01	0.03
Shoulder	0.91	0.68	0.53
Arm/wrist/hand	0.72	0.12	0.66

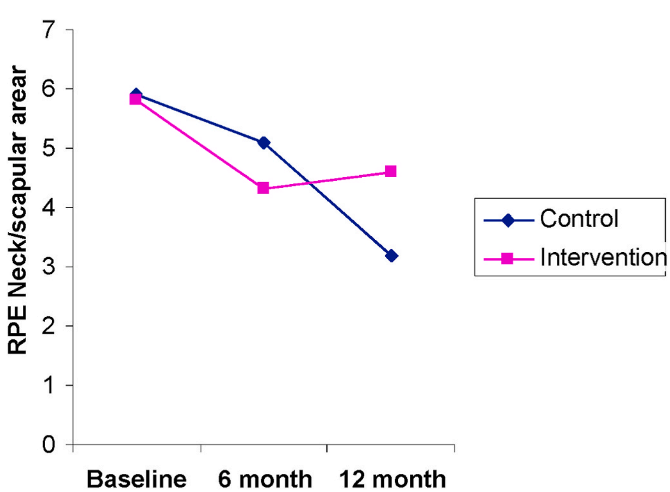

Fig. 2. Changes in rated perceived exertion over time in the neck/shoulder area. Based on the model means from the mixed effects linear regression analysis.
RPE = rated perceived exertion.

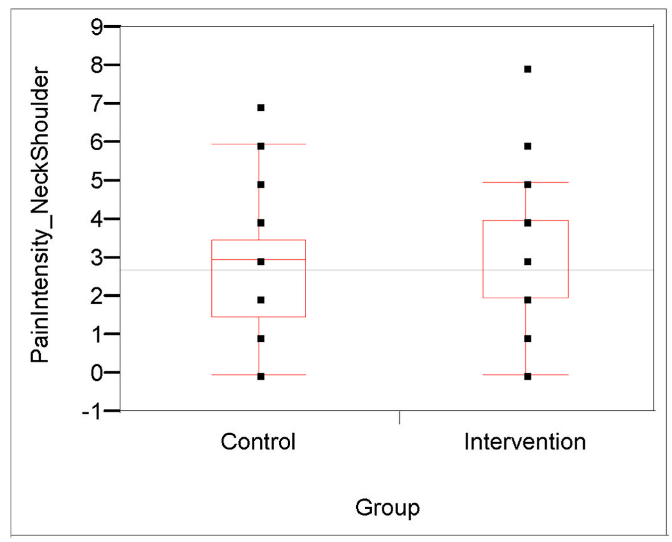

Fig. 3. Rated pain intensity in the neck/shoulder area at baseline for the groups. Median, range (min, max) and 25th-75th percentile are presented.

Table 6
Changes over time in pain intensity in the neck/shoulder and arm/hands/fingers for the control group and the intervention group respectively. Changes are presented as numbers of subjects (n) and percentage (%) of total within the groups.

Pain intensity	Neck/shoulder area				Arm/hand/fingers			
	Control		Intervention		Control		Intervention	
	n	%	n	%	n	%	n	%
Baseline-6 month								
Decreased	9	60	7	38	7	47	11	61
Unchanged	4	27	8	44	4	27	3	17
Increased	2	13	3	16	4	27	4	22
Baseline-12 month								
Decreased	9	64	9	56	7	47	7	47
Unchanged	4	29	4	25	5	33	7	47
Increased	1	7	3	19	3	20	1	7

controlled study from 2021 found that interventions to increase either active breaks or postural shifts reduced new onset of neck pain (Waongenngarm et al., 2021).

A possible explanation to why we were not able to detect any statistically significant differences between the groups might be that both groups were exposed to a great amount of attention in connection to the baseline measurements as well as the follow up measurements, i.e., 3–4 h with technical measurements, clinical examinations, and interviews. Furthermore, both groups were asked to write a diary including exposure data, pain experiences and any changes made concerning workplace layout, working technique, and working postures one week before baseline measurements, and follow ups. It is likely to believe that this was a non-negligible intervention in itself and that it might have

Table 7
Exposure to long duration of computer use without breaks (4 h without breaks at least once a week) at baseline and at 6 and 12-month follow up. Numbers of subjects (n) and percentage (%) of total within the groups, and p-value (p) for the group differences are given.

	Control		Intervention		Difference
	n	%	n	%	p
Baseline					
Exposed	9	47	10	50	0.55
Unexposed	10	53	10	50	
Baseline-6 month					
Exposed	7	47	4	24	0.16
Unexposed	8	53	13	76	
Baseline-12 month					
Exposed	8	44	2	14	0.06
Unexposed	10	56	12	86	

Table 8
Changes made at baseline (last 6 month), between 0 and 6 month and between 0 and 12 month regarding workplace layout and working technique to reduce symptoms/pain. Within groups changes are presented as % of total. P-values of the group differences are presented.

Workplace layout	Control	Intervention	Difference p
Baseline	53%	42%	0.73
0–6 month	38%	50%	0.51
6–12 month	31%	53%	0.29
Working technique			
Baseline	65%	74%	0.72
0–6 month	69%	90%	0.20
6–12 month	69%	80%	0.68

influenced the results to a large extent.

This may explain why changes were seen in both groups over time indicating that an intervention with technical measurements, clinical examinations, writing a diary and interviews, influence perceived exertion, pain, and working postures.

The stage of change model (Haslam, 2002; Oakman et al., 2016) proposed that an individual's readiness for change is likely to improve uptake and success. Writing the diary and participating in the interview together with the clinical examination and the technical measurements may have influenced the results. This randomized controlled intervention study on young computer users with neck and upper extremity symptoms aimed to explore the effect of an intervention found a significantly lower incidence of symptoms in neck, wrist, and hand in the intervention group (Baydur et al., 2016).

The perceived exertion in the neck/scapular area was reduced from baseline to 12-month follow up in both groups. An ecological model for explaining the mechanisms of occurrence of musculoskeletal symptoms has been suggested by Sauter and Swansson (Sauter et al., 1996). This model contains a description of the transition between exposure and symptoms i.e., "an intermediate station" (intermediates). A modified model, specifically targeting computer work has been proposed by Wahlstrom et al. (Wahlstrom, 2005). In this model, biomechanical factors, psychosocial factors, and mental stress, modified by individual factors, was suggested as different early signs preceding more manifest musculoskeletal symptoms.

It has been shown in an earlier study that high perceived exertion in neck, shoulder, arm, and hand was associated with an increased risk of developing neck and upper extremity symptoms (Lindegard et al., 2012). Hence, a reduction in the perceived exertion, as in the present study, may be of importance for the risk of developing neck and upper extremity symptoms.

Also, the rated pain intensity was decreased in the neck/shoulder area in both groups, which can be an effect of the decreased perceived exertion. Hence, the intervention with technical measurements, clinical examination, interview, and diary had an effect both as a prevention to prevent future pain but also an effect on existing pain by reducing the pain intensity. Further studies are necessary to evaluate which intervention or interventions contributed to the effects.

Furthermore, there were changes in working postures in both groups from baseline to follow-ups. A statistically significant decrease in wrist extension was seen in both groups. However, the neck flexion increased in both groups from baseline to follow-ups. We have no explanation for this increase in neck flexion, but a change of about 5° in neck flexion is a small difference from a clinical point of view especially when measured with a manual goniometer. Therefore, the result can be considered as uncertain.

4.1. Strength and limitations

The strength of this study is the RCT-design. However, since we had no control over changes in life situation (e.g., perceived stress, sleep disturbance, and physical activity) among the participants between baseline and follow-ups, this may have affected the results in and between the groups, due to the multifactorial background to the development of musculoskeletal symptoms.

The working postures in neck, shoulders, and wrists were manually measured with a manual goniometer. This causes an uncertainty about the results since there were only small differences in postures. Technical measurements with electro-goniometer could have given a more reliable result.

Another limitation of the study is the self-reported computer time. Monitoring computer time objectively with software installed on computers would have given more reliable results.

5. Conclusion

Biofeedback training in combination with ergonomic discussions did not significantly improve working technique and working postures, nor reduce pain intensity and perceived exertion in the intervention group compared to the control group. However, there was a statistically significant reduction in reported pain intensity in the neck/shoulder for the whole group. Also, there was a trend that time spent with computer work without breaks was more reduced in the intervention group than in the control group.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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