Effects of intermittent stretching exercises at work on musculoskeletal pain associated with the use of a personal computer and the influence of media on outcomes

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Received 31 July 2008
Accepted 7 January 2009

Abstract. Objective: The objective of this study was to evaluate the effects of regular stretching exercises on pain associated with working at a computer workstation, and to ascertain whether the type of media used for exercise instruction had an effect on outcomes.

Participants: Sixty-eight volunteers were divided into three equivalent groups. All of the subjects worked at computers for prolonged periods of time and reported that their pain had been a source of distress for at least three weeks prior to the intake evaluation.

Methods: A pretest-posttest-control group design with cluster randomization was used to evaluate the effect of a stretching program on pain. Thirty-six different stretches were performed by the subjects for 15–17 work days. Two intervention groups were directed to stretch once every six minutes. One group (n = 22) was reminded to stretch via a computer program, the second group (n = 23) by using a hard copy version of the stretches with pictures and written instructions, and a third group received no intervention.

Results: ANOVA analysis found a significant reduction in pain of 72% (p < 0.001) for the computer-generated stretching program, and of 64% (p < 0.001) using the hardcopy version of the intervention. The control group had an increase in pain of 1%.

Conclusions: Both software and hard copy stretching interventions contributed to a decrease in pain without making any changes to workstation ergonomics and there was no significant statistical difference in the outcomes of either intervention. The subjective evaluation of pain using both visual analog scales and a newly created “pain spot” assessment technique yielded similar results.

Keywords: Occupational disease, carpal tunnel syndrome, muscle spasm, computer, assessment, visual analog scale, media

1. Introduction

The association between the use of personal computers and symptoms of musculoskeletal disorders (MSD) has been well established in the current literature under a variety of names [2,7,16,25,30,38,44,47,50]. The National Occupational Research Agenda has identified pain of the upper extremities with associated prevention strategies and intervention effectiveness as priority areas [42].

The risk factors associated with MSD while working at a computer include being seated, repetitive or rapid work, length of time spent at the computer, lack of support for the extremities, non-neutral body positions, inactivity, lack of rest breaks, poor workstation ergonomics, insufficient recovery time, static muscle loading, age, poor physical, mental or social condi-
ations, pressure on blood vessels and nerves, pain-spasm cycles, stress on bone and connective tissues, working without variety in physical movements, and others [4, 17,19,28,44–46].

Specific types of ergonomic interventions were suggested to offset the injury attributed to the personal computer; however, since body types, posture, working habits and personal preferences differed with each individual, the interventions were often found to be ineffective [13,26,29,51]. The literature addressing the component parts of a computer workstation failed to identify workstation and computer hardware as the sole cause or cure of the related MSD [2,8,22,33,34].

Clerical workers and female computer operators were found to have the highest incidence of symptoms caused by static muscular work [6,10,14]. Electromyography (EMG) studies demonstrated that a five-minute break each hour decreased pain in a data entry population, that there was an association between contracted muscles and pain, and that computer users were often unaware of sustained muscle contractions while seated at their workstations. These sustained contractions often extended into the rest periods and may have been the cause of vasoconstriction in the affected muscles [14, 20,28,43].

At 5 and 10 percent of maximal voluntary contraction (MVC) the biceps muscle was found to have an initial decrease in oxygen concentrations that returned to baseline after 6 minutes and demonstrated muscle fatigue after 10 minutes. Other studies found that forearm tissue oxygenation decreased significantly during isometric muscle contraction of as little as 5 percent of the MVC when held for one minute and that decreased tissue oxygenation was associate with an increase in muscle fatigue [12,39,40].

Software programs have been used to compare mini-breaks every 5 minutes, to mini-breaks with exercise every 35 minutes but did not demonstrate an effect on the frequency and severity of complaints from computer users [51]. Other studies have demonstrated that resistance and stretching exercises during the work day yielded a decrease in subjective reports of “discomfort” but no changes in the “pain impact” as measured via a visual analog scale (VAS) [30]. Improvements in pain have been also been noted after weekends away from work, and muscle massage [3,43].

For those using interventions to address symptoms while seated at a computer it may be important to know if the type of media used to teach stretching techniques is key to the outcomes. While the use of media is an integral part of learning in today’s society, professionals often give instructions to clients in a written form. The effects of media on learning have been argued for many years. One side argues that while media may improve motivation, it is only a vehicle, while others point out that media allows for time to learn, reduces errors and can increase retention [5,9,15,18,27,32,41].

In summary, the specific causes of pain in those who use computers were not evident in the literature and are most likely multifactorial. Extended time at a computer was associated with an increase in pain which was likely due to decreases in tissue oxygenation, and regional blood flow. Additionally, no protocol for successfully decreasing the MSD associated with computer use was found [12,14,20,39,43].

2. Procedure

After Institutional Review Board approval was received the study began with three equivalent groups which were identified from a population of convenience. A pretest-posttest-control group design with cluster randomization was performed. Sixty-eight volunteers formed three equivalent groups and were employed by either the university or by one of two federally funded programs which were located on the campus. The university was located in the Appalachian region of the United States. The average age of the subjects was 43 years, ranging from 21 to 62. Eighty-eight percent (60) of the participants were female. All of the subjects worked at computers for prolonged periods of time and reported that their pain had been a source of distress for at least three weeks prior to the intake evaluation.

Thirty-six stretches lasting 10 to 15 seconds each were developed for this study by the researcher, a physical therapist, to address areas of potential muscle spasm which were identified while observing subjects who were working at computers. The stretches targeted muscles of the neck, upper extremities, trunk, lower extremities, eyes and breathing and were presented to the subjects in one of two ways. In the first intervention group (n = 22), a Computer Assisted Stretching Program (CASP) was used. This program was developed by the author for this study to guide the subjects through stretches using a real time audio and video display on the computer screen. If the subject was working on a document, only the verbal instructions were heard and the video remained hidden from the screen unless called up. The CASP program played one stretch every six minutes, by default, while the computer was operating (see Figs 1, 2 and 3). Six minutes between
stretches was selected as the interval between exercises for this study because it is the point at which oxygen returns to base line in muscles being used at 5 and 10% of MVC [12] and it adds 10 mini-breaks per hour that interrupt static positioning associated with use of the computer [30,43,51].

The second version of the intervention was called the Facsimile Lesson with Instructional Pictures (FLIP). This was a hard copy version of the CASP program and was also developed by the researcher for this study. The FLIP version incorporated selected still pictures and words transcribed from the CASP version of the program. These black and white pictures and text were placed on a spiral stand from which they could be “flipped” into place by the subject and followed the same order as that of the CASP program. The FLIP
version used a digital kitchen timer attached to the stand which was pre-set to alarm every six minutes once it was activated. The timer had to be restarted after each stretching exercise by the subject (Fig. 4). Each person was given a journal that was tethered to the computer to record the amount of time that the intervention was used each day. The subject was also asked to record their pain level at the end of each work day and to note if the program interfered with productivity. The third group \((n = 23)\) comprised the non-treatment control group.

Subjects were recruited via a campus wide email asking for volunteers who were experiencing pain that they attributed to use of their computer. The randomization sequence was established by listing the order of the date and time that the emails or phone calls were received by the secretary and alternating the interventions by assigning the CASP intervention to the first caller (or group if more than one subject was located in an office cluster), the FLIP intervention to the second caller or group, and the control category to the next caller who was isolated from anyone using an intervention program. Recruitment of subjects was ongoing and continued throughout the 4 months of data collection.

Inclusion criteria were that all subjects identified the computer as one of the causes of pain which they had experienced for at least three weeks prior to the beginning of the study and the subject used the computer five days a week. Exclusion criteria were prior dislocation of an upper extremity, a health condition that may interfere with the study (as reported by the subject and discussed with the researcher) or current professional treatment or medication for pain. Each subject used the intervention for 15 work days unless the study completion date fell on a day which was preceded by time off, in which case two days were added to negate the effect of the time away from work.

After informed consent was established, the researcher, a physical therapist, enrolled the participants and conducted the intake evaluation. A picture was taken of the subject’s workstation, a series of intake questions regarding subjective opinions about the work environment and an objective ergonomic assessment of the computer workstation was completed. The protocol for assessment of individual workstation risk factors was based upon consensus of authoritative input as published in the evidence based literature (Appendix A), \([1, 13, 16, 21, 24, 25, 28, 30, 31, 34–37, 48]\). Using this evaluation tool, one point was deducted for each problem area identified. For example, if the keyboard was not ergonomically designed, one point would be deducted from the maximum score.

The next evaluation employed a standard body diagram where the subject designated areas of pain and graded its intensity on 10 centimeter visual analog scales (VAS) below the diagram. Subjects were asked to evaluate the pain that they felt at the end of the workday and to mark the body image with sequential numbers to locate its position. The sum of the numbers...
evaluating pain on the visual analog scales were added to give a total pain index score. For example: if pain in the low back was rated as a 2 and pain in the neck was rated as a 4, the pain index would be 6.

The subject was then asked to select “pain spots” to describe his or her pain. Pain Spot Assessment (PSA) was a tool developed by the researcher that used circles cut from thin Styrofoam® sheets and varied in size using whole numbers from one to ten centimeters. They were placed in an eight by eleven inch shallow tray for selection by the subject, and were identified by random letters. Once the “pain spots” were selected by the subject to represent their pain, they were taped to the subject’s clothing in the area where pain was indicated, a picture was taken, and their positions were recorded. The sum of the diameters of the “pain spots” were measured in centimeters and added to determine a “pain spot” index. (Figs 5 and 6).

Pain was categorized into the following areas: cervical (neck), right shoulder, left shoulder, mid-back, low-back, lower extremity, right upper extremity (but not hand or wrist), right hand or wrist, left upper extremity (not hand or wrist), left hand or wrist, headache, and other pain. This data was recorded at both intake and outtake and was analyzed as a pain index via ANOVA and correlation analysis using SPSS. Subjects were asked to avoid making any changes to personal exercise programs or to their computer workstation for the duration of the study.

Hypothesis: After using either the Computer Assisted Stretching Program (CASP) or Facsimile Lesson with Instructional Pictures (FLIP) as an intervention for 15 to 17 work days, there will be a significant reduction in the amount of pain associated with working at a computer workstation.

3. Results

The 68 participants reported pain in the following areas of the body upon initial evaluation, in order of prominence: cervical (neck), right shoulder, left shoulder, mid back, low back, lower extremities, right upper extremity (not hand or wrist), right hand/wrist, left
68 Subjects complained of pain associated with computer use lasting for at least three week prior to beginning the intervention.

Random Assignment to CASP, FLIP, or control group

Self assessment of workstation and informed consent

CASP Subjects N = 23 at intake,

Workstation, VAS and PSA evaluations and instructions for daily journaling and use of intervention

FLIP Subjects N=24 at intake,

Control Subjects N=23 at intake,

CASP = Computer Assisted Stretching Program, FLIP = Facsimile Lesson with Instructional Pictures, VAS = visual analog scale, PSA = pain spot assessment. Intake and final subject numbers differ due to participant attrition.

Fig. 7. CASP = Computer Assisted Stretching Program, FLIP = Facsimile Lesson with Instructional Pictures, VAS= visual analog scale, PSA = pain spot assessment. Intake and final subject numbers differ due to participant attrition.

Table 1
The frequency with which pain was reported at intake by the 68 participants

<table>
<thead>
<tr>
<th>Area</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical (neck)</td>
<td>72%</td>
</tr>
<tr>
<td>Right shoulder</td>
<td>44%</td>
</tr>
<tr>
<td>Left shoulder</td>
<td>40%</td>
</tr>
<tr>
<td>Mid back</td>
<td>40%</td>
</tr>
<tr>
<td>Low back</td>
<td>40%</td>
</tr>
<tr>
<td>Lower extremities</td>
<td>13%</td>
</tr>
<tr>
<td>RUE (not hand or wrist)</td>
<td>13%</td>
</tr>
<tr>
<td>Right hand/wrist</td>
<td>35%</td>
</tr>
<tr>
<td>LUE (not hand or wrist)</td>
<td>13%</td>
</tr>
<tr>
<td>Left hand/wrist</td>
<td>20%</td>
</tr>
<tr>
<td>Headache</td>
<td>14%</td>
</tr>
<tr>
<td>Other areas</td>
<td>4%</td>
</tr>
</tbody>
</table>

upper extremity (not hand or wrist), left hand/wrist, headache, other areas (see Table 1).

Evaluation of both the visual analog scale (VAS) and the “pain spot” assessments (PSA) was completed using an ANOVA analysis before the intervention, after the intervention, and to compare the differences between the mean values of the initial and final results. The pain index used for comparison was the average numerical sum of all of the reported pain attributed to working at a personal computer by all of the subjects in each group (CASP, FLIP and Control). The visual analog scale was measured to the nearest millimeter to describe the pain, while the “pain spots” were graded as whole numbers only – one through ten centimeters.

The two intervention and one control group were found to be equivalent when being assessed by the VAS as supported by an F value of 1.20 with a significance of \( p = 0.30 \). Similarities were also supported by non-significance in the pair-wise comparisons of differences (ANOVA) for all groups as follows: computer /control, \( p = 0.68 \); computer/flip, \( p = 0.95 \); flip/control, \( p = 0.32 \). The 95 percent confidence interval further supported the similarities.

The mean values of the two intervention and the control groups using the “pain spot” evaluation tool also supported equivalency with an F value of 1.27 and a significance of \( p = 0.29 \). Similarities were also supported by the non-significant pair-wise comparisons (ANOVA) for all groups as follows: CASP /control, \( p = 0.45 \); CASP/FLIP, \( p = 0.99 \); FLIP/control, \( p = 0.41 \). The 95 percent confidence interval further supported the similarities (see Table 2).

The reduction in pain from the CASP intervention was 73% using the VAS scale and 70% using the PSA tool. Reduction of pain reported from the FLIP subjects was 64% using the VAS and 62% using the PSA tool.
Table 2
ANOVA: pair wise comparison of group means for cumulative pain index before the intervention was applied as measured by visual analog scale

<table>
<thead>
<tr>
<th></th>
<th>Mean (I)</th>
<th>Mean (J)</th>
<th>Difference (I-J)</th>
<th>Sig.</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>computer control</td>
<td>2.25</td>
<td>0.68</td>
<td>−3.26</td>
<td>0.68</td>
<td>−3.26</td>
<td>7.77</td>
</tr>
<tr>
<td>flip control</td>
<td>3.34</td>
<td>0.32</td>
<td>−8.59</td>
<td>0.32</td>
<td>−8.59</td>
<td>1.89</td>
</tr>
<tr>
<td>flip computer</td>
<td>2.09</td>
<td>0.95</td>
<td>−4.68</td>
<td>0.95</td>
<td>−4.68</td>
<td>6.87</td>
</tr>
</tbody>
</table>

Table 3
ANOVA comparison of group mean differences for pain from intake to end of intervention as evaluated by VAS

<table>
<thead>
<tr>
<th></th>
<th>Mean (I)</th>
<th>Mean (J)</th>
<th>Difference (I-J)</th>
<th>Sig.</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>computer control</td>
<td>10.80</td>
<td>0.000</td>
<td>−6.14</td>
<td>0.000</td>
<td>−6.14</td>
<td>−6.14</td>
</tr>
<tr>
<td>flip control</td>
<td>10.30</td>
<td>0.000</td>
<td>−14.48</td>
<td>0.000</td>
<td>−14.48</td>
<td>−14.48</td>
</tr>
<tr>
<td>flip computer</td>
<td>−0.050</td>
<td>0.994</td>
<td>−5.81</td>
<td>0.994</td>
<td>−5.81</td>
<td>4.81</td>
</tr>
</tbody>
</table>

Fig. 8. Mean value of pain index before the Intervention as measured by VAS. Computer = Computer Assisted Stretching Program.

(in all cases $p < 0.001$). There was an increase in pain reported from the control subjects of 1% using both the VAS and the PSA (See Table 3, Figs 7, 8 and 9). The differences in the percent of improvement for the CASP and FLIP interventions were not found to be significant.

When a Pearson’s Correlation comparing length of time the interventions were used during the 15 days of intervention with the reduction in pain the correlation was found to be $r = 0.48$, ($p < 0.001$). When the VAS for pain was compared with the ergonomic grade of the workstation at intake, $r = (-) 0.042$, ($p = 0.73$) for VAS.

The VAS assessment tool was compared to the PSA tool using Pearson’s Correlations to compare the numerical sum of the pain indices reported by each of the 68 subjects. The pre-intervention VAS to PSA tool resulted in an $r = 0.75$ ($p < 0.001$); post intervention VAS when compared with the PSA resulted in an $r = 0.86$ ($p < 0.001$) and the difference in the pre and post VAS to the PSA resulted in an $r = 0.76$ ($p < 0.001$).

The following are noteworthy comments from the pre
and post qualitative surveys and daily journals: Thirty percent of the treatment groups (CASP and FLIP) reported that they had no pain at the end of the 15-days of intervention. Seventy percent of the participants rated the ergonomics of his or her workstation as “bad.” The study subjects rated poor ergonomics as the primary reason that they had pain in both the pre and post intervention groups. This was followed by “no breaks.” The most common comments in the daily logs were that “the stretching feels good” (13 times), and that “the program has helped” (12 times). No comments were made regarding work productivity being affected.

4. Discussion

The data analysis supported a statistically significant decrease in pain when evaluated by both the VAS and PSA evaluation tools for both the CASP and the FLIP intervention groups and the hypothesis was supported. Reduction in symptoms as measured by the VAS tool was 74% for the CASP group and 64% for the FLIP group. The non-treatment control group was one percent worse at the end of the three-week period. When the mean values of the “FLIP” and “CASP” groups were compared, however, there was no significant difference in two treatment outcomes.

The favorable effects may have been due to the intervention alone, that someone was acknowledging the subjects’ complaints or may have been due to the friendly voice and smiling face incorporated in the computer program. With the similarity in outcomes of the two types of media (computer vs. hard copy) there should have been a difference in outcomes if there was a “media” affect and there was not.

The same physical therapist performed the intake and outtake evaluations and that may have brought about some unintentional bias. Analysis of the pre and post intervention results was deferred until all of the data for the study were collected, and the initial assessment was not consulted for the outtake evaluation. Since the participants were using visual analog scales and random pain spots, bias should have been buffered, but remained a possibility.

Eighty-eight percent of the subjects in this study were female. This may have been influenced by several factors. All of the secretaries and most of the clerical workers in this population of convenience were women and therefore more likely to be exposed to the offending stimulus. In other populations studied, when all conditions were equal, females who were working with computers were found to have a significantly higher incidence of neck and shoulder disorders when compared with their male counterparts [6,23,49].

Ergonomics should not have played a role in the outcomes since the workstations were not altered or changed either before or during the time that the subjects were taking part in the study. This was confirmed by before and after pictures. In areas where more than one subject was using the intervention, group support...
may have been a factor in the outcomes, but similarly positive results were demonstrated in both the isolated and the group situations.

In the case of the “pain spot” assessments, the evaluation tool was not as sensitive as the VAS. However, no significant differences were seen in the pair-wise comparisons of the means of the pre/ post intervention or control groups. In addition, the Pearson’s Correlation supported a similarity between the VAS and the PSA evaluation tools of between \( r = 0.76 \) and \( 0.86 \).

The stretching interventions appeared to be effective in decreasing pain even though seated work, awkward positions, overuse, poor ergonomics, poor posture, age, de-conditioning, stress on bone and connective tissues, behavioral issues, and general work environment were not changed. The only changes were the use of periodic stretching exercises as directed by an impersonal media and the attention given to complaints of pain. Since several studies have given attention to their subjects and used computer programs to encourage breaks from work, without similar positive results, this may also not be an issue. What did change was that a variety of stretches was introduced in a timely manner. This may have prevented static muscle loading, decreased blood flow to the area and the associated muscle spasms [11–13,17,20,39,40,43,51].

Seventy-eight percent of the participants in this study subjectively rated the ergonomics of their workstation as “bad.” After the post intervention evaluations were completed for all subjects in a given area of the campus, the researcher suggested ergonomic changes for the participants’ workstations. Of 20 participants with adjustable keyboard heights and angles, none of the subjects knew how to use the adjustment knobs that were an integral part of the keyboard. This remains in agreement with the findings of Alexander who reported that seventy-four percent of 404 office-support employees were “not aware of the ergonomic changes that could be made at their workstations” [2].

This intervention was used for a total of three weeks with each subject. Long term assessments were not done. The outcomes of this research suggest a possible treatment regime that may address the acute phase of pain, while long term outcomes are unknown.

Eighty-eight percent of the participants were white females from Appalachia. The external application of the program shows promise, but will need to be repeated with a larger, more representative population.

When comparing the specific areas of pain identified by the subjects in this study with other studies, the findings were similar [2,11]. While subjects were asked to comment on any interference in work productivity that the stretching programs might have caused, none was reported. Some did complain that the kitchen timer on the FLIP version of the stretches was too loud and that was modified by placing a piece of tape over the speaker on the device to decrease the volume.

5. Conclusions

When subjects were reminded to perform stretches once every 6 minutes while seated at a computer workstation, associated pain was significantly reduced. The type of media used to prompt stretching while at the computer was not related to a significant difference in outcomes. “Pain Spot” Assessments may be a reliable tool for evaluating pain. A study that extends the stretching protocol to a larger population with an extended follow-up is recommended.

References


Appendix A: Workstation evaluation

Subject # Picture # Date

Workstation and picture evaluation: A 17-point scale for evaluation of computer workstations and pictures. One point is to be deducted for each problem area detected. References that support the use of each item in the protocol follow the statements.

1. Keyboard type is ergonomic [13,21,28,48]
2. The mouse is held using a neutral position of the wrist [21,28,35]
3. Top of computer screen is at the level of the eyes (within 15 degrees) [13,21,25,28,35,36]
4. Chair height is adjustable [21,28,35]
5. There is space between back of knees and front edge of chair [13,21,34,35]
6. There are supportive arms on chair [13,21,28]
7. The back on the chair is supportive [13,21,24,34–36]
8. The back of the chair adjustable [13,21,24,28,35]
9. There is a lumbar support [13,21,35]
10. Elbow angle is 70–90 degrees when hands are on keyboard [21,24,28,35,36]
11. Elbows are supported when using the keyboard [12,13,16,21]
12. Elbows are supported when using the mouse [13,16,21,30,31]
13. Wrist angle is within 10 degrees of neutral when using the keyboard [13,21,28,34,35,48]
14. The feet touch on floor [13,21,28,34,35]
15. A 70–90 degree angles of the knees, and 90 degree angle of the buttocks is evident when seated at the workstation [13,21,28,34,35]
16. There is a document holder at eye level [13,21,28,35,36]
17. Glasses do not alter the neck position from neutral when using the computer [1,21,24,28,34,35]

This protocol for assessment of individual workstation risk factors was based upon consensus of the following authoritative input as published in the following literature [1,13,16,21,24,25,28,30,31,34–37,48].