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Prolonged slumped sitting causes neck pain and increased axioscapular muscle activity during a computer task in healthy participants – A randomized crossover study

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ABSTRACT

Introduction: Sitting posture may contribute to spinal pain. Effects of postures on pain, sensitivity and muscle activity during computer tasks were investigated.

Methods: Twenty-five healthy participants, seated at a workstation without backrest, completed four, 15-min typing tasks: A)Upright with forearm-support; B)Upright without forearm-support; C)Slumped with forearm-support; D)Slumped without forearm-support. Participants rated pain every minute on a numerical rating scale (NRS). RMS-EMG was recorded from upper/lower trapezius (UT, LT), serratus anterior and anterior/middle deltoid. At baseline and after tasks, pressure pain thresholds (PPTs) were recorded bilaterally over the head, UT, and leg.

Results: All tasks caused clinically relevant increased NRS ($\geq$2/10) compared to baseline ($P < 0.001$). NRS was higher in Task-D ($P < 0.003$) and lower in Task-B ($P < 0.005$) than others. PPTs did not change from baseline. Task-D caused higher UT and LT RMS-EMG ($P < 0.02$) than other tasks.

Conclusion: A 15-min task caused pain irrespective of posture with some causing larger changes than others.

1. Introduction

Musculoskeletal disorders are the biggest contributors to years lived with disability on a global scale, with spinal related pain being the dominating cause (Cieza et al., 2020; Safiri et al., 2020). The potential relationship between spinal pain and posture is a controversial topic. A commonly held belief amongst populations with and without pain (Korakakis et al., 2021; O'Sullivan et al., 2013) as well as health care professionals (Caneiro et al., 2019; Korakakis et al., 2019) is that there are optimal and suboptimal postures. Such beliefs are also reflected in passive treatment strategies such as posture-cueing shirts or thoracic bracing, intended to cue or improve posture, although there are contrasting findings to support their use (Christensen et al., 2021b; Gheitasi et al., 2022; Palsson et al., 2019).

For neck pain, sustained or awkward posture along with increased duration of computer work is commonly considered a risk factor (Brink et al., 2009; Jahre et al., 2020; Kazeminasab et al., 2022; Kim et al., 2018), as is a lack of arm support during computer work (Gerr et al., 2004; Marcus et al., 2002). Specifically, office workers with neck pain tend to have a more forward head posture (Chiu et al., 2002; Lee et al., 2022; Szeto et al., 2002, 2005b) and altered axioscapular muscle activity (Szeto et al., 2005a, 2009) than those without neck pain. Furthermore, people with neck pain seem to have problems keeping an upright posture during shorter computer tasks (Falla et al., 2007). Importantly however, it is difficult to determine whether such differences in posture are causal or merely coincidental, as several studies have failed to demonstrate such a relationship (Grob et al., 2007; Richards et al., 2016, 2021; Sarig Bahat et al., 2022).

In healthy populations, it is known in that even short durations of computer work seated on a chair with a back rest can cause pain and

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discomfort over time (Baker et al., 2018; Christensen et al., 2021b; Strom et al., 2009, 2012) and it has been suggested that this could also cause pressure hyperalgesia over the upper trapezius muscle (Park and Yoo, 2013; Strom et al., 2012). Additionally, adopting a flexed sitting position seems to cause higher activity of the cervical erector spinae muscles (Caneiro et al., 2010) as well as increased activity in both the upper and lower trapezius muscle, while a decrease was observed for the serratus anterior muscle during loaded shoulder flexion (Weon et al., 2010). However, so far it is unclear how pain intensity, pain sensitivity and muscle activity may change with different sitting postures during a computer task.

This study set out to investigate the immediate effect of different sitting postures during standardized computer tasks on perceived pain in healthy participants. The primary outcome was perceived pain intensity while the area of pain, pain sensitivity, muscle activity and perceived difficulty of performing the tasks were included as secondary outcomes. It was hypothesized that an upright sitting posture with forearm support, in accordance with current recommendation for computer work, would cause the least amount of pain, area of pain, and change in pain sensitivity when compared to non-recommended postures such as sitting in a slumped posture without forearm support. Muscle activity was expected to be different between tasks with different postures.

2. Materials and Methods

2.1. Participants

The sample size was based on pilot data where NRS scores were collected following 15-min writing tasks while sitting with either a slumped posture without arm support or in an upright position with forearm support. The data yielded an effect size of 0.75. A sample size calculation was conducted using G*power v3.1 (Heinrich-Heine-Universität, Düsseldorf, Germany) for a one-way analysis of variance with one group, four tasks, 80% power, α 0.05, giving a total sample size of 24 participants. A convenience sample of 25 healthy, right-handed participants were recruited from a university setting. For inclusion, participants had to have normal, pain free active neck and shoulder range of motion. Exclusion criteria were any current neck or shoulder pain along with any current pain in another body region, any neurological, rheumatological, or psychological conditions or pregnancy. For screening purposes, all subjects answered the Neck Disability Index questionnaire (NDI) where a cut-off score of 10% was used to rule out any clinically relevant neck conditions (Vernon, 2008). In addition, a short physical examination was conducted by a physiotherapist to ensure that participants had normal, pain free movement of the head and neck. Prior to enrolment, all participants gave verbal and written consent after receiving information about the study. The study was approved by the local ethics committee (N-20120018).

2.2. Protocol

This randomized crossover study was conducted in a laboratory setting with participants seated in an office setup (chair without a backrest, height-adjustable desk, PC, height-adjustable 24" widescreen monitor, mouse, keyboard) adjusted to each individual according to Danish recommendations for office workers (Bille and Jakobsen, 2020). From this position, participants completed four different writing tasks, each lasting 15-min. The pain intensity (if any) was registered regularly during this period. Likewise, electromyography was recorded bilaterally over five different neck and shoulder muscles during the tasks. Pressure pain thresholds (PPT) at the shoulder girdle, back and neck were determined at baseline and after each task.

2.3. Writing task

Four 15-min writing tasks separated by a 5-min washout period were conducted. The tasks were conducted in A) sitting upright with forearm support, B) sitting upright without forearm support, C) sitting slumped with forearm support, and D) sitting slumped without forearm support (Fig. 1). For the slumped posture, participants were instructed to "*sit as flexed as possible and stick your chin out*". This put their lumbar and thoracic spine in end of range flexion simultaneously with cervical extension caused by the forward head posture. The instruction for the upright posture was "*sit upright in a comfortable position*". For all sitting postures, during each task, the study participants were reminded to maintain the assigned posture. Participants were instructed to stand between each task, but it was not possible to walk around as electromyography (EMG) electrodes for recording muscle activity were connected to a stationary EMG amplifier. For the typing task, a publicly available online software (skrivhurtigt.dk) was used (Christensen et al., 2021b). The software allowed for a standardized text to be inserted after which the participants were given the task of copying the text. Four different texts from H.C. Andersen fairy tales were used for the typing task, one for each specific task. At the beginning of the session, participants drew a concealed envelope containing the order of the tasks which had been randomized in advanced by the assessor using all 24 possible combinations (4*3*2*1) of the four writing tasks.

2.4. Perceived pain and task difficulty during the writing tasks

At the beginning and after every minute throughout the 15-min computer tasks, participants were asked to rate the intensity of their neck pain using a 11-point verbal numeric rating scale (NRS) with the instruction "On a scale where 0 is no pain and 10 is maximum pain, please rate your neck pain" (Christensen et al., 2021b). Peak neck pain NRS scores and area under the curve (AUC) were extracted for further analysis. Following each writing task, a body chart was filled out with the perceived area of pain. The size of the area was calculated in arbitrary units using VistaMetrix (*v.1.38.0; SkillCrest, LLC, Tucson, AZ*) and extracted separately for each view of the chart (right, left, anterior posterior) while the perceived difficulty of the task was rated on a 6-point Likert scale: 0 = 'no problem', 1 = 'minimally difficult', 2 = 'somewhat difficult', 3 = 'fairly difficult', 4 = 'very difficult', to 5 = 'unable to perform' (Christensen et al., 2015, 2017a, 2017b).

2.5. Pressure pain thresholds

The Somedic handheld pressure algometer (*Hörby, Sweden*) mounted with a 1 cm^2 probe and a single-use cover was used to assess PPTs. The pressure was steadily increased with a slope of 30 kPa/s until the exact point where the participants rated the pressure as becoming painful. Here, they pushed a button wired to the algometer, allowing the tester to record the PPT (Christensen et al., 2015, 2017a, 2017b). PPTs were measured bilaterally over the intermediate portion of the temporalis muscle (Head) and splenius capitis muscle (Neck) lateral to the spinous process of C3, between the borders of the upper trapezius (UT) and the sternocleidomastoids muscle (Christensen et al., 2015, 2017a, 2017b). In addition, bilateral PPTs were recorded bilaterally over the UT muscle, approximately 3 cm lateral (leaving space for EMG electrodes at the midline) to the midline between the acromion and the spinous process of C7 (Christensen et al., 2021a; Malfliet et al., 2017), and over the quadriceps muscle (Leg), 10 cm above the base of the patella on a line towards the anterior superior iliac spine. All PPT sites were marked for repeated measures. PPTs were measured in triplets at baseline and in duplets after each typing task. Temporal PPT-changes were not investigated as this would have required a break during the typing task, potentially affecting pain perception. The mean values were calculated for each site and extracted for data analysis. PPT assessments have shown to be reliable, even for novice assessors (Waller et al., 2015; Walton et al., 2011) with a minimal detectable change for UT of 42.7 kPa in a healthy population (Walton et al., 2011).

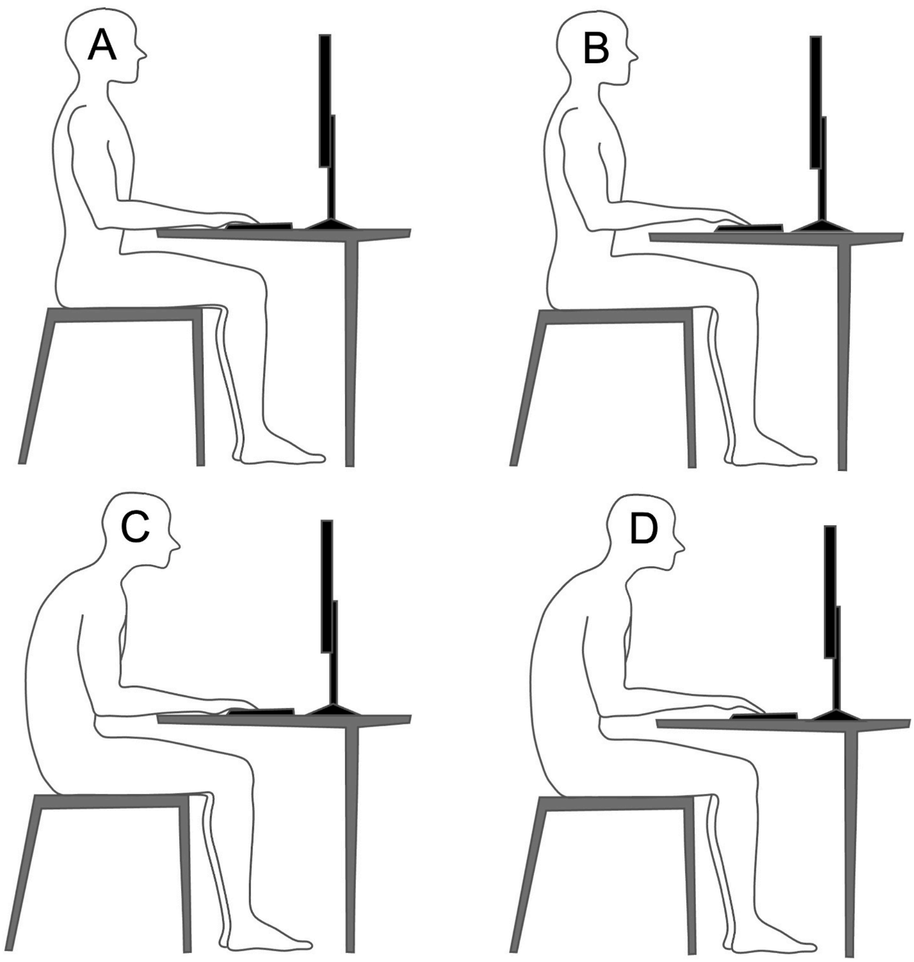

Fig. 1. A depiction of the four positions from which the writing task was conducted. A) Sitting upright with forearms supported B) Sitting upright without forearm supported C) Sitting slumped with forearms supported D) Sitting slumped without forearm supported.

2.6. Electromyography

Electrodes (*Neuroline 72,001-k; Ambu A/S, Ballerup, Denmark*) were place over the skin bilaterally, following the SENIAM recommendations (Hermens, 1999) for the following muscles: Upper trapezius (UT) at the midline between acromion and C7; Lower trapezius (LT) two thirds on a line from trigonum spinae on scapula to T8; Anterior deltoid (AD) approximately 2 cm distal and anterior to the acromion on an imaginary line towards the thumb; Middle deltoid (MD) over the greatest muscle bulge, on a line from the acromion towards the lateral humeral epicondyle. Serratus anterior (SA) electrodes were placed anterior to the latissimus dorsi in the direction of the muscle fibers over ribs 6 to 8 (Basmajian and Blumenstein, 1989) which have previously been used in laboratory studies (Christensen et al., 2015, 2017a, 2017b). EMG signals were sampled at 2048 Hz with a gain of 1000. EMG recordings were performed in three epochs, lasting 3 min each: Epoch1 (0–3 min), Epoch2 (6–9 min), and Epoch3 (12–15 min). From each epoch the root-mean-square (RMS) EMG was extracted. The EMG data was normalized to and expressed as a percentage of a submaximal isometric muscle activation recorded during a 10-s static standing posture recorded at baseline. Here, participants elevated their outstretched arm into flexion with pronated forearm, so the tip of the fingers were level with the top of the head. This was first done with the right arm followed by the left. A recent study employed a similar EMG normalization procedure and found this to both be reliable and to give similar results as when data was normalized to maximal voluntary contractions (Cooper and Karduna, 2022).

2.7. Statistics

The statistical analysis was performed using SPSS v.27 (*IBM, Chicago, IL, USA*). The Shapiro-Wilks test was used to determine the normality of data before choosing the appropriate method of analysis. In case data were not normally distributed, they were log10 transformed. Pending the distribution of data, they were analyzed using a repeated measures analysis of variance (RM-ANOVA) or the non-parametric equivalents. To adjust for multiple comparisons, the Bonferroni test was used. When indicated (non-parametric data only), a Wilcoxon's test was used for post-hoc analysis with a Bonferroni adjusted level of significance to account for multiple comparisons.

Peak neck pain NRS score and body chart data (right, left, anterior posterior) were compared between time points (baseline, writing task A, B, C & D) while AUC for pain NRS scores and Likert scores were compared between tasks (A, B, C & D) using a Friedman's ANOVA. A Kendall's W was reported along with the Friedman's ANOVA while the Wilcoxon's test was reported together with Eta Squared (η^2).

PPT data were analyzed separately for each site (Head, Neck, UT, Leg) using an RM-ANOVA with side (right, left) and task (baseline, writing task A, B, C & D) as within-subject factors. RMS-EMG data were analyzed separately for each muscle (UT, LT, SA, AD, MD) using an RM-ANOVA with side (right, left), task (writing task A, B, C & D) and epoch (1–3) as within-subject factors. When indicated, a Greenhouse-Geisser correction was implemented. For RM-ANOVAs, a partial Eta Squared (η_p^2) was reported while Cohen's *d* was reported for pairwise comparisons based on data without log-transformation to allow for meaningful and conservative interpretation. PPT and EMG data were presented without log-transformation. In this paper, Eta Squared and partial Eta Squared effect sizes were interpreted as small (0.01), moderate (0.06), or large (≥0.14) (Cohen, 1988; Ellis, 2010; Richardson, 2011). Cohen's *d* was interpreted as small (0.2), medium (0.5), or large (0.8) (Cohen, 1988; Ellis, 2010). Kendall's W was in this work interpreted using Cohen's criteria of small (0.1), moderate (0.3), or large (≥0.50) effect sizes (Cohen, 1988; Ellis, 2010).

Results are presented as either mean and standard deviation or median and interquartile range (25th-75th) in text and figures unless otherwise stated. Level of significance was set to $P < 0.05$.

3. Results

All 25 enrolled participants (13 women, 12 men) completed the study. Participants had a mean age of 27.4 (SD 5.4) years old, were 180 (SD 0.1) cm tall, weighed 74.4 (SD 13.6) kg and scored 1.3% (SD 2.4) on the NDI.

3.1. Perceived pain and task difficulty during the writing tasks

At the start of task D, one subject reported a neck pain intensity of 1/10. For all other tasks, all participants scored 0 at the start of each condition. The Friedman's ANOVA indicated a significant difference between conditions for both peak NRS neck pain score ($\chi2(4) = 77.0$, $P < 0.001$, $W = 0.770$) as well as for AUC ($\chi2(3) = 46.9$, $P < 0.001$, $W = 0.626$). All tasks caused an increase in peak NRS neck pain score compared to baseline (Wilcoxon: $P < 0.001$, $\eta^2 > 0.622$). Moreover, task D caused higher peak NRS neck pain scores and larger AUC than any other task (Table 1; Wilcoxon: $P < 0.003$, $\eta^2 > 0.486$). An increase in peak NRS neck pain score and AUC was found for tasks A and C compared to task B (Wilcoxon: $P < 0.05$, $\eta^2 > 0.32$).

For the body chart data (Fig. 2), the most commonly identified area of perceived pain was over the neck and shoulder area, which were especially evident during task D. The Friedman's ANOVA indicated significant differences for the right ($\chi2(4) = 17.3$, $P = 0.002$, $W = 0.173$), left ($\chi2(4) = 16.8$, $P = 0.002$, $W = 0.168$), anterior ($\chi2(4) = 13.6$, $P = 0.009$, $W = 0.136$) and posterior (Fig. 2; $\chi2(4) = 55.2$, $P < 0.001$, $W = 0.552$) views. However, the post-hoc test only revealed significant differences for the posterior view where all tasks caused larger areas of perceived pain compared to baseline (Table 1; Wilcoxon: $P < 0.001$, $\eta^2 > 0.615$). Additionally, task D caused larger areas compared to all other tasks (Wilcoxon: $P < 0.05$, $\eta^2 = 0.329$).

A significant difference for the Likert score of task difficulty was indicated by the Friedman's ANOVA ($\chi2(3) = 43.6$, $P < 0.001$, $W = 0.581$) with the post-hos test showing that task D caused higher scores than any other task (Table 1; Wilcoxon: $P < 0.005$, $\eta^2 > 0.458$). Additionally, task C caused higher scores than task B (Wilcoxon: $P < 0.005$, $\eta^2 = 0{,}448$).

3.2. Pain sensitivity

For the PPTs (Fig. 3), a significant main effect of task was found at the neck site (RM-ANOVA: F [3.3, 78.8] = 3.8; $P = 0.011$, $\eta_P^2 = 0.108$). The post-hoc test showed PPTs for task D were 18% greater than task A (Fig. 3; $P = 0.048$, $d = 0.25$). No other significant difference was found for any other site.

3.3. Electromyography

EMG data were discarded for one person due to technical problems. Additionally, data from the middle deltoid muscle were discarded for two subjects on the right side (six epochs in total) and three subjects on the left side (six epochs in total) due to technical problems with the EMG amplifier.

For UT muscles, a main effect of task was found (RM-ANOVA: F[3, 69] = 23.6; $P < 0.001$, $\eta_P^2 = 0.507$, Fig. 4a). Task A caused 102.4% higher RMS-EMG than task B (Fig. 4a; $P < 0.001$, $d = 1.05$) while task D caused >102.2% increased activity than all other tasks ($P < 0.001$, $d > 0.98$).

A main effect of task (RM-ANOVA: F[3, 69] = 11.7; $P < 0.001$, $\eta_P^2 = 0.305$) and epoch (RM-ANOVA: F[2, 46] = 5.1; $P = 0.01$, $\eta_P^2 = 0.069$) was found for the LT muscles (Fig. 4b). The post-hoc comparison showed that task A caused 24.8% higher RMS-EMG than task B (Fig. 4b; $P = 0.047$, $d = 0.25$) while task D caused >89.8% higher RMS-EMG than all other tasks ($P < 0.012$, $d > 0.63$). Epoch 1 showed 10.5% greater activity than epoch 3 ($P = 0.039$, $d = 0.13$).

For the SA muscles (Fig. 4c), a main effect of side was found (RM-ANOVA: F[1, 23] = 6.3; $P = 0.019$, $\eta_P^2 = 0.163$) with a 40.9% higher RMS-EMG on the left side than the right side. A main effect of task was also observed (RM-ANOVA: F[3, 69] = 8.9; $P < 0.001$, $\eta_P^2 = 0.202$) with the post-hoc test revealing 22.5% higher SA RMS-EMG during task A than task B (Fig. 4c; $P = 0.024$, $d = 0.26$). Furthermore, task D caused >21.9% higher SA RMS-EMG than task B ($P = 0.004$, $d = 0.39$) and C ($P = 0.022$, $d = 0.26$).

A main effect of both task (RM-ANOVA: F[3, 69] = 7.5; $P < 0.001$, $\eta_P^2 = 0.200$) and epoch (RM-ANOVA: F[1.45, 33.5] = 4.5; $P = 0.029$, $\eta_P^2 = 0.033$) was indicated for the AD muscles (Fig. 4d). During task D, >118.4% higher RMS-EMG was recorded than task B (Fig. 4d; $P = 0.003$, $d = 0.72$) and C ($P = 0.011$, $d = 0.78$). EMG activity during epoch 2 was 7.5% higher than epoch 3 ($P = 0.011$, $d = 0.09$).

The MD muscle was the only muscle for which an interaction between side and task was identified (Fig. 4e; RM-ANOVA: F[1.97, 37.4] = 4.1; $P = 0.025$, $\eta_P^2 = 0.071$) where all tasks showed >88.1% higher

Table 1
Showing median (interquartile range: 25th percentile and 75th percentile) for peak NRS scores (0 = no pain, 10 = maximum pain), NRS area under the curve (AUC; arbitrary unit), areas marked on the right, left, anterior and posterior view of a body chart (arbitrary unit) and Likert scale of perceived difficultness of performing the task. Data is presented for baseline where relevant and for writing task A-D. *Significantly different compared to baseline, #task B, and/or ◆all other tasks (Significance level: Peak NRS & Body chart analysis: $P < 0.05$; AUC & Likert analysis: $P < 0.05$).

NRS scores for the neck					
	Baseline	Task A	Task B	Task C	Task D
Peak pain	0 [0-0]	3 [2–6]*#	2 [1–3]*	3 [1–6]*#	6 [5–9]*◆
AUC	–	29 [13–56.5]#	7,5 [1.5–28]	34,5 [12.5–50]#	60,5 [44.5–75.5]◆
Body chart					
	Baseline	**Task A**	**Task B**	**Task C**	**Task D**
Right	0 [0-0]	0 [0-0]	0 [0–233]	0 [0–214]	0 [0–701]
Left	0 [0-0]	0 [0-0]	0 [0–299]	0 [0–453]	0 [0–616]
Anterior	0 [0-0]	0 [0–36]	0 [0–144]	0 [0–702]	0 [0–1117]
Posterior	0 [0-0]	2176 [1250–3640]*	1186 [368–5490]*	1860 [912–4311]*	5144 [2223–6914]*◆
Likert					
	Baseline	**Task A**	**Task B**	**Task C**	**Task D**
Likert	–	1 [1–2]	1 [0–1]	2 [1–2]#	3 [2–4]◆

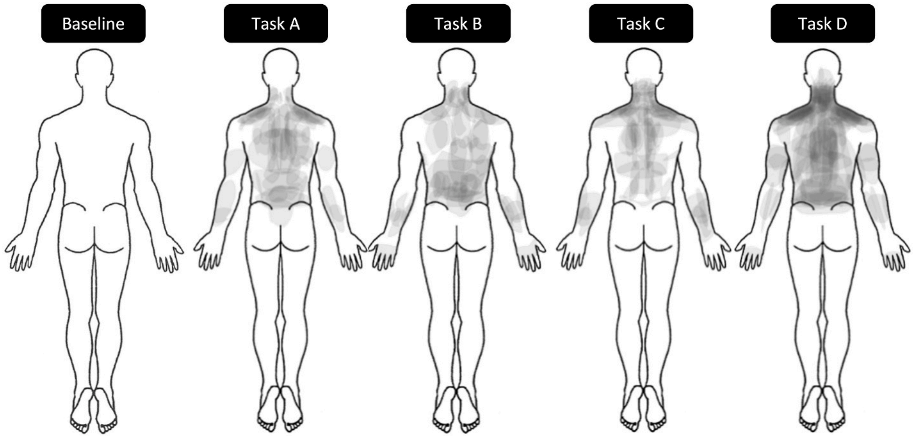

Fig. 2. Superimposed body chart drawings (posterior view; darker color indicates more frequently marked area) for baseline and task A-D.

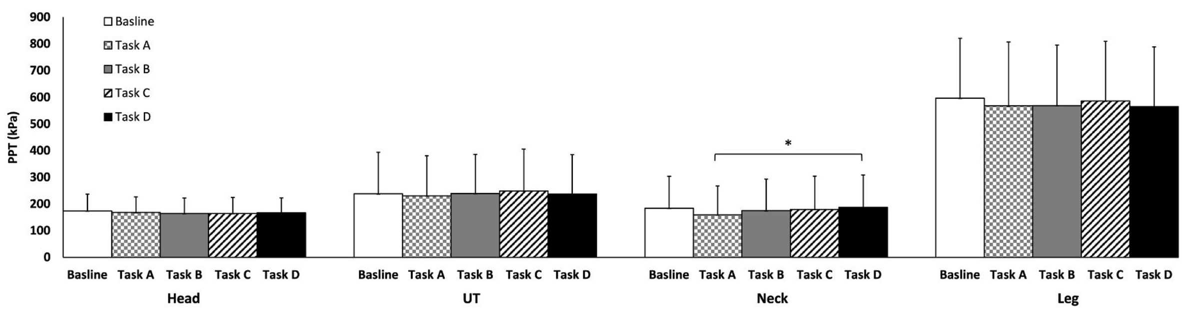

Fig. 3. Mean bilateral pressure pain threshold (PPT) with standard deviations (SD) for baseline and tasks A-D (A: Sitting upright with support, B: Sitting upright without support, C: Sitting slumped with support, D: Sitting slumped without support) at the head, upper trapezius (UT), neck and leg sites. *Significant different between tasks ($P < 0.05$).

EMG activity for the right side compared to the left (Fig. 4e; $P < 0.05$, $d > 0.49$).

4. Discussion

The study investigated the immediate effect of four different standardized seated computer tasks on perceived pain, pain sensitivity and muscle activity in healthy participants. The study found that all four tasks caused increased pain when compared with baseline. However, sitting without forearm support in either upright (Task B) or slumped position (Task D) caused the lowest (Task B) and highest (Task D) pain NRS score, respectively. In general, the greatest changes in axioscapular muscle activity were observed for task D compared to other tasks. Increased PPT scores were recorded over the neck site during task D compared to task A but neither of these were significantly different from baseline.

4.1. Static postures increase the perception of pain regardless of sitting posture

Despite variation, all tasks evoked pain (Table 1) with a median NRS score of 2 or more, indicating clinically relevant changes compared to baseline (MacDowall et al., 2018). Short-lasting computer tasks have previously been shown to cause pain and discomfort from all body regions in healthy participants (Baker et al., 2018; Christensen et al., 2021b; De Carvalho et al., 2020; Strom et al., 2009, 2012). In the current study, where focus was on neck pain, this was most intense during the seated slumped position with forward head posture and without arm support (task D, Fig. 1). These findings may relate to prolonged isometric loading of neck muscles as well as loading of passive joint structures (Briggs et al., 2004). Surprisingly, task B caused lower pain intensity than task A, which contrasts with previous findings in the literature where arm support during a computer task has been shown to reduce discomfort (Cook et al., 2004; Rempel et al., 2006). This alleviating effect of arm support could be explained by reduced strain on passive structures as well as levels of muscle activity needed to maintain the posture (Briggs et al., 2004) which would in turn reduce the load on both shoulders and the cervical spine (Behrsin and Maguire, 1986; Cook et al., 2004). One potential explanation for task B being perceived as the least painful one in this study could be that it lies closer to the participants habitual posture during computer work. This would be in line with a study showing that 'ideal' and habitual postures are not necessarily the same (Korakakis et al., 2021), where it could be argued that it would be easier to relax in a habitual posture.

In this study, the healthy, pain free participants reported relatively high levels of pain intensity during all tasks. One explanation could be that the included participants were not accustomed to a sustained load or strain imposed on the neck and shoulder area during computer work, irrespectively of spinal posture or arm support. However, this seems an unlikely explanation as the participants were recruited from a university setting and should therefore be highly familiar with computer work. Another explanation could be that no back rest was provided for any of the tasks, as back rests have previously been shown to improve sitting comfort (Akkarakittichoke et al., 2022; Curran et al., 2015). Although the lack of a back rest may have been a contributing factor to the pain reported, it does not explain the between task difference in pain intensity. Although task D was expected to cause some discomfort, considering that the sitting posture does not follow current recommendations for computer work (Bille and Jakobsen, 2020; Emerson et al., 2021), this did not apply for task A which still resulted in pain equivalent to an average of 3 on an NRS scale (Table 1). Another potential explanation for all postures causing pain could be that participants

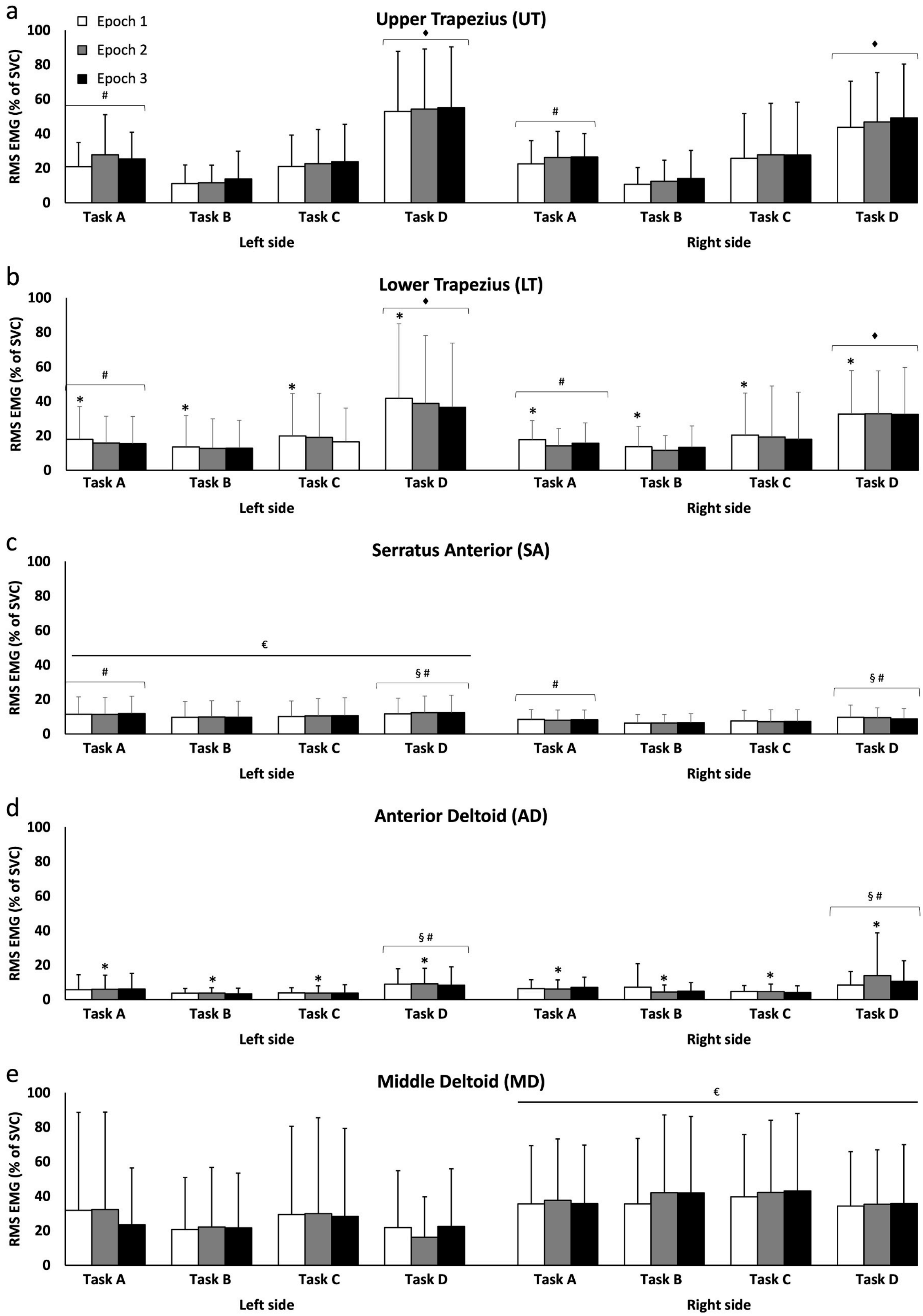

Fig. 4. Mean (+SD) expressing percentage of the maximal RMS-EMG obtain during a static posture at baseline for the a) upper trapezius (UT), b) lower trapezius (LT), c) serratus anterior (SA), d) anterior deltoid (AD) and e) middle deltoid (MD) muscles bilaterally for all epochs (1–3 during tasks A-D (A: Sitting upright with support, B: Sitting upright without support, C: Sitting slumped with support, D: Sitting slumped without support). Significantly different compared to #task B, §task C, ◆all other tasks, *epoch 3 and/or €opposite side ($P < 0.05$).

reinterpreted the NRS scale to reflect the intensity of what they experienced, such as discomfort during the tasks rather than pain intensity (Christensen et al., 2021b; Kemp et al., 2012). If this were the case, this would have been a systematic error and the levels of pain intensity should therefore be interpreted with caution. The current study used predetermined postures which participants were requested to maintain for the whole duration of each task without allowing for a normal shift of posture as would be expected when experiencing discomfort (Waongenngarm et al., 2020). People experiencing neck-shoulder or back pain seem to do the opposite i.e., display reduced movement variability and thereby spend a greater part of the working day in the same positions (Madeleine and Madsen, 2009; Wong et al., 2009). Taken together, the increased neck pain in some tasks, and that participants were not allowed to change spinal posture or modify the arm support during the tasks, may potentially explain the perceived difficulty of performing the task. This is supported by the fact that both peak NRS pain scores and Likert score followed a similar trajectory in each task.

In the current study, participants were asked to rate their neck pain. Based on their drawings (Fig. 2), it is evident that they also perceived pain from other parts of the back. It is therefore possible that some participants rated the pain experienced in other body parts and not just the neck despite being specifically asked to rate any potential neck pain.

4.2. Static postures have a limited effect on pain sensitivity

Even though participants reported relatively high pain intensity during the writing tasks in the current study, this did not have any impact on pain sensitivity when compared to baseline. In contrast, previous studies have shown that 20–90 min of computer work increases pressure pain sensitivity for the upper trapezius muscle in both healthy participants and a neck-shoulder pain population, and for the latter, these increases correlated to the reported pain intensity (Park and Yoo, 2013; Strom et al., 2012). A simple explanation for the lack of changes in the current study could be the shorter duration of the computer tasks, although evoked pain intensity was comparable to that recorded by Strom et al. (2012). Another explanation for the lack of changes could be the responsiveness of PPT measurements. However, during task D where participants were seated slumped without arm support, the PPT for the neck site increased significantly when compared to task A where they were seated upright with arm support. Here however, it is important to note that in contrast to pain intensity, the PPTs did not change significantly from baseline in either of these tasks, thereby limiting a meaningful interpretation of this finding.

4.3. Healthy individuals use different muscle strategies during stationary computer work

In the current study, great variability was observed in muscle activity between and within tasks over time. In general, task D caused the highest muscle activity for most muscles, though this only differed significantly for muscles UT and LT. For the UT muscle, a tendency of increased EMG activity was observed over time for most tasks, which is in line with previous findings (Park and Yoo, 2013) and could be interpreted as a sign of fatigue (Oberg, 1995). In contrast, a decreased activity over time was observed for the LT muscle with higher activity during epoch 1 compared to 3, which could indicate a temporal redistribution of EMG activity occurring within the different parts of the trapezius muscle, irrespective of sitting posture. Changes in posture affect the EMG activity of postural (Caneiro et al., 2010) and axioscapular muscles (Wegner et al., 2010; Weon et al., 2010). In a previous study by Wegner et al. (2010), people with neck pain were noted to have reduced EMG activity of the LT muscle during a computer task, compared with controls, which was normalized when the scapular position was adjusted. The increase in EMG activity of both UT and LT muscles seen during task D is in line with previous findings by Weon and colleagues (Weon et al., 2010) who found a similar increase from a forward head posture. In addition, the lacking arm support during task D may also have contributed to the increased muscle activity. This is supported by previous studies showing increased UT, middle trapezius, and AD activity without arm support compared to when this was used (Bolderman et al., 2017; Goncalves et al., 2017). For the UT, LT and SA muscles (Fig. 4) similar changes were seen in activity between tasks, with task D causing the highest activity. The similar changes observed for these muscles, may be explained by UT, LT and SA acting as synergists for upper limb movements (Kibler, 1998; Kibler and McMullen, 2003). However, this does not explain why sitting upright without arm support (task B) resulted in lower muscle activity compared to the same posture with arm support (task A). This contrasts our hypothesis and is not easily explained. Although speculative, the observed changes in muscle activity between tasks could be linked to pain. From the results, muscle activity (Fig. 4) along with pain intensity and area of perceived pain follow similar trajectories (Table 1) between tasks. Pain has been suggested to result in a redistribution of muscle activity (Hodges and Tucker, 2011) collectively acting as a protective mechanism to avoid further pain. The proposed theory could thereby explain why task B resulted in lower activity for muscles such as UT, LT and SA compared to task A as the perceived pain was also lower. However, while pain increased from zero at baseline during each task, a similar increase was not seen over time for EMG in the recorded muscles (Fig. 4) although a tendency was observed for UT. It is possible, that changes may have occurred in muscles not monitored in this study and based on the current results it is not possible to determine if this was the case.

4.4. Strengths and limitations

The standardized setup in this study with a randomized crossover design was a strength, where participants acted as their own controls and thereby accounted for any potential order effects as the randomization of the four tasks resulted in 24 unique combinations of tasks. To standardize the sitting posture in slumped, the assessor position instructed the participants to find their end of range in spinal flexion and forward head posture and ensure that it was kept throughout each writing task. However, it is possible that participants changed their posture slightly during each writing task. Nevertheless, the current results indicate a clear difference in pain intensity between conditions, which implies that the participants maintained the intended sitting posture throughout the task.

When interpreting EMG data, it is important to note that as the current study tested different positions, electrodes attached to the skin may alter position relative to the muscle as the skin moves and adapts to a new position (Besomi et al., 2019). In the context of this study, it would mean that the EMG recordings reflected an altered position of the electrodes relative to the muscle in each writing task instead of altered muscle activity. This is however speculative, as this cannot be confirmed or rejected in the current study.

In this study, the chairs did not have a back rest nor were participants allowed to alter their position during the computer tasks which may have amplified the perceived pain and resulted in a steeper increase compared to normal office work. In addition, although speculative, the frequent pain ratings during tasks may have increased focus on the perceived pain and potentially cause this to be rated differently compared to if this had only been rated after the tasks. However, as pain ratings were recorded consistently for all tasks this should not have impacted the observed differences between tasks. Lastly, the participants were relatively young and may therefore reflect findings in an older population.

5. Conclusion

This study showed that a 15-min seated computer task caused pain in an otherwise healthy population, irrespective of sitting posture. Although all investigated postures caused pain over time, a posture with slump sitting without arm support caused higher pain intensity, larger area of pain and increased difficulty completing the task, as well as increased muscle activity compared to other postures. Both the lowest muscle activity and pain intensity were reported for an upright posture without arm support, indicating that arm support may not always be needed to reduce discomfort when compared to a similar posture with arm support. Taken together, there may be no ideal sitting posture as all static postures may cause discomfort over time.

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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