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ORIGINAL ARTICLE

Changes in microcirculation of the trapezius muscle during a prolonged computer task

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Abstract The aim of this study is to investigate if there is a change in oxygen saturation and blood flow in the different parts of the trapezius muscle in office workers with and without trapezius myalgia during a standardized computer task. Twenty right-handed office workers participated; ten were recruited based on pain in the trapezius and ten as matching controls. Subjects performed a combination of typing and mousing tasks for 60 min at a standardized workstation. Muscle tissue oxygenation and blood flow data were collected from the upper trapezius (UT), the middle trapezius (MT) and the lower trapezius (LT), both on the left and right side at seven moments (at baseline and every tenth minute during the 1-h typing task) by use of the oxygen to see device. In all three parts of the trapezius muscle, the oxygen saturation and blood flow decreased significantly over time in a similar pattern ($p < 0.001$). Oxygenation of the left and right UT was significantly higher compared to the other muscle parts ($p < 0.001$). Oxygen saturation for the MT was significantly lower in the cases compared to the control group ($p = 0.027$). Blood flow of the UT on the right side was significantly lower than the blood flow on the left side ($p = 0.026$). The main finding of this study was that 1 h of combined workstation tasks resulted in decreased oxygen saturation and blood flow in all three parts of the trapezius muscle. Future research should focus on the influence of intervention strategies on these parameters.

Keywords Oxygenation · Blood flow · Trapezius myalgia

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Introduction

Work-related neck pain is an ongoing and increasing problem in office workers, especially with the demands of computer-based tasks and activities, both inside and outside the working environment. Although the pathophysiological mechanisms underlying work-related neck pain are unclear, plausible hypotheses have been put forth. It has been proposed that continuous long-lasting low-level muscle activity is likely to coincide with selective and sustained activation of type I motor units as proposed in the Cinderella hypothesis putting them to risk of being overloaded (Hägg 1991). Biopsy studies on work-related myalgia have demonstrated various mitochondrial disturbances in type I fibers (ragged red fibers), a higher percentage of large type I fibers (megafibers), and reduced capillarization per muscle fiber cross-sectional area (Kadi et al. 1998; Mackey et al. 2010; Andersen et al. 2008; Larsson et al. 2004). This may indicate an ongoing energy crisis, in which continuous activity of a subset of muscle fibers impedes the delivery of oxygen to other, deprived muscle fibers. In this way, muscle metabolism turns toward an anaerobic state.

Several studies have reported changes in microcirculation in subjects with long-standing neck and shoulder myalgia, of which oxygenation and blood flow are two commonly investigated parameters. Oxygenation is frequently measured by spectroscopy. Flodgren et al. (2009, 2010) found significantly decreased oxygenation in the trapezius muscle of both healthy females and patients with trapezius myalgia in response to low-load work, although no statistically significant differences for oxygenated hemoglobin was reported between patients with trapezius myalgia and healthy controls (Sjogaard et al. 2010). For the evaluation of blood flow, although several techniques have been used in the past, such as photoplethysmography and microdialysis, laser Doppler flowmetry has been most commonly used. By use of the latter, Larsson et al. (1999) showed that subjects with trapezius myalgia had impaired muscle blood flow in the painful side during static contraction at different levels, compared to controls. However, the level of muscle activation was much higher than that measured during office work. Strom et al. (2009a) evaluated trapezius muscle blood flow during a 90-min standardized task of correcting text on a word processor. They concluded that neck/shoulder pain may develop in healthy pain-free subjects during 90 min of office work and that it seemed to be related to the regulation of trapezius muscle blood flow.

The O2C (oxygen to see) is a relatively new, non-invasive device, based on the combination of white light spectroscopy and laser Doppler technique. The evaluation of perfusion and oxygenation can be performed simultaneously. This technique has been used for the evaluation of microcirculation in a variety of conditions (e.g., Achilles tendon problems (Knobloch et al. 2006b, c; Kraemer et al. 2009), ulcer and burn wounds (Reenalda et al. 2009), and during operative monitoring as a predictor for organ function (Klein et al. 2010). To our knowledge, the O2C system has not been used for evaluating trapezius muscle microcirculation in patients with work-related neck and shoulder pain.

The aim of this study is to investigate if there is a change in oxygen saturation and blood flow in the different parts of the trapezius muscle in office workers during the performance of a standardized computer task. We hypothesize that oxygen saturation and blood flow decreases over time in the upper part of the trapezius muscle. Furthermore, we hypothesize that both parameters are decreased during rest and when exposed to computer tasks in patients with trapezius myalgia when compared with healthy controls.

Materials and methods

Subjects

Right-handed office workers, performing at least 4 h of computer work as part of their daily job duties, were recruited. Subjects with a history of traumatic injuries or surgical interventions of the neck or upper limb regions were excluded. Ten subjects were recruited in the case group and met the following criteria: (1) neck/shoulder pain or discomfort of more than 30 days during the last year in the neck or shoulder region; (2) pain frequency of at least once a week; and (3) an intensity of pain of at least two on a scale from 0 to 10. Correspondingly, ten controls were selected provided they had not experienced pain or discomfort for more than 8 days during the last year in the neck/shoulder region with intensity of two or less. Prior to the experiment, the case group was asked to complete the Neck Disability Index (NDI) (score out of 50) (Vernon and Mior 1991). The mean and standard deviation for average perceived disability was 17 ± 4.5. There were no significant differences between the control and case group concerning age, height and weight (Table 1). All subjects provided informed and signed consent prior to inclusion in the study. The local ethical committee approved the study.

Table 1 Characteristics of the control and case group

	Controls	Cases	*p* value
Age	31.22 (±9.05)	38.89 (±10.25)	0.112
Length	1.75 (±0.08)	1.71 (±0.08)	0.400
Weight	68.83 (±10.35)	73.77 (±13.26)	0.391

General protocol

Each subject performed a combination of typing and mousing tasks for 60 min, including copy-typing and editing text from a typing training program. Subjects were asked to perform the task continuously at their usual speed without changing posture. The workstation was standardized for all subjects, including a standard computer desk with an adjustable slideout tray for a keyboard and mouse, as well as a height-adjustable chair with no arm rests. Each subject was instructed to adjust the keyboard tray and the chair in order to assume a position of comfort, with hip, knee and elbow joints at approximately 90°. A footrest was provided for subjects who were not able to place their feet flat on the ground. The height and distance of the computer display were adjusted to a comfortable level, taking into account some ergonomic rules: the uppermost line of the display was at or slightly below eye level. The viewing distance between the subject's eyes and the screen was approximately 75 cm (17 inch screen), while the neck was in a neutral position.

Measurements

O2C (oxygen to see)

Muscle tissue oxygenation and blood flow data were collected with the O2C device at seven time points throughout the 1-h typing tasks (prior to the task and every tenth minute). The O2C is a relatively new non-invasive device capable of measuring the perfusion and oxygenation of the subcutaneous tissue up to a depth of 8 mm. O2C technology is based on two physical principles: white light spectroscopy (wavelengths of 500–800 nm) and the laser Doppler technique (830 nm and 30 mW). The white light spectroscopy allows detection of hemoglobin parameters, such as oxygen saturation and the relative amount of hemoglobin. The degree of oxygen saturation of hemoglobin is determined by changes in the color of blood. Oxygen saturation of hemoglobin is expressed in percent sO2 (%) and reflects mainly the capillary-venous oxygen saturation, as 85% of the hemoglobin is in the capillary-venous compartment of the microcirculation (Knobloch et al. 2006a). The laser Doppler flowmetry allows determining perfusion parameters in the tissue as it detects all moving erythrocytes. The number of moving erythrocytes combined with the blood flow velocity is processed to the parameter blood flow. This is expressed in arbitrary units (AU).

The reproducibility of the blood flow values determined with the O2C system has been tested in the forearm of 20 healthy subjects using a test–retest design. An average 5% intra-subject variability was calculated (Ghazanfari et al. 2002). Recently, Forst et al. (2008) conducted an analogous study in both diabetic and healthy subjects establishing intra-individual reproducibility data of all parameters (r values varying between 0.65 and 0.85).

Oxygenation and perfusion were recorded from six points, the upper trapezius (UT), the middle trapezius (MT) and the lower trapezius (LT), both on the left and right side (Fig. 1). The O2C allows evaluation of the different parameters at two distinct tissue depths (2 and 8 mm). As previous studies have calculated that the mean distance between the skin surface and the fascia of the trapezius muscles is 5.8 ± 1.7 (Sandberg et al. 2007) and 6.2 ± 1.8 (Flodgren et al. 2006), only the depth at 8 mm was further used to evaluate the oxygenation and perfusion parameters in the trapezius muscle.

Pain intensity and rate of perceived exertion

Prior to the task (T1) and every 20 min (T3, T5 and T7), each subject rated their pain using a numerical rating scale (NRS), ranging from 0 (no pain) to 10 (worst possible pain). Also, rate of perceived exertion (RPE) was self-reported at the same time points using a scale from 6 to 20, where 6 equates to “no exertion at all” and 20 is “maximal exertion”.

Statistical analysis

Analysis was performed using the PASW statistics 18. Descriptive statistics (mean and standard deviation) were calculated for oxygen saturation, blood flow, NRS and RPE. These parameters were further analyzed by use of analysis of variance with repeated measures with within-subject factors being group (case–control) and time (T1–T7). The within-subject factors side (left–right) and muscle part (UT, MT and LT) were added for the analyses of oxygen saturation and blood flow. Post hoc pair-wise comparisons were made when required. Statistical significance was accepted at the 0.05 alpha level.

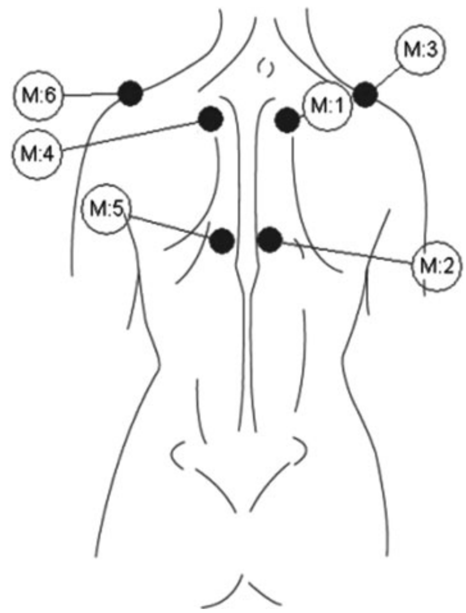

Fig. 1 Localization of the measurement points: *M1* right MT, *M2* right LT, *M3* right UT, *M4* left MT, *M5* left LT, *M6* left UT

Results

Oxygen saturation

The multivariate analysis of variance yielded a significant main effect for time ($p < 0.001$) and muscle part ($p < 0.001$) and a significant interaction effect for muscle part × group ($p = 0.049$) (Fig. 2). In all muscle parts, the oxygen saturation decreased significantly over time in a similar pattern. Post hoc tests revealed a significant decrease from T1 to T3 ($p < 0.022$), no differences between T3 and T5, and again a significant decrease at T6 and T7 compared to T1–T5 ($p < 0.050$). The oxygenation of the left and right UT was significantly higher compared to the other muscle parts ($p < 0.001$).

Post hoc tests revealed a significant difference between the cases and controls for the left and right MT only ($F = 6{,}000$; $p = 0.027$), in which the oxygen saturation was significantly lower in the cases compared to the control group at all moments, except T5 for the right MT.

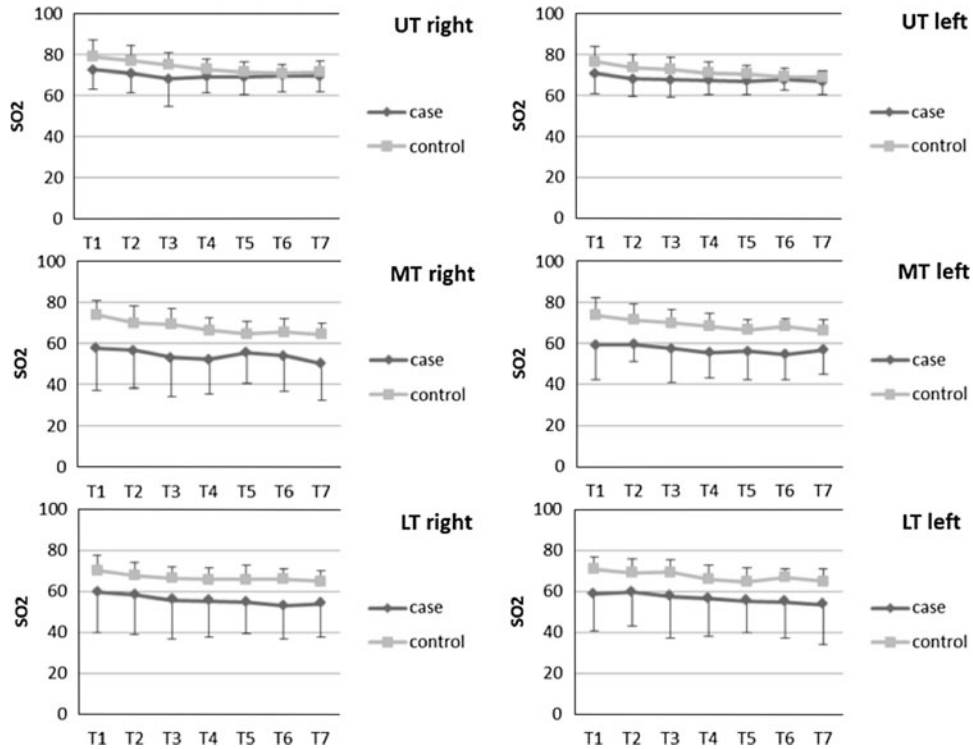

Fig. 2 Mean oxygen saturation (%SO2) (±SD) of the right and left UT, MT and LT during seven time moments (T) (at baseline and every tenth minute during a 1-h typing task)

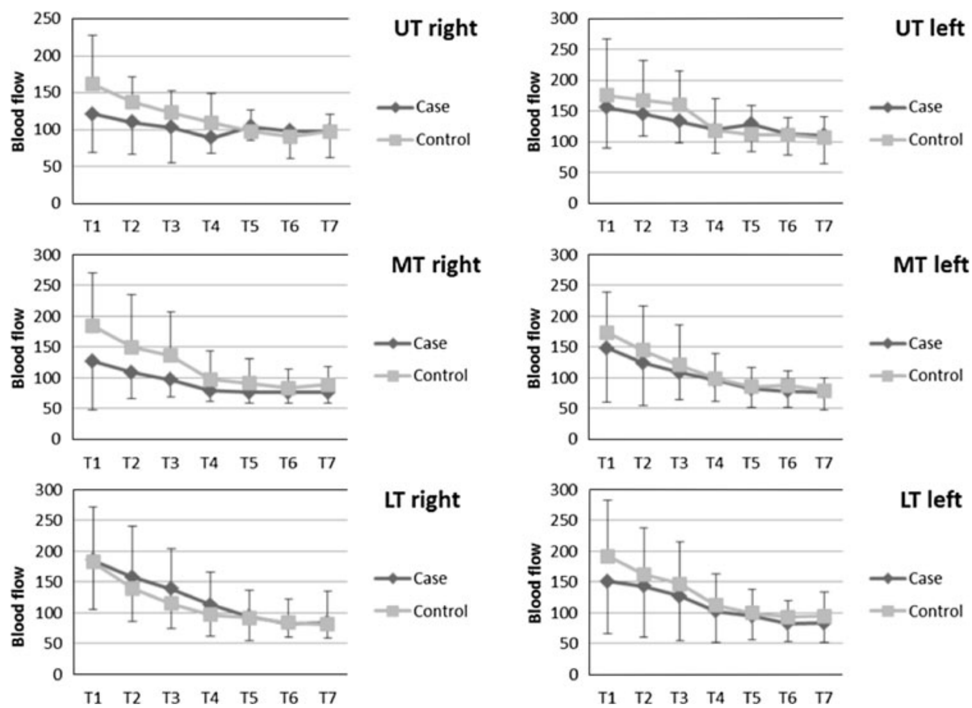

Fig. 3 Mean blood flow (±SD) of the *right* and *left* UT, MT and LT during seven time moments (T) (at baseline and every tenth minute during a 1-h typing task)

Blood flow

The multivariate analysis of variance yielded a significant main effect for time ($F = 16{,}927$; $p < 0.001$) and side ($F = 5{,}608$; $p = 0.032$), and a significant interaction effect for time × muscle part ($F = 3{,}890$; $p = 0.010$) (Fig. 3). Post hoc tests on each muscle separately revealed that blood flow decreased significantly over time in all muscle parts. In the UT, there was a significant decrease in blood flow between T1 and T4, but the blood flow remained constant between T4 and T7 ($p = 0.010$). In the MT, blood flow decreased significantly from T1 to T4 ($p \leq 0.023$), but there was no further significant decrease from T4 to T7. In the LT, blood flow decreased significantly between each time point, except between T6 and T7 ($p \leq 0.034$).

There was only a main effect of side for the UT muscle ($F = 6{,}075$; $p = 0.026$), in which the blood flow on the right was significantly lower than the blood flow on the left side. This was the case at T2 to T5 ($p < 0.044$), but not at T1, T6 and T7.

Pain intensity and rate of perceived exertion

Pain intensity ($F = 18{,}263$; $p \leq 0.001$) and rate of perceived exertion ($F = 18{,}397$; $p \leq 0.001$) increased over time in both case and control group (Figs. 4, 5). Pain intensity was significantly higher in the case group compared to the control group at all moments ($p < 0.05$), except at baseline (T1). Rate of perceived exertion was only significant between cases and controls at T1 ($p = 0.016$) and T3 ($p = 0.021$).

Discussion

The main finding of this study was that a 1-h typing task influenced both the oxygen saturation and blood flow in all three parts of the trapezius muscle. More specifically, (1) oxygen saturation and blood flow decreased significantly over time for all muscle parts, (2) blood flow was significantly lower in the right UT compared to its counterpart and (3) oxygen saturation of the MT was significantly lower in the case group compared to the controls.

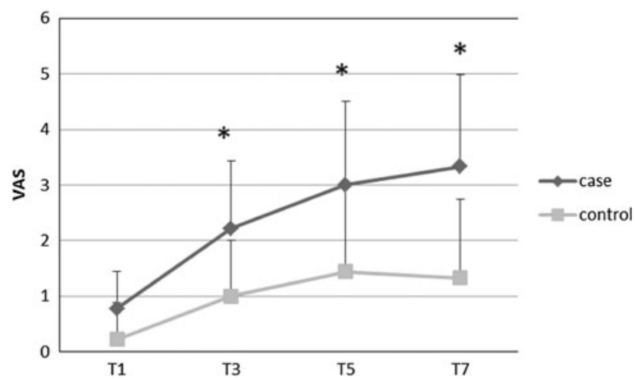

Fig. 4 Mean values of VAS ratings prior to the task (T1) and every 20 min (T3, T5 and T7) during a 1-h typing task

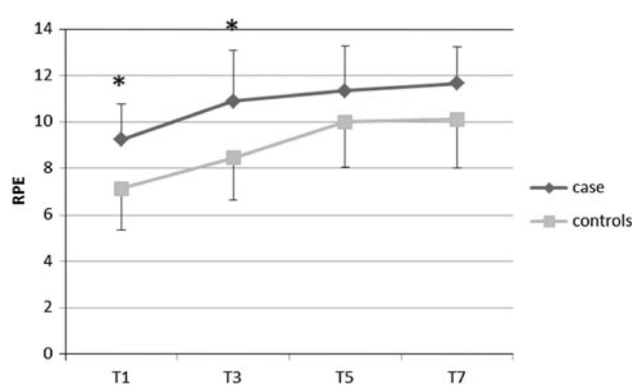

Fig. 5 Mean values of BORG ratings prior to the task (T1) and every 20 min (T3, T5 and T7) during a 1-h typing task

It was hypothesized that oxygen saturation and blood flow decreased over time in the upper part of the trapezius muscle. However, oxygen saturation and blood flow decreased over time for all parts of the trapezius muscle. The decrease in oxygen saturation was significant from T1 to T3 with no differences between T3 and T5. A significant decrease was again observed at T6 and T7 compared to T1–T5. There is a paucity of available studies, whereby the oxygenation of the trapezius muscle was investigated and results are conflicting. It is however important to highlight that most of these studies used other methods to investigate oxygenation, like near-infrared-spectroscopy (NIRS) and that they only measured this in the upper portion of the trapezius muscle, between the C7 spinous process and the acromion (Heiden et al. 2005; Elcadi et al. 2011; Flodgren et al. 2009, 2010). Heiden et al. (2005) evaluated muscle oxygenation in healthy subjects during a 45-min standardized mouse-operated computer task, but did not find a difference in oxygenation between rest and the task, whereas others determined that low-load repetitive work influenced oxygen saturation. Elcadi et al. (2011) investigated the oxygenation in the trapezius muscle during a 5-min low-intensity (10%) contraction. They found a significant decrease of oxygenation throughout the contraction. Flodgren et al. (2009, 2010) investigated the saturation in the middle third of the UT by use of spectroscopy and found a decrease from 83.1% ±9.8 at baseline to 77.4% ±12.0 during repetitive work.

As local muscle oxygen saturation represents the balance between oxygen delivery and consumption, the decrease in oxygenation may be due to either limited delivery or increased consumption. In this study, there was a significant decrease of blood flow over time, which suggests reductions are due to limited delivery. This is in agreement with the findings of Sjogaard et al. (2010). However, Sjogaard et al. (2010) and Flodgren et al. (2010) demonstrated by analyzing oxygen saturation (NIRS) and lactate concentration (microdialysis) also a significant increase in lactate during work and recovery, indicating that increased consumption was even likely. An increase in lactate was also demonstrated by Rosendal et al. (2004) and Strom et al. (2009b), who evaluated blood flow invasively in subjects with trapezius myalgia during a low-force exercise and office work task, respectively. However, they found a significant increase in blood flow during exercise, which was the exact opposite to our findings. The elevated blood flow was suggested to be a regulatory response triggered by the exercise-induced increase in lactate (Rosendal et al. 2004).

It is striking that both oxygen saturation and blood flow decrease in most muscle parts from T1 to T4, which then remain rather constant to T7. It is difficult to compare these results with other studies, as in most other studies a maximum of 45 min was evaluated. However, this finding may be correlated with results from previous EMG studies, which has shown that during a prolonged task there is a gradual increase in EMG activity, which then reaches a plateau (Strom et al. 2009a, b; Flodgren et al. 2009).

Although saturation was equal in both the left and right UT, blood flow was significantly lower in the right UT compared to its counterpart. This may not be surprising as all participants were right-handed and right-sided activation was greater during the mousing tasks. It is hypothesized that reduced blood flow may be related to sympathetically mediated vasoconstriction and/or higher intramuscular pressure (Heiden et al. 2005). Although low-intensity work tasks often involve fairly low levels of intramuscular pressure, Sjogaard et al. (1986) suggested that local intra-muscular pressure might be much higher in parts of the muscle where individual motor units are active compared to overall muscle activity. Indications for this clustering of motor units have been found in the trapezius muscle, which may support this hypothesis (Jensen and Westgaard 1997). Based on this, it was hypothesized that a low-force contraction would induce a time-dependent increase in intramuscular pressure and a subsequent decrease in oxygenation and, hence, muscle fatigue. However, quite recently, Vedsted et al. (2006), Sjogaard et al. (2004) and Blangsted et al. (2005) demonstrated that the mean intramuscular pressure was unchanged with time in the biceps (Blangsted et al. 2005; Vedsted et al. 2006) and supraspinatus (Sjogaard et al. 2004) muscle.

It was hypothesized that both parameters would be decreased during rest and when exposed to the computer task in patients with trapezius myalgia when compared with healthy controls. In this study, only the oxygen saturation of the MT was significantly lower in the case group compared to the controls, whereas no differences in oxygenation or blood flow between cases and controls were found in the UT. The lack of significant differences between groups may partly be explained by the wide variability observed in the values, especially in the patient group.

The decrease in oxygenation in the MT in the patient group is in agreement with previous studies, where a larger and more sustained oxygen deficit during the start of the work task in subjects with myalgia was seen compared with healthy controls (Sjogaard et al. 2010). In the present study, saturation of the MT was measured close to the upper part of the medial border of the scapula, which is also the localization of a known trigger point (TP5) (Simons et al. 1999). This point is frequently indicated as a tender point in patients with work-related myalgia and may be susceptible to disturbed microcirculation.

Based on this observation and the fact that a gradual decrease in blood flow and saturation was linked with a phased increase in pain, it is important to think about the link between muscle pain and hypoperfusion. Until now, it is unclear whether muscle pain is caused by or causing reduced blood flow and oxygen saturation. The concept that chronic muscle pain could be due to intramuscular hypoperfusion was documented in different studies, which concluded that an impaired regulation of the microcirculation in the local muscle may cause nociceptive pain (Maekawa et al. 2002). It is suggested that chronic disturbances in muscle microcirculation might produce an increase in nociceptive neuronal activity by sensitizing the regional muscle nociceptors. However, the current results could also be interpreted as pain causing hypoxia. According to Graven-Nielsen and Arendt-Nielsen (2002), local edema in the vicinity of the nociceptor induced by release of substance P and calcitonin gene-related peptide may locally enhance intramuscular hypoperfusion. So although the current study further confirms the relationship between microcirculation and pain, the cause–effect relationship is still unclear.

The present study used the O2C to measure the perfusion and oxygenation simultaneously and non-invasively. Muscle oxygenation and blood flow have been reliably measured by several methods in the past; however, the techniques are invasive, which could influence the measured parameters. The non-invasive monitoring of the O2C makes it appealing to both researchers and clinicians. Of further advantage is that the technology provides real-time data, and is easy to set up and to use even for continuous measurements. The major limitation of the O2C device is that parameters of microcirculation are insufficiently validated and normalized for human trapezius tissue. Although previous studies have demonstrated good reliability in measuring forearm muscles (Ghazanfari et al. 2002; Forst et al. 2008), further studies are recommended to investigate the validation and reliability of this equipment in measuring the trapezius muscle. Another important shortfall of the technology is that measurements of blood flow are represented in arbitrary units. To calculate the blood flow in milliliters per minute, it would be necessary to compare with a method that measures the blood flow in milliliters per minute (for example, plethysmography, microspheres) for each organ. Then the arbitrary units can be converted into milliliters per minute.

A further limitation was that all measurements were taken at a depth of 8 mm. Due to the variability of the subcutaneous layer and the thickness of the trapezius muscle, no exact location could be determined. Different previous ultrasound studies have measured the thickness of skin, subcutaneous tissue and muscle tissue. The thickness between the skin surface and the fascia of the trapezius muscle differed from 5.8 ± 1.7 (Sandberg et al. 2007) and 6.2 ± 1.8 (Flodgren et al. 2006) to 7.7 ± 1.7 (Nielsen et al. 2010) and 9.5 ± 0.5 mm (Rosendal et al. 2004). These data indicate that, at a depth of 8 mm, the measurement is limited to the upper part of the trapezius muscles and that in cases with a thick subcutaneous layer there remains the possibility that the measure is performed outside the muscle.

Insight into the physiological mechanisms involved in the development and perpetuation of work-related neck pain is of great importance with respect to prevention, diagnosis, treatment and rehabilitation of this disorder. As this and other studies have demonstrated a decrease in blood flow and oxygenation, it is important to implement intervention strategies to counteract this decline. Only a few studies have investigated the effect of 'exercise' on muscle oxygenation (Andersen et al. 2010; Crenshaw et al. 2006; Sogaard et al. 2012). Crenshaw et al. (2006) investigated the effects of active versus passive pauses implemented during a 60-min computer mouse work on muscle oxygenation and found that both pauses induced an enhancement in oxygenation for computer mouse work. Andersen et al. (2010) evaluated the effect of cycling on trapezius muscle oxygenation by use of near-infrared spectroscopy in controls and patients with trapezius myalgia. For both groups, oxygenation of the passive trapezius increased in a linear fashion over time with no significant group differences. Sogaard et al. (2012) recently performed a randomized controlled trial to compare the effect of 10 weeks of leg-bicycling training with relaxed shoulders to specific strength training locally for the affected muscle on myalgic trapezius activation, muscle oxygenation, and pain intensity. Leg-bicycling decreased pain development during repetitive work tasks, possibly due to improved oxygenation of the painful muscles. Specific strength training lowered the overall level of pain, both during rest and work, possibly due to a lowered relative exposure as evidenced by a lowered relative EMG. This indicates differential adaptive mechanisms of contrasting physical exercise interventions on chronic muscle pain at rest and during repetitive work tasks. More research is now needed to further investigate the effect of intervention strategies on the microcirculation of the trapezius muscle.

In conclusion, computer work decreases oxygen saturation and blood flow over time in all three parts of the trapezius muscle. Blood flow was significantly lower in the right UT compared to its counterpart, whereas only oxygen saturation of the MT was significantly lower in the case group compared to the controls. Future research should focus on the influence of intervention strategies on these parameters.

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