Inducing exposure variability during computer work in the shoulder girdle with and without experimental pain

Afshin SAMANI and Pascal MADELEINE

Center for Sensory-Motor Interaction (SMI), Department of Health Science and Technology, Aalborg University, Denmark

Abstract. We present a short review of studies comparing the effect of passive with active pause during computer work and their interaction with the experimental muscle pain. The subjects performed a standardized computer task. We asked them to either perform an isometric shoulder elevation (active pause), or simply relax (passive pause) on a regular basis. Subsequently, exogenous and endogenous models of experimental pain were applied to the trapezius muscle. We observed a more variable pattern of muscular activity in response to active pause but this potentially beneficial effect was less potent in presence of experimental pain.

Keywords. Musculoskeletal disorders, active and passive pause, exposure variation analysis.

1. Introduction

The lack of exposure variation has been suggested to be associated with the development of work-related musculoskeletal disorders (WMSD) in occupations involving repetitive movements (Buckle & Jason Devereux, 2002). In particular, computer workers are characterized as individuals with the risk of WMSD development especially in the shoulder region (Juul-Kristensen, Søgaard, Stroeyer, & Jensen, 2004).

As a remedy, ergonomists have suggested exploiting the redundancy of human motor control to increase the variation in patterns of biomechanical exposure at work (Srinivasan & Mathiassen, 2012). Low variability may imply that some specific compartments of the musculature become excessively overloaded. Furthermore, a system with low variability is less likely to exhibit exploratory behavior, and thus is less capable of adapting to perturbations (Stergiou, Harbourne, & Cavanaugh, 2006).

Some studies have suggested that by implementing a pause regime at work, the incidence of WMSD can be decreased (Balci & Aghazadeh, 2003; A. G. Crenshaw, Lyskov, Heiden, Flodgren, & Hellstrom, 2007). However, some individuals display a persistent activity of the upper trapezius muscle with both short and long passive pauses during computer work (Blangsted, Søgaard, Christensen, & Sjøgaard, 2004). This may render the beneficial effect of a passive pause regime negligible. An active pause regime has been introduced as an alternative to a passive regime (A. Crenshaw, Djupsjöbacka, & Svedmark, 2006). A brief increase in the exerted force has been shown to result in motor unit recruitment and de-recruitment in the trapezius muscle (Westad, Westgaard, & Luca, 2003).

Pain in deep structures including cartilage, tendons, ligaments, and muscles is one of the most consistent symptoms associated with WMSD in, e.g., the upper extremity (Madeleine, 2008). Additionally, one can wonder whether a beneficial effect of active pause would remain in presence of pain. A way to answer such a question is to apply the modalities of experimental muscle pain models and investigate their interaction with a pause regime. Experimental muscle pain models cause transitory well-controlled muscle pain that mimic clinical conditions in some aspects. Experimental muscle pain can be induced endogenously or exogenously, for example by means of inducing delayed-onset muscle soreness (DOMS) or intra-muscular injection of algogenic substances like hypertonic saline, respectively. We performed a set of studies to investigate the effect of pause type on the pattern of muscular activity in the shoulder region, in particular, in the trapezius and, to study the interaction between muscle pain and pause type.

2. Methods

Hereafter, we refer to the reviewed studies with Latin numbers I to III (Samani, Holtermann, Søgaard, & Madeleine, 2009a; Samani, Holtermann, Søgaard, & Madeleine, 2009b; Samani, Holtermann, Søgaard, & Madeleine, 2009c).

2.1 Subjects

In total, 24 healthy (without neck-shoulder disorders) right-handed male subjects have volunteered in studies I-III (in studies I and II, 12 subjects with age: 22±3 yrs, height: 183±9 cm and body mass: 77±7 kg and in study III, 12 subjects with age: 23±3 yrs, height: 183±8 cm and body mass: 77±11 kg). The volunteers were experienced with computer use with no history of chronic pain or diseases in the shoulder and neck region. The studies were approved by the local Ethical Committee (N-20070004 MCH), and informed consents were obtained from all subjects.

2.2 Experimental procedure

Once the subjects had received instructions and surface electromyography (EMG) electrodes were placed (see below), the computer workplace was individually adapted according to guidelines. The recordings were sequentially performed as follows. (1) Reference contraction: The subjects performed one reference contraction consisting of bilateral arm abduction at 90° in the frontal plane for 5 s while sitting. Reference voluntary electrical activity (RVE) was calculated as the EMG root mean square (2) Maximum voluntary contraction: Three maximum bilateral isometric shoulder elevations were performed for 5 s while sitting and holding hand-held straps fixed to the legs of the chair. The subjects rested at least 2 min between trials.

In study I, two 10-min sessions consisting of computer mouse work were performed. The sessions were at least 2 min apart, with the subjects relaxing between sessions. The computer work consisted of a standardized computer game in which the subject duplicated various graphs showing six circular targets linked to each other by straight lines. During the computer work, two different types of pause were used in a randomized order. The passive pause involved relaxation for approximately 8 s with palms of the hands on the table and the active pause consisted of isometric bilateral shoulder elevation at 30% MVC in the sitting position for approximately 8 s. Pauses were performed every 2 min.

A similar procedure was conducted in study II but the computer work sessions lasted only 2 min. After finishing the first two sessions, one 0.5-ml bolus of hypertonic saline (5.8%) was injected into the belly of the dominant upper trapezius muscle. The induced pain intensity lasted for approximately 5 min. In presence of the experimental pain, the subjects performed two computer sessions with either passive or active pause applied with 40 s intervals. The order pause type was randomized for each subject.

In study III (similar to study II), the subjects performed two 2-min computer work sessions with either passive or active pauses before, immediately after and 24 hours after an intensive eccentric exercise protocol. The eccentric exercise (ECC) induced delayed onset muscle soreness (DOMS) in the neck-shoulder region. The subjects had to resist against the pushing force (100% maximum elevation force) of the dynamometer and after each 10 contractions (1 bout), the subjects relaxed for 2 min. Five bouts of ECC were performed in total.

2.3 Data recording

A force sensing resistor device was placed on the mouse click button to identify the onsets and offsets of pause intervals. EMG was collected from four parts of the right trapezius muscle, i.e., clavicular, descending, transverse and ascending. The reference electrode was placed on the C7 vertebra. The EMG signals were properly amplified and band pass filtered [5-1000 Hz]. EMG signals were sampled at 3 kHz, converted into digital form and stored on a disk. Further, EMG signals were digitally band-pass filtered (Butterworth, 4th order, 10-1000 Hz) and a notch filter (4th order Butterworth band stop with rejection width 1 Hz centered at first two harmonics of the power line frequency (50 Hz)). The activity recorded during active and passive pauses from computer work were removed from the signal.

2.4 Data analysis

EMG root mean square was calculated for 1 s non overlapping epochs. Exposure variation analysis (EVA), representing joint density estimate of repetitiveness and load, as previously defined was implemented. EVA quantifies the accumulated proportion of recorded time that the exposure level remains uninterruptedly within pre-determined limits (“exposure level” categories, ExL) for pre-determined periods of time (“sequence duration” categories, SqD). In ergonomics studies, EVA has mainly been applied with recordings of posture (e.g. Straker et al., 2008) and electromyography (e.g. Samani et al., 2009a).

In study I, EVA categories were constructed using intervals of (0–1), [1–3), [3–10), [10–23), [23–50), [50–103), [103–200) and (>200) % RVE and (0–8), [8–24), [24–56), [56–120), [120-200) and [>=200) (s) along the ExL and SqD categories, respectively. These categories in the EVA were set arbitrarily to avoid a too coarse or a too fine EVA outcome. In studies II and III, the SqD categories were modified as (0–1.5), [1.5–4.5), [4.5–12), [12–25), [25-40) and [>=40) (s) to match the recording duration. The centroid of the EVA outcome was extracted in a 2D plane of the ExL and SqD categories.

2.5 Statistics

Pause types (passive and active) and stages in studies II and III (pain and no pain in study II and before, immediately, and 24 hours after the ECC in study III) were introduced as factors in a full-factorial repeated measures analysis of variance for the EVA centroid along both the exposure level and sequence duration categories as dependent variables in each of the trapezius parts. In all tests, $p<0.05$ was considered significant. If a factor with more than two levels was defined as significant, a corrected Bonferroni post hoc test was applied.

3. Results

In study I, the centroid of the EVA along the SqD categories differed between pause types for the transverse trapezius ($p=0.04$) and was lower for the active compared with the passive pause (figure 1). In study II, a similar effect of the active pause on the EVA centroid along the SqD categories was observed over all trapezius parts ($p<0.05$ for all parts). Further, the interaction between stages and pause type played a significant role ($p<0.05$) in the transverse trapezius. In the painful condition, there was no significant difference between the active and passive pause whereas the active pause shifted the EVA centroid, similar to study I, to lower SqD categories compared with the passive pause (table 1). The active pause also moved the EVA centroid up along the ExL categories in the clavicular trapezius ($p<0.001$). Similarly, muscle pain moved the EVA centroid up along the ExL categories in descending and ascending trapezius ($p<0.05$ for both cases). In study III, a similar effect of active pause as in studies I and II was observed in the descending trapezius ($P=0.02$) and a non-significant interaction of stages and pause type ($P=0.1$). However, the interaction played a significant role in the clavicular trapezius ($P=0.02$) indicating the active pause effect only before the ECC (table 1). Compared with the passive, the active pause also moved the EVA centroid up along the ExL categories in the clavicular and descending trapezius (respectively, $P<0.01$ and $P=0.02$). Further, compared with before the ECC, the EVA centroid moved down along the ExL immediately after the ECC stage in the descending trapezius ($P=0.03$).

4. Discussion and Conclusion

The active pause shifted the centroid of EVA along SqD towards lower values compared with the passive pause. This implied a more variable pattern of trapezius activity. However, in presence of muscular pain, the effect of active pause either vanished or became less potent.

The aforementioned effect of the active pause can be seen as a potentially beneficial effect because changing the activity pattern during monotonous work tasks may be a well-suited intervention strategy for preventing WMSD. However, the absence or degradation of such a beneficial effect may imply that the nociceptive influx due to muscle pain presumably resulted in a more restricted motor strategy (Madeleine, Mathiassen, & Arendt-Nielsen, 2008).

Both types of applied experimental pain e.g. exogenous and endogenous resulted in the degradation of the potentially beneficial effect of active pause. It is worth noting that the two modalities of experimental pain may involve two different mechanisms underlying muscle pain (Madeleine, 2008).

The moving of the EVA centroid up along the exposure level categories in response to muscle pain in study II may imply a functional reorganization of activity across the trapezius muscle. Such functional reorganisation of muscle activity may indicate the ability of the motor system to recruit synergistic muscles, e.g. the lower trapezius assists in rotation of the scapula mainly carried out by the upper trapezius. Conversely, it may also be detrimental in case of recurrent pain as it contributes to increasing the load to the other muscles and could explain the spreading of pain seen in clinical conditions. All in all, this set of studies highlights the role of muscle pain in altering the muscle activation pattern during computer work and thereby increasing the potential risk of developing WMSD.

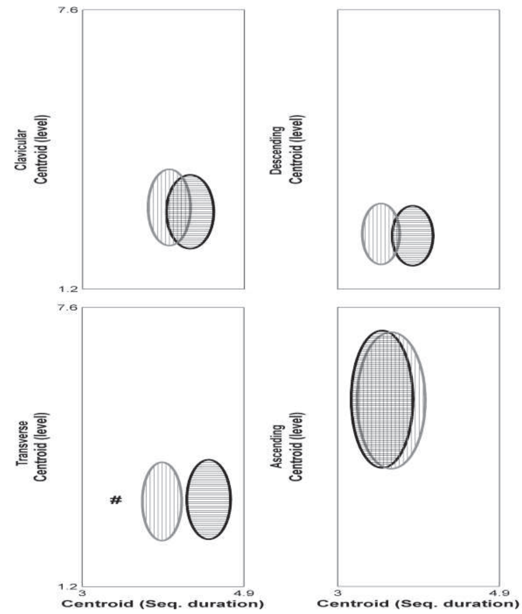

Figure1. Centroid of exposure variation analysis (EVA) in the 6-by-8 plane of sequence duration and exposure level categories (Study I) for clavicular, descending, transverse and ascending trapezius. Center and vertices of ellipses indicate the mean and standard error of EVA centroid, respectively. The black and gray ellipses represent the passive and active pause, respectively. # p<0.05 along sequence duration.

Table 1. Location of exposure variation analysis centroid (EVA) in the plane of sequence duration (SqD) and exposure level (ExL) categories (Studies II and III) for the clavicular, descending, transverse and ascending trapezius. Significant effects are bolded.

			Study II		Study III		
			No pain	Pain	Before	Immediate after	24 h after
Clavicular	C_{SqD}	Passive	**4.4 (0.4)**	**4.5 (0.4)**	**5.6 (0.1)**	4.9 (0.2)	4.7 (0.3)
		Active	**3.7 (0.4)**	**3.7 (0.2)**	**4.6 (0.2)**	4.7 (0.2)	4.9 (0.2)
	C_{ExL}	Passive	**1.8 (0.5)**	**1.8 (0.5)**	**2.2 (0.6)**	1.9 (0.5)	**2.0 (0.6)**
		Active	**2.1 (0.6)**	**2.0 (0.6)**	**2.7 (0.7)**	2.1 (0.6)	**2.4 (0.7)**
Descending	C_{SqD}	Passive	**5.0 (0.3)**	**4.5 (0.3)**	5.1 (0.2)	**5.7 (0.1)**	**5.3 (0.2)**
		Active	**3.7 (0.2)**	**3.3 (0.2)**	5.0 (0.2)	**4.9 (0.2)**	**4.7 (0.2)**
	C_{ExL}	Passive	1.3 (0.4)	1.6 (0.4)	**1.6 (0.4)**	1.3 (0.3)	1.5 (0.4)
		Active	1.6 (0.5)	1.7 (0.5)	**1.9 (0.5)**	1.4 (0.4)	1.7 (0.4)
Transverse	C_{SqD}	Passive	**4.7 (0.3)**	4.6 (0.5)	5.1 (0.2)	5.1 (0.3)	4.9 (0.3)
		Active	**3.3 (0.4)**	4.0 (0.3)	4.9 (0.2)	4.6 (0.3)	4.6 (0.2)

	C_{ExL}	Passive	2.0 (0.6)	2.3 (0.6)	2.7 (0.7)	2.5 (0.7)	2.6 (0.7)
		Active	1.9 (0.5)	2.2 (0.6)	2.6 (0.7)	2.6 (0.7)	2.6 (0.7)
Ascending	C_{SqD}	Passive	**4.0 (0.5)**	**3.6 (0.4)**	4.5 (0.3)	4.4 (0.2)	4.4 (0.3)
		Active	**3.4 (0.4)**	**2.7 (0.3)**	4.5 (0.3)	4.4 (0.2)	4.2 (0.3)
	C_{ExL}	Passive	4.3 (1.2)	4.9 (1.4)	4.8 (1.3)	4.8 (1.3)	4.7 (1.3)
		Active	4.3 (1.2)	4.8 (1.4)	4.8 (1.3)	4.7 (1.3)	4.6 (1.3)

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