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Effects of visually demanding near work on trapezius muscle activity

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ABSTRACT

Poor visual ergonomics is associated with visual and neck/shoulder discomfort, but the relation between visual demands and neck/shoulder muscle activity is unclear. The aims of this study were to investigate whether trapezius muscle activity was affected by: (i) eye-lens accommodation; (ii) incongruence between accommodation and convergence; and (iii) presence of neck/shoulder discomfort. Sixty-six participants (33 controls and 33 with neck pain) performed visually demanding near work under four different trial-lens conditions. Results showed that eye-lens accommodation *per se* did not affect trapezius muscle activity significantly. However, when incongruence between accommodation and convergence was present, a significant positive relationship between eye-lens accommodation and trapezius muscle activity was found. There were no significant group-differences. It was concluded that incongruence between accommodation and convergence is an important factor in the relation between visually demanding near work and trapezius muscle activity. The relatively low demands on accommodation and convergence in the present study imply that visually demanding near work may contribute to increased muscle activity, and over time to the development of near work related neck/shoulder discomfort.

1. Introduction

Poor visual ergonomics, such as inadequate lighting, debilitating glare, incorrect eyeglass correction, close viewing distance, demanding 3-D viewing, full time microscopy, or long periods of work without breaks, increase visual discomfort (Blehm et al., 2005; Kreczy et al., 1999; Wee et al., 2012; Wolkoff et al., 2012; Yan et al., 2008). Visual discomfort is a common symptom among professional users of information technology, and has also been linked to neck/shoulder discomfort, which is another common concurrent complaint (Bhanderi et al., 2008; Cagnie et al., 2007; Helland et al., 2008; Richter et al., 2011b; Robertson et al., 2013; Rosenfield, 2011; Wiholm et al., 2007; Woods, 2005).

To bring an object (e.g. a computer screen or a smart phone) at a near distance into clear focus and single vision requires three mechanisms in the eye to work together: (1) an increase in the optical power of the eye-lens (eye-lens accommodation), (2) an inward movement of the eyes (convergence), and (3) a change in pupil size. Eye-lens accommodation enables a clear image from objects at different distances, and is achieved by activity in the ciliary muscles. Convergence is necessary to maintain single vision during normal binocular viewing (i.e. viewing with both eyes), and is controlled by the extra ocular muscles. The size of the pupil changes the depth of focus, and is controlled by the iris (Kaufman et al., 2003). Under normal viewing conditions, accommodation and convergence are synergistically coupled. When a blurred object is brought into focus, both accommodation and convergence are active to counteract the blurred image. Similarly, both convergence and accommodation counteract double vision. (Miles et al., 1987). The process of keeping a close object in focus is only possible if the eyes are stationary with respect to the object in focus. The vestibulo-ocular reflex is an important mechanism to keep the gaze stable. If, for example, the head is turned to the right, the reflex causes the eyes to move to the left, in order to keep the gaze stable at the object in focus (Kaufman et al., 2003).

A possible explanation for the link between visual discomfort and neck/shoulder discomfort is a tightly coordinated relationship between eye and neck/shoulder muscles to stabilize gaze (Bizzi et al., 1971; Corneil et al., 2008; Richter et al., 2011a; Tu and Keating, 2000). Such a relationship is perhaps most evident when the vestibulo-ocular reflex produces an eye-movement in the opposite direction to a head movement. The vestibulo-ocular reflex is predominantly a vision stabilizer that activates extra-ocular muscles (Brandt and Dieterich, 1999; Wurtz, 2008). However,

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whether there is a reflex or physiological mechanism which acts in the opposite direction, that is increasing activity in head and neck stabilizing muscles in response to visually demanding tasks, is unclear (Richter et al., 2011a; Richter and Forsman, 2011). At present, the support for a relationship between visual demands and neck/shoulder muscle activity during visually demanding near work is inconclusive (Brewer et al., 2006; Lie and Watten, 1987; Richter et al., 2011a; Simons, 1943).

To date, only a few studies have explored the functional aspects of eye–neck–shoulder interactions. Lie and Watten (1987) showed increased neck/shoulder muscle activity as a function of visual demands during near work, although they did not measure whether participants met the demands of the visual task (i.e. whether they had sufficiently activated their eye muscles). In a more recent laboratory study compliance with a demanding near work task was assessed by measuring eye-lens accommodation with an auto refractor (Richter et al., 2010). The study showed that accommodative responses during the near work task were associated with trapezius muscle activity. However, the visual demands were high and not comparable to normal every day computer work demands. Therefore, it remains unknown if visual demands occurring during normal every-day computer work are associated with trapezius muscle activity.

In a binocular minus-lens condition, Richter et al. (2011a) showed that trapezius muscle activation started to increase when subjects began to compensate for experimentally induced blur, i.e. subjects who had increased eye-lens accommodation, also exhibited higher levels of muscle activity. One hypothesis arising from this result is that eye-lens accommodation, through ciliary muscle activity, is a mediating mechanism behind increased trapezius muscle activity. One way to study the isolated effect of accommodation is through monocular viewing (i.e. viewing with one eye). Monocular viewing does not require convergence to be actively involved when an object at near is brought into focus. Successful performance under monocular viewing involves only sustained contraction of the ciliary muscles to overcome blur while the convergence is inactive (Franzén et al., 2000). Another hypothesis arising from the study by Richter et al. (2011a) is that incongruence between accommodation and convergence give rise to trapezius muscle activation. Incongruence occurs when there are conflicting demands on accommodation and convergence. It has been shown that incongruence can cause work-related visual fatigue (Birnbaum, 1984; Ukai and Howarth, 2008), and in the clinic, convergence insufficiency is associated with musculoskeletal discomfort (Borsting et al., 2003; Sucher, 1994). Incongruence between accommodation and convergence can be created by making subjects binocularly focus at an object at near through minus lenses. The minus-lenses require increased accommodation, while convergence remains fixed on the object. Increased accommodation leads to increased incongruence between accommodation and convergence responses (Miles et al., 1987).

Several studies have reported that computer users with neck pain have increased neck/shoulder muscle activation under a variety of working conditions (Szeto et al., 2005a,b,c). Increased muscle activity amplitude and reduced rest time in motor units during computer work among subjects with neck pain has also been reported (Hägg and Åström, 1997; Thorn et al., 2007). Whether persons suffering from prolonged neck pain employ different levels of neck/shoulder muscle activity than healthy controls in response to visually demanding near work has not yet been fully explored (Hoyle et al., 2011; Richter et al., 2011a; Treaster et al., 2006; Valentino and Fabozzo, 1993).

The overall purpose of this study was to use a computer based task with realistic visual demands to investigate whether sustained periods of accommodation and convergence affects trapezius muscle activity. The first aim (i) was to investigate whether eye-lens accommodation, through ciliary muscle activity, is a mediating mechanism behind increased trapezius muscle activity. The second aim (ii) was to investigate if incongruence between accommodation and convergence affects trapezius muscle activity. And the third aim (iii) was to investigate whether presence or absence of neck/shoulder discomfort affects trapezius muscle activity during visually demanding near work.

2. Materials and methods

2.1. Participants

Thirty-three participants with neck pain (median age 39, range 20–47, 27 females and 6 males) and 33 healthy age and gender matched controls (median age 37, range 19–47, 27 females and 6 males) were recruited. The inclusion criteria for the neck group were experience of neck/shoulder pain during the last 12 weeks, and 10–68 points on the Neck Disability Index (Vernon and Mior, 1991). The median score on Neck Disability Index was 26 (range 10–50). To exclude participants with eye diseases, the participants were examined by a licensed optometrist. No one was excluded due to eye diseases. The optometrist also assessed visual acuity for distance with a Snellen chart. All participants were recruited through advertisement. Informed consent was obtained from each participant and the study was approved by the Uppsala University Medical Ethical Review Board, Uppsala, Sweden (2006:027).

2.2. Procedure

Participants visited the laboratory on one occasion and undertook visually demanding near work at a computer screen. A standardized vision task was performed four times; each time with different trial-lenses mounted on trial frames. The session started with preparations, where refraction errors were measured with an auto refractor (Power Refractor R03, Plusoptix, Nürnberg, Germany) (Blade and Candy, 2006) and trial-lenses for the experiment were selected. Any spherical refractive errors (±0.25 D) detected were corrected with trial-lenses during the experiment. Thereafter the participant's dominant eye was determined using a modified version of Dolmans method. Participants were instructed to form a hole using both hands, hold the hands with straight arms in front of the eyes, and focus on a target approximately 3 m away, through the hole. The participant then closed one eye at the time, and when the dominant eye was closed, the participant could not see the target (Cheng et al., 2004; Fink, 1938). Binocular accommodation ability was measured with the RAF ruler (Clement Clark International, Harlow, Essex, UK) (Antona et al., 2009; Rosenfield and Cohen, 1996) with the eyeglass correction needed according to the auto refractor. Next, the participant was set-up with electrodes for electrocardiography (ECG) and electromyography (EMG). ECG was collected through two disposable pre-gelled general-purpose snap electrodes placed laterally on each sixth rib (EL503, BIOPAC Systems, Inc., Santa Barbara, CA, USA). EMG was collected bilaterally from the descending part of the upper trapezius muscles with two disposable Ag-electrodes (Neuroline 725, Ambu A/S, Ballerup, Denmark) gelled with 0.5% saline-based electrode paste (GEL101, BIOPAC Systems, Inc., Santa Barbara, CA, USA). The electrodes were centered 20 mm lateral to the midpoint of the line between vertebra C7 and acromion, with a center-to-center distance of 20 mm. A reference electrode was placed on C7 (Mathiassen et al., 1995). At each recording site the skin was rubbed with fine abrasive paper and cleaned with alcohol. Thereafter, each participant did three normalization trials using submaximal reference contractions (Mathiassen et al., 1995). The trials were 15 s in duration interspaced by 30 s of rest. Reference contraction used was 90° abduc-