Work 41 (2012) 3379-3384
DOI: 10.3233/WOR-2012-0611-3379
IOS Press

Temporal aspects of increases in eye-neck activation levels during visually deficient near work

Hans O. Richter[a,*], Lodin Camilla[a] and Mikael Forsman[a,b]
[a]*Center for Musculoskeletal Research, Department of Occupational and Public Health Sciences, Faculty of Health and Occupational Studies, University of Gävle, SE-801 76 Gävle, Sweden.*
[b]*Division of Occupational and Environmental Medicine, Department of Public Health Sciences, Karolinska Institutet, SE-171 76 Solna, Sweden.*

Abstract. In an experimental study two levels of oculomotor load were induced via optical trial lenses. Trapezius muscle activity was measured with bipolar surface electromyography and normalized to a submaximal contraction. Sixty-six subjects with a median age of 36 (range 19–47, std 8) viewed a black and white Gabor grating (5 c/deg) for two 7-min periods monocularly through a 0 D lens or binocularly through -3.5 D lenses. The effect of time was separately regressed to EMG in two different subgroups of responders: a High-Oculomotor-Load (HOL) and a Low-Oculomotor-Load (LOL) group. A linear regression model was fitted on group level with exposure time on the x-axis and normalized trapezius muscle EMG (%RVE) on the y-axis. The slope coefficient was significantly positive in the -D blur condition for only the HOL subgroup of responders: $0.926 + \text{Time}_{\text{min 1-7}} \times 0.088$ ($p = 0.002$, r^2=0.865). There was no obvious sign of this activity to level off or to stabilize. These results suggest that professional information technology users that are exposed to a high level of oculomotor load, during extended times, are at an increased risk of exhibiting an increased trap.m. activity.

Accommodation, Computer work, EMG recordings, Eye movements, Motor control, Near work

1. Introduction

According to our research hypothesis, an increase in visual loads, due to deficient optical/physiological aspects of the near work (e.g., incorrect optometric correction or uncorrected visual error, deficient work station layout, insufficient rest periods, etc), causes not only eye symptoms, but also a parallel increase in musculoskeletal load and neck/scapular area symptoms. This might be due to hard-wired sensorimotor reflexes and/or a generally very tight functional coupling between the eye-neck/scapular area effectors [1]. Recent work has shown that extended periods of large amplitudes of ocular accommodation, when the ciliary muscle is highly contracted, are coupled to a bilateral increase in static trap.m. activity level.

Previous results [1,2] showed that increasing the tone of the ciliary muscle, by placing an optical minus lens in front of the eye and at the same time seeing to that the lack of focus incurred is compensated for by increasing eye-lens accommodation, was significantly coupled to a bilateral increase in trapezius muscle activity. These results suggested that sustained eye-lens accommodation has the ability to regulate gaze by triggering a postural stabilization response. The temporal aspects of exposure to deficient visual ergonomics so far have not been addressed.

The accommodation/vergence system, when exposed to deficient optical/ physiological aspects of the near work, might exhibit different types of adaptive responses and/or time dependencies, each and

*Corresponding author. E-mail: hrr@hig.se

one which theoretically could impact on the trapezius muscle activity in its own unique way. An increase in trapezius muscle activity could e.g. be associated with a declining accommodative response, a constant high level of eye-lens accommodation or a successive increase in eye-lens accommodation. The trapezius muscle activity similarly may exhibit a number of different dependencies on oculomotor load. It is of interest to learn more about the temporal pattern of such eye-neck/scapular area interactions. A secondary consideration in this context is that measurements under laboratory conditions by necessity are rather limited in time relative to "real-world" exposure conditions. Hence, any experimental musculoskeletal effects detected in the laboratory, due to the deficient near work condition, should be extrapolated to more ecologically valid (i.e., more prolonged) exposure durations occurring "in real life". Only then might it be possible to evaluate the magnitude of the musculoskeletal activation caused by oculomotor load in its own right.

The objective of the current laboratory study was to quantify the effects of exposure to high levels of oculomotor load on the magnitude and temporal pattern of eye-neck/scapular area coupling and to discuss exposure levels and durations occurring "in real life" in relation to the results. Only a partial report is given here.

2. Methods

2.1. Subjects

Sixty-six participants (median age 36, range 19-47) participated in the study. The study followed ethical committee guidelines and informed consent was given by each subject before participation in this study. The study was approved by the Uppsala University Medical Ethical Review Board.

2.2. Optometric eye exam

To avoid inclusion of subjects with eye disease, all subjects but three were examined by an authorized optician. To ensure that the defocus stimulus during the experimental set-up was task-appropriate and similar for all subjects, ammetropias were measured in the laboratory with an auto refractor (Power Refractor R03, Plusoptix, Nürnberg, Germany). Any detected spherical ammetropias (±0.25D) were corrected with trail lenses during the experiment.

2.3. Crystalline eye-lens accommodation

Continuous sampling was made with the auto refractor during fixation task. The optometer records accommodation, convergence and pupil size at 25 Hz. The range of measurement for accommodation is -8.0 D to +6.0 D, with ±0.25 D accuracy, depending on pupil size and direction of pupil axes. The pupil size is specified in millimeters and the smallest pupil size the camera can detect is 2.8 mm. The recorded accommodation was transformed into response diopters.

2.4. Contrast sensitivity

The subjects viewed a black and white Gabor grating (5 c/deg) (Cambridge Research System) monocularly through a ±0 D lens or binocularly through -3.5 D lenses at a distance of 65 cm (1.54 D) for 7 minutes. The gaze angel was approximately 15° downwards. Individual Michelson estimates of contrast-sensitivity ($C=L_{max}-L_{min})/\ (L_{max}+L_{min})$/were obtained in using the Bekésèy tracking method. Before the fixation task started, the contrast of the pattern was zero and the pattern was invisible to the subject. To start the task, the subject pushed a low force button (hand held) and the contrast of the pattern increased (speed 0.8 units/s.). When the subject perceived the pattern, he/she pushed the button and the contrast froze for a short time. After a short pause of random length (1.5-3.5 s), the contrast of the pattern decreased, and when the pattern was invisible to the subject, he/she pushed the button. This was repeated several times during the task that continued for seven minutes.

2.5. Electromyography recordings

Electromyography (EMG) was collected bilaterally during baselines and fixation from the descending part of the upper trapezius muscle. The skin was cleansed with alcohol and rubbed with a fine cloth. Two disposable Ag–AgCl electrodes (Neuroline 725, Ambu A/S, Ballerup, Denmark) were placed along the direction of the muscle fibers with a centre-to-centre distance of 2 cm. The electrodes were centred 2 cm lateral of the mid-point of the line connecting vertebra C7 and acromion. Electrocardiography (ECG) was recorded to facilitate filtering of heart signal disturbances in the EMG signals. The EMG and ECG signals were amplified, band-pass filtered (30–3000 Hz) and sampled at 2000 Hz (EMG100C, BIOPAC Systems Inc., Santa Barbara, CA, USA). The EMG data were normalized to the root-mean-square (RMS) value of the middle 10 s of 15-s submaximal contractions (the reference voluntary electrical activity; RVE). During the reference contractions both arms were straight and horizontal in abduction [3], which corresponds to 15–20% of a maximal voluntary contraction. The mean value of three repeated RVE contractions was used to normalize and express the measurement data in %RVE. The results of each minute were normalized to submaximal reference contractions. The EMG recordings were RMS-converted in 100-ms windows and quadratically adjusted for noise (the lowest 400-ms moving RMS value of a recording during relaxation). The 10th percentiles of each minute's RMS values were chosen as an indicator of muscular activity level. For more details see[1].

2.6. Procedure

During the experiment, the subject sat leaned back in an office chair in a dark room. The chair was adjusted to the subject's morphology and the neck was supported. Because the eyes had to be aligned to the measurement axis of the optometer, movements from the neck/scapular area were not allowed. The participants performed the fixation task in two conditions, the order of which was counterbalanced between the subjects. These conditions were preceded by a three minute baseline when the subject rested with eyes closed. The subjects viewed the grating for two 7-min periods monocularly through a 0 D lens, i.e. only the correction needed (*monocular neutral*) or binocularly through -3.5 D lenses (*binocular minus)*. In the monocular condition, a black lens was mounted in the trial frame in front of the non-dominant eye. In the *binocular minus* condition, the spherical power of the condition lens was -3.5 D, together with the distance to the screen (1.5 D) the ocular load induced was 5 D. To overcome the induced blur in this condition, and to get a sharp image of the pattern, the subject were required to sustain contraction in the ciliary muscle corresponding to 5 D change of optical power in the crystalline eye lens. In condition *monocular neutral*, the induced ocular load equaled the distance to the screen, i.e. 1.5 D.

2.7. Data processing

Subjects were excluded due to poor EMG signal quality or failing refraction data. If the baseline EMG RMS value of one trapezius (left or right) was higher than 2.5%RVE, that side was excluded and the analyses were conducted on EMG-values from the remaining side.

2.8. Statistical tests

Response-diopters during minute 1-7 were first graphically displayed. Changes in trapezius muscle EMG as a function of time and averaged level of oculomotor load (pooled over minutes 1-7) was next assessed using linear regression analysis. All statistical tests on EMG were run on a mean of left and right trapezius using the 10^{th} percentile %RVE. A high and a low subgroup of oculomotor responders were created by dichotomizing the variable response diopters in each experimental condition. The regression analysis was conducted separately on these two subgroups of responders. Statistical analyses were performed with PASW 18.0 for Windows (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Response diopters

The group averaged amplitude of accommodation across time during the neutral condition ranged between 1.39 – 1.54. The difference between the two subgroups of responders was marginal. The averaged amplitude of accommodation during the minus condition ranged between -0.96 to +2.33 D in the LOL-group (N=24) and +2.38 to +5.25 D in the HOL-group (N=27). On the average the HOL group used 28% of their accommodative amplitude in the neutral condition (range 17-47) and 48% in the blur condition (range 21-86). See Fig. 1-2.

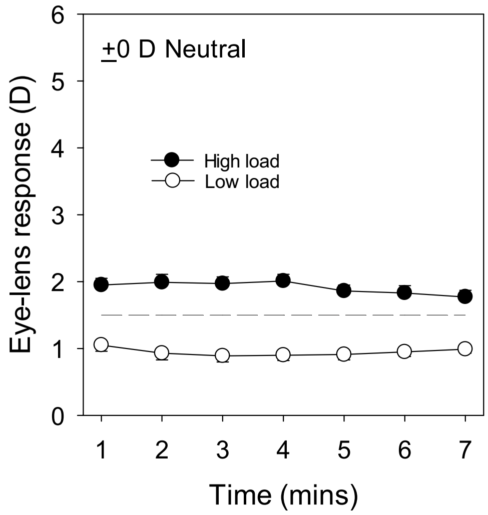

Figure 1. Averaged amplitude of eye-lens response in the monocular neutral condition for the high and low subgroup of responders. Stippled line equals stimulus diopters

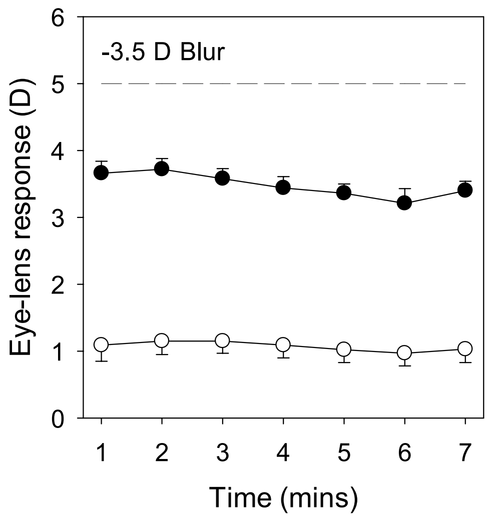

Figure 2. Averaged amplitude of eye-lens response in the binocular minus condition for the high and low subgroup of responders. Conventions as in Fig. 1

The overall convergence response (pooled across time) averaged 1.46 D in the monocular neutral condition (std 0.60) and 0.98 D in the binocular blur condition (std 0.61).

Age was negatively correlated with eye-lens response diopters during the binocular minus condition (r_{xy} -0.566, $p < 0.0001$). The median age in the HOL subgroup of responders was 31 yrs. (range 19-47) and 40 yrs. (range 21-47) in the LOL subgroup.

3.2. Spatial contrast sensitivity

The group averaged amplitude of spatial contrast sensitivity during the neutral condition varied between 0.03 – 0.93. The group averaged amplitude of contrast sensitivity during the minus blur condition ranged between 0.02 – 0.71 and was highly correlated to response diopters, the latter which accounted for 50-38 % of the variance in the contrast sensitivity data ($p < 0.0001$).

3.3. Effect of eye-lens accommodation on trapezius muscle activity

During the neutral control a relatively small linear increase in EMG as a function of time could be observed in the HOL subgroups of responders = 0.929 + $\text{Time}_{\text{min } 1\text{-}7}$ x 0.04 ($p = 0.015$, $r^2 = 0.724$). In the binocular minus condition the HOL-group exhibited a more pronounced linear increase in group averaged EMG magnitudes = 0.926 + $\text{Time}_{\text{min } 1\text{-}7}$ x 0.088 ($p = 0.002$, $r^2=0.865$). There was no obvious sign of the group activity to level off or to stabilize. In contrast, the LOL-groups exhibited a none significant trends in their averaged $\text{EMG}_{\text{min } 1\text{-}7}$ ($p > 0.05$). See Fig. 3-4.

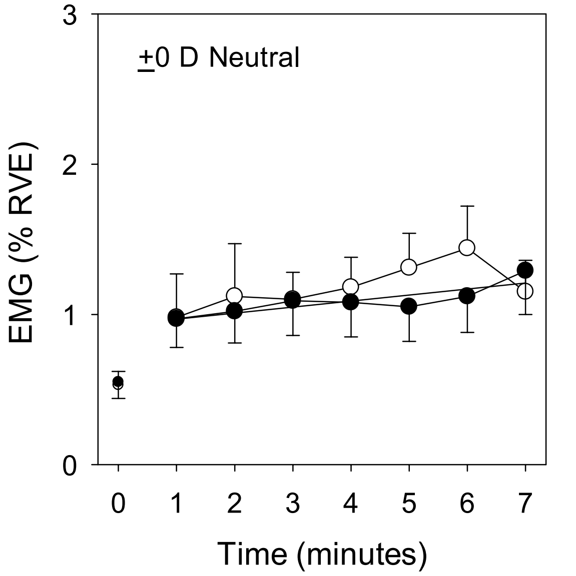

Figure 3. Averaged trapezius muscle EMG across time during the monocular neutral condition (baseline EMG activity denoted in the lower left corner). Conventions as in Fig. 1

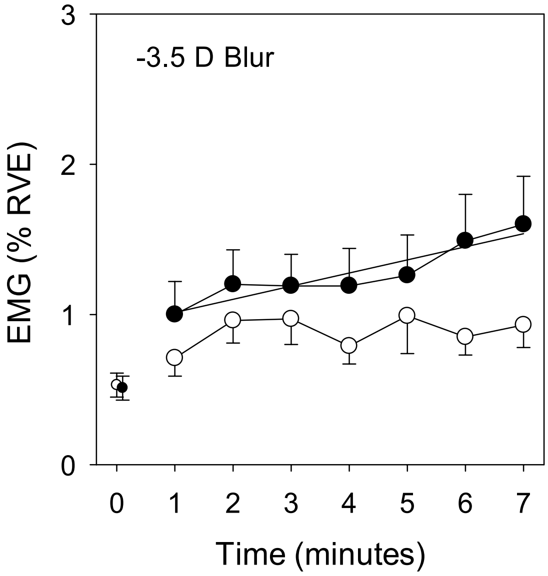

Figure. 4. Averaged trapezius muscle EMG across time during the binocular minus condition (baseline EMG activity denoted in the lower left corner). Conventions as in Fig. 1

4. Discussion

The results from this study suggest that professional information technology users that are exposed to a high level of oculomotor load, during extended times, are at an increased risk of exhibiting an increased trap.m. activity.

Eye-lens/convergence response diopters on the average were task appropriate during the neutral viewing condition. The relatively tight relationship between response diopters and contrast sensitivity in the minus condition was expected and provides a measure of internal validation of the data.

The goal of imposing strain on the accommodation/vergence system in the minus lens condition was achieved in approximately half of the study sample. The level of load utilized was purposefully exaggerated relative exposure levels resulting from ordinary near-work.

The absences of a systematic increase in EMG activity in the LOL-group in the neutral experimental condition suggest a lack of an effect from the constrained sitting posture. The increase in EMG activity in the HOL-subgroup of responders suggests that a small but systematic effect from oculomotor load occurred even in the neutral experimental condition.

The absences of a systematic increase in EMG activity in the LOL- group during the minus condition could suggest that defocus blur *per se* does not give rise to EMG increases. The increase in EMG observed in the HOL- group point to sustained eye-lens activity as a cause behind the EMG increases.

Extrapolated group average EMG following simulated exposure up to 60 minutes was in the final analysis predicted for the two subgroups of responders which were exposed to high levels of oculomotor loads using the parameter estimates obtained from the previous analyses. Predicted group average EMG activity following 60 minutes exposure in the HOL subgroup of responders were 3.30% (%RVE) (95% CI: 1.52 – 5.14) in the neutral condition. Predicted group average EMG activity following 60 minutes exposure in the HOL subgroup of responders in the minus condition was almost double, namely 6.21% (%RVE) (95% CI: 3.63 – 8.72).

Acknowledgements

The research reported in this article was supported by grants from the Swedish Research Council and the Swedish Council for Working Life and Social Research (2005-0488 and 2009-1761).

References

[1] H.O. Richter, T. Bänziger and M. Forsman, Eye-lens accommodation load and static trapezius muscle activity, European Journal of Applied Physiology, 111 (2011), 29-36.
[2] H.O. Richter, T. Bänziger, S. Abdi and M. Forsman, Stabilization of gaze: a relationship between ciliary muscle contraction and trapezius muscle activity, Vision Research 23 (2010), 2559-2569.
[3] S.E. Mathiassen, J. Winkel and G.M. Hägg, Normalization of surface EMG amplitude from upper trapezius muscle in ergonomic studies – A review, Journal of Electromyography and Kinesiology 5 (1995), 197–226.
[4] M. Rosenfield, Computer vision syndrome: a review of ocular causes and potential treatments, Ophtalmic and Physiological Optics 31 (2011), 502-5.