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Physical workload, trapezius muscle activity, and neck pain in nurses' night and day shifts: A physiological evaluation

Corinne Nicoletti [a,b,*], Christina M. Spengler [b,c], Thomas Läubli [a,d]

[a] Department of Health Sciences and Technology, ETH Zurich, Sensory-Motor Systems Lab, 8092 Zurich, Switzerland
[b] Exercise Physiology Lab, Institute of Human Movement Sciences and Sport, ETH Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland
[c] Zurich Center for Integrative Human Physiology (ZIHP), University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland
[d] Holistics Prosthetics Research Center, Kyoto Institute of Technology, Matsugasaki, Sakyo-ku 606-8585, Japan

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ABSTRACT

The purpose of this study was to compare physical workload, electromyography (EMG) of the trapezius muscle, neck pain and mental well-being at work between night and day shifts in twenty Swiss nurses. Work pulse (average increase of heart rate over resting heart rate) was lower during night (27 bpm) compared to day shifts (34 bpm; $p < 0.01$). Relative arm acceleration also indicated less physical activity during night (82% of average) compared to day shifts (110%; $p < 0.01$). Rest periods were significantly longer during night shifts. Trapezius muscle rest time was longer during night (13% of shift duration) than day shifts (7%; $p < 0.01$) and the 50th percentile of EMG activity was smaller ($p = 0.02$), indicating more opportunities for muscle relaxation during night shifts. Neck pain and mental well-being at work were similar between shifts. Subjective perception of burden was similar between shifts despite less physical burden at night, suggesting there are other contributing factors.

1. Introduction

Musculoskeletal disorders (MSDs) commonly affect nurses (Harcombe et al., 2009; Long et al., 2012; Smith et al., 2004), possibly due to the strenuous workload (Baptiste, 2011; Heiden et al., 2013) and irregular shift schedule that are an integral part of nursing (Caruso and Waters, 2008). The financial consequences of MSDs are substantial and the direct cost of low back pain in Switzerland accounts for 6.1% of total health care expenses (Wieser et al., 2011). MSDs have a detrimental effect on occupational and private activities and thereby reduce quality of life (Scuffham et al., 2010). This might explain the relatively short careers of Swiss nurses, who work for an average of only 13.5 years in nursing (Dolder and Grünig, 2009).

The most common MSDs in nurses are low back and neck pain. The prevalence of neck pain is between 50 and 60% (Harcombe et al., 2009; Warming et al., 2009), and a prevalence of even 83% has been reported (Long et al., 2012). Several studies have reported that sustained trapezius muscle activity correlates with the presence of neck pain or may predict the development of neck pain (Aaras, 1994; Hanvold et al., 2012). The commonly used method to evaluate trapezius muscle activity is surface electromyography (EMG, Mathiassen et al., 1995). The most important determinant for neck pain was reported to be a lack of rest time, demonstrated by no periods without measurable activity in EMG (Hagg and Astrom, 1997; Veiersted et al., 1993). This concept is based on the so-called Cinderella hypothesis (Hagg, 1991) which states that during a prolonged low-level activity the same muscle fibers are always active. Such prolonged low-level activities are frequently observed in the trapezius muscle (Ostensvik et al., 2009). If rest time is lacking, these so-called Cinderella fibers may become overloaded (Hagg, 1991). Early histological studies of trapezius muscle found changes at the cellular level in subjects suffering from neck pain (Lindman et al., 1991). Newer studies found evidence for the malfunctioning of single muscle cells (Sjogaard et al., 2010) but additional mechanisms, such as sensitization, are also assumed to play a role (Visser and van Dieen, 2006). The discussed insufficient rest time is strongly correlated with the type of workload and mental stress and neck pain was shown to be correlated with shift work (Elfering et al., 2008; Farina et al., 2008; Läubli and Müller, 2009).

The type of workload has an effect on prolonged periods of low-level activity. During a variable load the trapezius muscle demonstrates a shift of activity (Falla and Farina, 2007), while no shift of

* Corresponding author. Department of Health Sciences and Technology, ETH Zurich, Sensory-Motor Systems Lab, ML G57, Sonneggstrasse 3, 8092 Zurich, Switzerland. +41 44 632 87 69.
E-mail addresses: corinne.nicoletti@hest.ethz.ch (C. Nicoletti), christina.spengler@hest.ethz.ch (C.M. Spengler), tlaeubli@ethz.ch (T. Läubli).

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activity occurs during a constant load. Without a shift of activity and if the duration is long enough overexertion results (Farina et al., 2008). During standardized stress tasks in laboratory experiments, Sjogaard et al. (2010) reported higher EMG levels in females with trapezius myalgia compared to females without myalgia, and the relative load was higher in females with trapezius myalgia. In an earlier study where assessments were conducted at the subjects' work places using the same case definitions, Larsson et al. (2008) found no difference in EMG measurements between cases and controls. The authors suggested that under normal working conditions at the actual workplace, cases and controls work at the same relative load, leading to the same strain for cases and controls.

Mental stress increases the activity of the trapezius muscle (Nimbarte et al., 2012) and is suggested to cause prolonged low-level activity of muscles which prevents muscle relaxation and regeneration of the allostatic system (Sjogaard et al., 2000). Elfering et al. (2008) found a correlation between MSDs and the stress hormones epinephrine and norepinephrine. Time pressure also causes higher levels of trapezius muscle activity (Birch et al., 2000).

Rotating shift work is a well-known risk to health (Conway et al., 2008; Costa, 1996) and the associated health risks are assumed to be caused by a disruption of the circadian rhythm (Bonde et al., 2012). Estryn-Behar et al. (2008) showed that nurses working shifts that included night shifts demonstrated a higher risk of burnout than nurses not working night shifts, while nurses with regular day work or shift work excluding night shifts did not differ for this risk. Läubli and Müller (2009) showed an association between night shifts and MSDs. In addition, shift work increases the risk of work-family conflict (Camerino et al., 2010), which in turn is associated with neck pain (Hammig et al., 2011; Kim et al., 2013).

The aim of the present study was to investigate physical workload and trapezius muscle activity during night and day shifts and their association with neck pain and mental well-being at work in nurses. Based on the burden associated with the disruption in the circadian rhythm and the fact that in Switzerland nursing staff is reduced during night shifts, we assumed that night shifts would be associated with more burden than day shifts. Therefore, we hypothesized that workload and trapezius muscle activity would be greater during night than day shifts and that night shifts would be associated with more neck pain and worse mental well-being at work.

2. Methods

2.1. Participants

Twenty female nurses (aged 33.5 ± 10.1 years) employed at four Swiss secondary care hospitals of similar size participated in the study. They were recruited through the head of the unit or through personal contacts. Participants worked in an orthopedic clinic ($n = 11$), in intensive care ($n = 6$), the emergency department ($n = 2$), or in the post anesthesia care unit ($n = 1$). On average, night shifts were of longer duration than day shifts. All participants had an education equal to a registered nurse and had worked for at least one year in the present job, either part-time (≥80%) or full-time. Exclusion criteria were: skin disease; clinical findings of MSDs; cardiovascular, psychological or neurological disease; intake of muscle relaxants or any other medication. The Ethical Committee of the canton of Zurich (Switzerland) approved the study and all participants gave their written informed consent.

2.2. Apparatus

Bipolar surface EMG (PS11-UD, THUMEDI GmbH & Co. KG, Thum-Jahnsbach, Germany) was used to record the activity of the descending part of the trapezius muscle of the dominant arm at a sampling rate of 2048 Hz. Before analysis data was filtered with an analog 3rd order high pass filter with a cut off frequency of 4 Hz (−3 dB) and a 10th order anti-aliasing filter adjusted to 650 Hz (−3 dB). Subsequently, a digital high pass filter at 12 Hz, a digital band replacement filter at 50 Hz, 100 Hz, 150 Hz, 200 Hz, 250 Hz, 300 Hz and 350 Hz, and two algorithms which used low and very low frequencies (7–13 Hz and 0.5–1.7 Hz) were applied. The flatness (ripple) of the transfer function from 20 Hz to 500 Hz of the device is ±0.1 dB and the intrinsic effective noise of the entire system was about 250 nV (12–650 Hz).

The electrodes used were pre-gelled Ag/AgCl electrodes (35 × 26 mm, Kendall Arbo, Covidien, England) and the subjects' skin was prepared with abrasive paste (Nuprep, Weaver and Company, Aurora, CO, USA). To ensure that the position of the electrodes remained the same for all three measurements of a participant, the distance from the acromion to the midpoint of the electrodes was noted.

A two-electrode electrocardiogram (ECG) was acquired by the PS11-UD to remove ECG artifacts by a template-based algorithm (Clancy et al., 2002). The heart rate calculated from the ECG was used for the classification of work activities. An accelerometer and a position sensor were also part of the measurement device PS11-UD.

2.3. Procedure

For each participant measurements were taken during three shifts (one night shift and two day shifts on the same ward). The order of the shifts was randomized. The night shift selected was the second in a row of night shifts, and on one occasion the third.

On each shift participants were asked to measure their resting heart rate on waking. Before starting work, the measurement devices were applied. Based on the recommendation of SENIAM (2012) the EMG electrodes were placed on a line from the acromion to the cervical vertebra 7 (C7). The midpoint of the two electrodes was 2 cm medial of the midpoint of this line. The electrode–electrode distance was 2 cm. The reference electrode was placed on C7. For the ECG one electrode was placed on the left side of the chest wall below the breast, the other below the clavicle. The accelerometer was placed on the top third of the upper arm and was used to measure arm acceleration. The position sensor was placed on the thoracic spine allowing the assessment of trunk flexion and extension. To reduce movement artifacts the cables were taped to the skin. The recording device was worn at the waist.

At the beginning of every shift, participants performed a submaximal reference contraction, slightly modified from the description by Mathiassen et al. (1995). Participants were requested to hold their arms in a horizontal position laterally extended in 90° abduction for 20 s. This was repeated three times with a 40 s break in between. At six different time points across each shift, participants completed a diary to assess neck pain/mental well-being at work/time pressure on a scale from "1" to "5", where "1" meant "no pain"/"very stressed"/"great time pressure" and "5" meant "intense pain"/"totally relaxed"/"far too little work".

2.4. Analysis

All data were processed with Matlab R2010b. The 250 ms root mean square (RMS) of the EMG was normalized with the reference voluntary electrical activation (RVE) of the three reference contractions and given as % RVE. Thereby RVE was the mean of the averaged values from every reference contraction. All data above 1000% RVE were removed. Rest time and the 50th and 90th percentile of the activity were calculated, where rest time was defined as percentage of the shift duration below 5% RVE (based on