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Head movements during two computer work tasks assessed by accelerometry

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ABSTRACT

We investigated whether potential differences in head inclinations and accelerations for two highly similar computer work tasks could be detected using (1) a triaxial accelerometer and (2) a simulated uniaxial accelerometer.

Ten subjects' head movements were registered with a triaxial accelerometer system for two similar document-management tasks at their work place: a fully electronic document-management task and one also involving paper documents.

In situations where head movements were small, a triaxial accelerometer was able to discriminate between the different degrees of static work of the neck in terms of range of head inclinations and accelerations. A difference in head acceleration was also found by using a simulated uniaxial accelerometer. Thus, in terms of head movement and for work similar to this office work, potential dynamic differences in observationally similar work tasks can be investigated by using a triaxial accelerometer. For acceleration alone, a uniaxial accelerometer can also be used.

1. Introduction

Neck and shoulder symptoms are common among computer workers (Chiu et al., 2002; Gerr et al., 2002; Korhonen et al., 2003; Wahlstrom, 2005). Epidemiological and experimental studies have shown that lack of neck movements, i.e. static neck work, is associated with discomfort and pain (Bernard, 1997; Sluiter et al., 2001; Szeto et al., 2005). Computer work tasks may involve different degrees of static work for neck and shoulder muscles (Arvidsson et al., 2006; Laursen et al., 2002).

In order to evaluate the effects of ergonomic interventions in terms of changes of the physical load levels or in terms of the occurrence of musculoskeletal disorders, quantitative exposure data is needed (Bernard, 1997; Fallentin, 2003; Westerterp, 2009; Winkel and Mathiassen, 1994).

Accelerometers are commonly used for measuring whole body movements to estimate physical activity or energy expenditure (Chen and Bassett, 2005; Godfrey et al., 2008; Hagstromer et al., 2007; Welk et al., 2004). Accelerometers have also been used to evaluate posture and movements of single body parts, e.g. the head, back and arms (Kazmierczak et al., 2005; Leijon et al., 2005; Nordander et al., 2008). Both uniaxial and triaxial accelerometer systems with data loggers are available.

The data used in this paper were collected at a company where the occupational health service had found that a new computer work task was causing more discomfort and pain in the neck region than had the traditional computer work task. This new work task involved reading scanned, handwritten electronic documents on a computer display instead of reading from paper documents. The discomfort and pain reported by the workers when performing this new task could be due to a higher degree of static work for the head, i.e. lack of head movements when performing this specific task in comparison to before. Observational methods generally show a low correspondence with technical measurements (Takala et al., 2010). Posture may be observed with a certain precision, but direct measurements of velocity and acceleration are needed (Spielholz et al., 2001). The checklists previously used in computer work (Lindegard et al., 2003; Norman et al., 2004) have overly broad categories, which prohibit discrimination between similar tasks carried out by the same individual at the same work station.

A triaxial or even a uniaxial accelerometer might be useful for detecting whether head movements differed when performing this new specific computer work task in comparison to the traditional.

The purposes of the present study were:

1. To investigate if potential differences in head inclinations and accelerations during two similar computer work tasks could be detected using a triaxial accelerometer.

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2. To investigate if potential differences in head accelerations during two similar computer work tasks could be detected using a uniaxial accelerometer.

2. Material and methods

2.1. Subjects

To be included in the study at least 20% of the employee's work time must be devoted to this new electronic document-management task. Thirty workers fulfilled this criterion, and all had experience with both tasks. Ten persons, eight women and two men, were chosen randomly, with the restriction that three offices and both genders should be included. All consented to participate in the present study. The woman-to-man ratio was approximately representative of the work place. The mean age of the women was 49 years (range 38–60 years). The two men were 43- and 60-years old. Five subjects worked at the main office and five worked at two local offices. The study subjects could withdraw from the trial if they felt discomfort during the testing procedure, although no one chose to withdraw.

2.2. The computer work tasks

The two computer tasks studied were: 1) Electronic document management, 2) Traditional document management. Electronic document management involved reading handwritten, scanned electronic documents on one half of the computer screen and to insert data into the other half of the screen. Traditional document management involved reading handwritten paper documents placed on the work table or mounted at the side of the computer screen, and to insert data (to the computer) via the screen.

2.3. Accelerometer system

Each subject's head movements were registered with a triaxial accelerometer system (Logger technology HB, Åkarp, Sweden) while the subjects performed these two work tasks at the work place. The system can measure inclination from a vertical line (in degrees) and the acceleration (m/s^2) for up to 4 body parts (Bernmark and Wiktorin, 2002; Hansson et al., 2001, 2003). The system consists of four triaxial accelerometer sensors and a data logger with a memory card. The sensor uses a force principle, and records both movements and gravitation (g) data. The system sampling frequency is 20 Hz, which is sufficient for movement measurements (Hansson et al., 2003).

A laboratory test in a jig showed a system accuracy of 1.3° in static conditions (Hansson et al., 2001). For movements with normal to high velocities, the system can measure the inclination with high precision (Bernmark and Wiktorin, 2002).

A uniaxial accelerometer was simulated from the triaxial device by using the three spatial axes directions, *x*, *y*, and *z* separately to investigate whether a uniaxial accelerometer could be used to detect differences in head accelerations between the two work tasks. It is not possible to measure the forward/backward head inclination with a uniaxial accelerometer.

2.4. Procedure

One triaxial sensor was used in the present study. The sensor was calibrated to gravity prior to each measurement by placing each of the six sides of the sensor on a flat horizontal surface to provide a signal output corresponding to +1 g and −1 g in each direction (Hansson et al., 2001). Prior to measurement, the sensor was taped on the subject's forehead with a skin-friendly tape and secured with a headband to reduce soft-tissue sensor movements (Fig. 1) (Hansson et al., 2006). The sensor was placed to position the accelerometers approximately correctly in all three axes (x, y, z): the horizontal forward–backward direction (x-axis), the horizontal medial–lateral direction (y-axis), and the vertical direction (z-axis). The data logger was attached at the waist using a belt. After attaching the system, the reference posture (0° inclination) of the head was defined as the head posture obtained with the subject standing upright and looking straight forward. Forward direction of the head inclination was defined by letting the subject sit on a chair and leaning the head forward looking at the floor (Hansson et al., 2006). Each subject's head movements were registered continuously during the two different work tasks. After each measurement, data was transferred to a computer for analysis.

Each subject was asked to perform each of the two work tasks for at least one hour on the day of measurement. Due to organisational reasons at the subjects' workplaces the order of the tasks could not be controlled by the researchers. Seven subjects started with the electronic document management and three with traditional document management. The subjects were instructed to work as usual.

2.5. Data analysis and statistics

Head movements were characterised as 1) the range between the 5th and the 95th percentiles of forward–backward head inclination (Arvidsson et al., 2006) and 2) the median head acceleration. Measurements from the each work task (electronic and traditional) were analysed separately for each subject.

The head inclination angles relative from the vertical line were calculated by computing how the gravity was distributed over the three directions and then compared with the distribution of gravity in the reference postures (Hansson et al., 2006). The accelerations (a) of the sensor received by head movements were calculated after excluding the gravitational component from the raw signal. This was achieved by letting each of the three orthogonal direction signals pass through a 4th order Butterworth high-pass filter, with a cut-off frequency of 0.25 Hz (Mathie et al., 2003). The output from the triaxial accelerometer was analysed for each accelerometer direction individually (a_x, a_y, a_z). The total acceleration, the vectorial sum, a_{tot}, was calculated as the square-root of the sum of the squared accelerations for each direction.

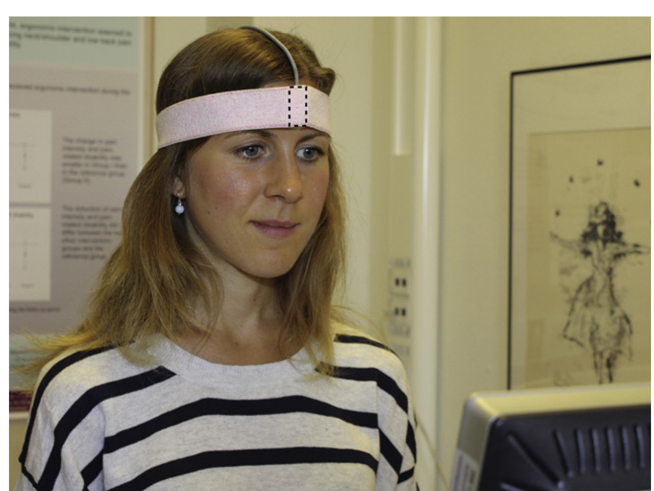

Fig. 1. A triaxial accelerometer sensor was taped to the skin on the forehead and secured with a headband.