CHAPTER 1

General introduction

The earliest forms of office work that have been documented in the literature consisted of pressing characters onto a clay tablet with a stylus of wood or cane. In later times, a lot of office work was performed by monks, which mainly consisted of copying books and documents by writing. Today's forms of office work originate from the industrial revolution in the beginning of the 19th century, when business correspondence greatly increased. At this time, the organization of office work changed from allowing workers to perform many tasks to restricting workers to performing only a few, constantly recurring, routine tasks (labour division), aiming to increase productivity. With the coming of the typewriter (1873), these routine tasks for example included typing documents that were already drafted. A peak in the occurrence of physical symptoms among office workers, whose main task was typing documents, was observed (1).

Since the introduction of the personal computer, which made its entry into the office work environment in 1981, it has become impossible to imagine today's office work without the use of computers. The fact that in 2005 for half of the Dutch working population their main daily work tasks are performed using a computer (2), implies that today this involves around four million people in The Netherlands alone (Based on CBS 2012, (3)). Comparable to the situation at the beginning of the 19th century, performing computer tasks can be monotonous and productivity expectations are high.

Among today's office workers, non-specific physical symptoms, mostly located in the neck and upper extremities, are a common health problem. In the literature, different terms are used to indicate these symptoms, such as musculoskeletal disorders (MSDs), repetitive strain injury (RSI), cumulative trauma disorders (CTD), and work-related neck and upper extremity (WRNUE) symptoms. Twelve-month prevalence of symptoms in the neck, shoulder, hand/wrist, and elbow/lower arm among computer workers are reported to be 55%, 38%, 21%, and 15%, respectively (4). As a result of increasing computer usage, the absolute numbers are expected to grow. Besides the personal burden of these symptoms, workers' productivity decreases, and sick-leave and medical consumption increase (5;6). This results in high costs for employers and society (2). Up to date, preventive interventions regarding office ergonomics, a combination of office ergonomics and ergonomics training, and computer use and computer break patterns have been examined, revealing some positive effects (7-9). However, based on a systematic review that combined results from former systematic reviews on this topic, Andersen and colleagues (10) concluded that no effective interventions that can reduce the occurrence of work-related neck and upper extremity symptoms have been documented. Knowledge about the underlying injury mechanisms, which are still unclear, might help developing interventions that can help preventing future pain symptoms among this group of workers.

Epidemiological studies have identified several independent risk factors for developing work-related neck and upper extremity symptoms from a wide range of factors including computer-task related factors, individual factors, and psychosocial factors (11-13). Regarding computer-task related factors, such as work pace and computer use patterns, it is not very clear whether the association is causal (10) and in some studies no association with work-related symptoms was indicated (14;15). There is no clear evidence regarding the pathways through which indentified risk factors can result in neck and upper extremity symptoms. The most accepted theory is that these risk factors affect the physical demands of the job and the internal biomechanical loading of tissues during computer use, which in turn may lead to tissue injury via overexertion. Internal biomechanical loading refers to a worker's upper extremity physical exposures such as forces, muscle activity, postures, velocities and accelerations. However, while some studies have shown associations between force (16) or posture (17) and neck and upper extremity symptoms, other studies have reported no association (10), and the overall evidence for associations between physical exposures and neck and upper extremity symptoms is limited. Assumingly, work-related neck and upper extremity symptoms are the result of a combination of computer-task related, individual, and work-related psychosocial factors. Since office work mostly consists of performing a computer task while performing cognitively demanding and/or stressful tasks at the same time, it might be of value to have a better understanding via which injury mechanism(s) psychosocial stressors at work[1] may contribute to neck and upper extremity symptoms.

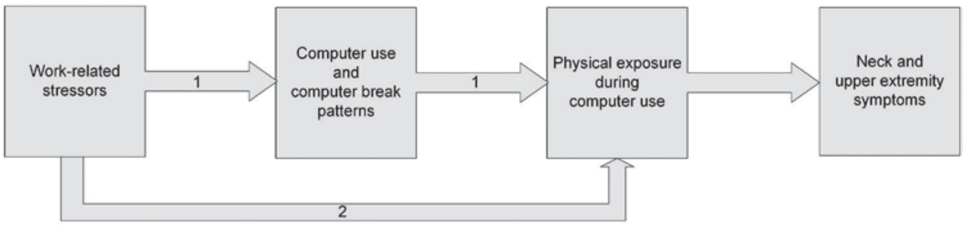

Figure 1. Two pathways that may play a role in work-related neck and upper extremity symptom development.

Work-related stressors include a variety of stressors such as time pressure, high mental processing, performing multiple tasks at the same time, low social support from co-workers or supervisors, high efforts and low reward, low decision authority, and high overcommitment (e.g. 13;18-20). Time pressure, mental processing, and multi-tasking represent demands that are related to the job itself. Effort and reward represent a worker's experience to demands from the job and to what extent a worker feels distressed by this typical experience. Overcommitment can be perceived as personality trait and is defined as excessive work-related commitment and a high need for approval (21). Associations between the aforementioned work-related stressors and neck and upper extremity symptoms have been indicated (12;13;22;23). Two pathways that could lead to work-related neck and upper extremity symptoms may play a role, as indicated in figure 1.

First, a worker's physical exposure may be affected indirectly in response to these stressors through altered computer use patterns (24) such as increased work pace, and increased total computer use duration, reduced break durations and altered break

[1] The terms "work-related stressors" and "workplace stressors" are both used to indicated this type of factors throughout the present thesis.

distribution across a workday (e.g. 13;25-31). These changed computer use patterns might influence (mainly the temporal aspects, such as frequency and duration, of) a worker's postural dynamics and muscle activity, as well as forces applied to the keyboard and computer mouse (Figure 1, pathway 1). For example Wang and colleagues (32) found that typing at a higher pace compared to a worker's comfortable pace resulted in increased muscle activity in the neck, shoulder, and forearm muscles. Furthermore, it was shown that higher levels of overcommitment coincided with more adverse work patterns, such as having less breaks and working trough pain (23). Also, high supervisor support, high decision authority, and high skill discretion (Job Content Questionnaire, (18)) decreased a worker's time spent on computer-based tasks and duration of mouse use, and coincided with more optimal placement of the computer monitor (33). Long computer use duration and/or having few (short) computer breaks per workday could increase the time that a worker adopts a relatively static posture, as a result of the constrained nature of computer use. In case this concerns adverse non-neutral postures, entrapment of nerves or blood vessels could occur. Via mechanical friction nerves could get irritated, causing swelling and internal pressure, resulting in pain. Entrapped blood vessels can reduce blood flow to the muscles. Waste materials could accumulate and nutrient/oxygen supply could be reduced, resulting in local problems in the muscle that may lead to pain (34).

Second, a worker's physical exposure may be affected directly by work-related stressors without alterations in computer use patterns (Figure 1, pathway 2). It has been indicated that median and static muscle activity increase with high mental demands and that very short periods of muscle relaxation ("gaps") decrease (35;36). The finding that median muscle activity increases with high mental demands is supported by findings of others also (37-40). Furthermore, it was found that force exertions on the computer mouse (click and grip forces) increased with high mental pressure (41). These direct influences of work-related stressors on workers' physical exposures can result from increased general arousal or can be due to more specific psychogenic mechanisms, such as co-contraction. Co-contraction is a motor adaptation strategy that can occur, for example, when a person has to perform a precise movement at a high pace, such as tapping a key. To have a successful movement and hit the target, kinematic variability needs to be constrained, which can be achieved by increasing joint stiffness through co-contraction of agonist and antagonist muscles around a joint (42). This adaptation strategy has also been observed when a person has to perform a (fine) motor task while performing a cognitive demanding task. An explanation for this finding could be given by the neuromotor noise theory (43). This theory states that co-contraction is a way to deal with increased noise in the neuromotor system, originating from the high mental load. This noise results in larger kinematic variability during task performance, which needs to be suppressed to meet task demands. The Cinderella hypothesis (44), which is based on the "size principle" (45), assumes that motor units are recruited sequentially with small motor units recruited first and that sustained muscle activity could lead to over-use of (mainly) these small motor units, resulting in tissue damage.

So far, indications concerning possible injury mechanisms of work-related stressors (pathways 1 and 2; indirectly via computer use patterns (1) and directly (2), Figure 1) are either based on effects of simulated work-related stressors in a laboratory setting, or on self-reported computer use patterns from the field. Data from objectively measured physical exposures and computer use patterns in a natural field setting are currently lacking. It might be questioned whether the results from controlled laboratory settings would be the same in a field setting, which includes many additional degrees of freedom. Physical exposures measured during computer use in the field have been shown to be different from those measured in the laboratory (46). Factors such as workstation set-up (47;48) and working technique (49) may provide additional sources of variability that may alter or eliminate the association between physical exposures and computer activities in a field setting. Therefore, there is a need for measurements of physical exposures during computer use in natural field settings. Physical exposure assessment using self-report can be imprecise (50). Direct measurements of physical exposures (electromyography, video analyses and motion caption systems) are believed to be the most accurate (51;52). However, these measurements are challenging when used in a natural field setting. First, to allow a worker to move freely without measurement devices constraining movements or preventing participants from leaving their workstations, unobtrusive, wireless equipment needs to be used. Also, the measurement devices may not alter workstation set-up and must be light and practical to allow for easy set-up and transfer between participant's offices. Last, since physical exposure data have large intra-individual variability (53), the systems need to be able to store or transmit data for at least two hours. Supported by the introduction of wireless logger systems, systems that are appropriate for direct measurements in the field, have recently been developed and tested (54-56).

Although assessing workers' physical exposures during computer work in the field is possible, examining the association between these exposures and neck and upper extremity symptoms is difficult. Since measures of physical exposure have a large intra-individual variance and are strongly dependent on the time of measurements (57-60), the association needs to be examined in large, preferably longitudinal, cohorts. However, direct measurements of physical exposures are, besides unpractical to use in field settings, time consuming and costly. As a result large datasets including these data are currently lacking. A solution for this problem might be the use of physical exposure predictions. Prediction models of physical exposures can be based on self-reported questionnaires, expert observations, and/or software-recordings of computer use, data that is often available in large (longitudinal) cohorts, and then linked to data on neck and upper extremity symptoms occurrence. In this way the association between physical exposures and symptoms can be studied in large longitudinal cohorts (61).

Aims of the thesis

The scope of this thesis includes the role of work-related stressors in the aetiology of work-related neck and upper extremity symptoms in office workers (Figure 2). Furthermore, exposure assessment methods for field studies and future opportunities for more practical and less-expensive assessment methods are presented.

The main aims of the present thesis were to:

1) Assess office workers' physical exposures during computer use in a realistic work setting (Chapter 3).
2) Examine the effects of a variety of work-related stressors on office workers' physical exposures in the neck and upper extremities during computer work, and whether these exposures were (partly) affected via altered computer use patterns (Chapters 2, 4, 5, and 6).
3) Examine methods to predict physical exposures among office workers in the field, to facilitate less expensive and less time-consuming data collection (Chapter 7).
4) Examine the effects of high levels of predicted neck-shoulder and arm-wrist-hand exposures during computer use in relation to work-related neck and upper extremity symptoms in a large cohort of office workers (Chapter 8).

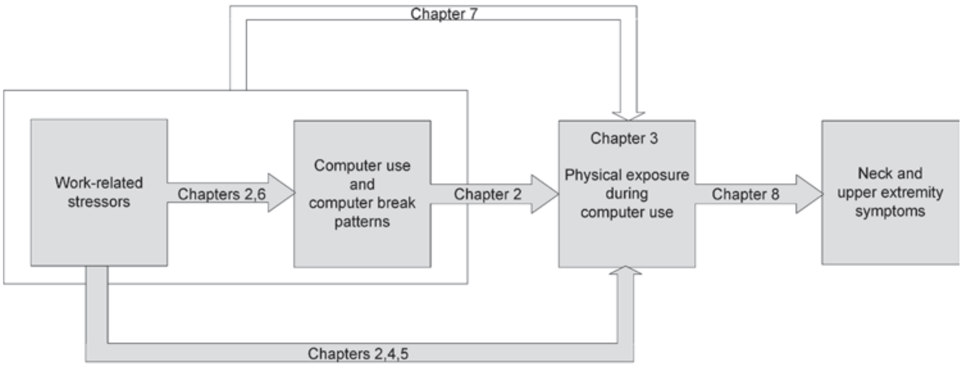

Figure 2. Hypothesized pathways by which work-related stressors (directly or via computer use and computer break patterns) may affect computer workers' physical exposures and consequently the occurrence of neck and upper extremity symptoms.

Outline of the thesis

In Chapter 2, we reported on a literature study including meta-analyses that were performed to get an overview of the evidence in the literature supporting or contradicting our hypothesis that work-related stressors increase neck and upper extremity muscle activity during computer work. From this literature study we observed that results from field studies were lacking. Because results from laboratory settings might not be generalizable to a realistic work setting, we conclude that field studies on this topic are needed. In Chapter 3, we describe exposure measurement techniques appropriate for a realistic field situation, and how exposures during computer use in the field differ between the different components of computer use (i.e. keyboard use, mouse use, and idle activities). Chapters 4 and 5 present the differences in neck-shoulder and arm-wrist-hand exposures during computer use in the field between workers with high compared to low work-related stressors (reward and overcommitment). Chapter 6 describes a study on the association between office workers' level of work-related stressors and their computer usage and computer break patterns. In Chapter 7, the development and quality of exposure prediction models are presented. Using these models, field measured physical exposures during computer use were linked to a large (longitudinal) epidemiological dataset on work-related neck and upper extremity symptoms, facilitating examination of the relation between physical exposures and work-related neck and upper extremity symptoms, which is the topic of Chapter 8. Finally, Chapter 9 presents a general discussion of the findings of Chapters 2-8, as well as final conclusions, suggestions for future research, and practical implications.

REFERENCES

(1) Dembe AE. The changing nature of office work: effects on repetitive strain injuries. Occup Med 1999 Jan;14(1):61-72, iii.

(2) Blatter BM, Houtman I, Van den Bossche S, Kraan K, van den Heuvel S. Health damage and costs of RSI and psychosocial work load in The Netherlands: Report on demand of The Dutch Ministry of Social Affairs and Employment. 2005.

(3) Statistics Neherlands. http://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLNL&PA=81108NED&D1=a&D2=0&D3=a&D4=0&D5=1,11,21,31,(l-7)-l&HD=130703-1528&HDR=G1,G2,T&STB=G3,G4 Accessed: June 13th 2014, last update website: June 25th 2013.

(4) Klussmann A, Gebhardt H, Liebers F, Rieger MA. Musculoskeletal symptoms of the upper extremities and the neck: a cross-sectional study on prevalence and symptom-predicting factors at visual display terminal (VDT) workstations. BMC Musculoskelet Disord 2008;9:96.

(5) Hagberg M, Vilhemsson R, Tornqvist EW, Toomingas A. Incidence of self-reported reduced productivity owing to musculoskeletal symptoms: association with workplace and individual factors among computer users. Ergonomics 2007 Nov;50(11):1820-34.

(6) van den Heuvel SG, IJmker S, Blatter BM, de Korte EM. Loss of productivity due to neck/shoulder symptoms and hand/arm symptoms: results from the PROMO-study. J Occup Rehabil 2007 Sep;17(3):370-82.

(7) Brewer S, Van Eerd D, Amick BC, Irvin E, Daum KM, Gerr F, et al. Workplace interventions to prevent musculoskeletal and visual symptoms and disorders among computer users: a systematic review. J Occup Rehabil 2006 Sep;16(3):325-58.

(8) Driessen MT, Proper KI, van Tulder MW, Anema JR, Bongers PM, van der Beek AJ. The effectiveness of physical and organisational ergonomic interventions on low back pain and neck pain: a systematic review. Occup Environ Med 2010 Apr;67(4):277-85.

(9) Kennedy CA, Amick BC, Dennerlein JT, Brewer S, Catli S, Williams R, et al. Systematic review of the role of occupational health and safety interventions in the prevention of upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time. J Occup Rehabil 2010 Jun;20(2):127-62.

(10) Andersen JH, Fallentin N, Thomsen JF, Mikkelsen S. Risk factors for neck and upper extremity disorders among computers users and the effect of interventions: an overview of systematic reviews. PLoS One 2011;6(5):e19691.

(11) Eltayeb S, Staal JB, Hassan A, de Bie RA. Work related risk factors for neck, shoulder and arms complaints: a cohort study among Dutch computer office workers. J Occup Rehabil 2009 Dec;19(4):315-22.

(12) Hauke A, Flintrop J, Brun E, Rugulies R. The impact of work-related psychosocial stressors on the onset of musculoskeletal disorders in specific body regions: A review and meta-analysis of 54 longitudinal studies. Work Stress 2011 Sep 1;25(3):243-56.

(13) Huysmans MA, Ijmker S, Blatter BM, Knol DL, van Mechelen W, Bongers PM, et al. The relative contribution of work exposure, leisure time exposure, and individual characteristics in the onset of arm-wrist-hand and neck-shoulder symptoms among office workers. Int Arch Occup Environ Health 2012 Aug;85(6):651-66.

(14) IJmker S, Huysmans MA, van der Beek AJ, Knol DL, van Mechelen W, Bongers PM, et al. Software-recorded and self-reported duration of computer use in relation to the onset of severe arm-wrist-hand pain and neck-shoulder pain. Occup Environ Med 2011 Jul;68(7):502-9.

(15) Richter JM, van den Heuvel SG, Huysmans MA, van der Beek AJ, Blatter BM. Is peak exposure to computer use a risk factor for neck and upper-extremity symptoms? Scand J Work Environ Health 2012 Mar;38(2):155-62.

(16) Feuerstein M, Armstrong T, Hickey P, Lincoln A. Computer keyboard force and upper extremity symptoms. J Occup Environ Med 1997 Dec;39(12):1144-53.

(17) Marcus M, Gerr F, Monteilh C, Ortiz DJ, Gentry E, Cohen S, et al. A prospective study of computer users: II. Postural risk factors for musculoskeletal symptoms and disorders. Am J Ind Med 2002 Apr;41(4):236-49.

(18) Karasek R, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B. The Job Content Questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. J Occup Health Psychol 1998 Oct;3(4):322-55.

(19) Siegrist J, Klein D, Voigt KH. Linking sociological with physiological data: the model of effort-reward imbalance at work. Acta Physiol Scand Suppl 1997;640:112-6.

(20) van den Heuvel SG, van der Beek AJ, Blatter BM, Hoogendoorn WE, Bongers PM. Psychosocial work characteristics in relation to neck and upper limb symptoms. Pain 2005 Mar;114(1-2):47-53.

(21) Siegrist J, Starke D, Chandola T, Godin I, Marmot M, Niedhammer I, et al. The measurement of effort-reward imbalance at work: European comparisons. Soc Sci Med 2004 Apr;58(8):1483-99.

(22) Bongers PM, Kremer AM, ter Laak J. Are psychosocial factors, risk factors for symptoms and signs of the shoulder, elbow, or hand/wrist?: A review of the epidemiological literature. Am J Ind Med 2002 May;41(5):315-42.

(23) van den Heuvel SG, van der Beek AJ, Blatter BM, Bongers PM. Workstyle and overcommitment in relation to neck and upper limb symptoms. Int J Behav Med 2007;14(1):12-20.

(24) Harrington CB, Feuerstein M. Workstyle in office workers: ergonomic and psychological reactivity to work demands. J Occup Environ Med 2010 Apr;52(4): 375-82.

(25) Bongers PM, Ijmker S, van den Heuvel S, Blatter BM. Epidemiology of work related neck and upper limb problems: psychosocial and personal risk factors (part I) and effective interventions from a bio behavioural perspective (part II). J Occup Rehabil 2006 Sep;16(3):279-302.

(26) Henning RA, Jacques P, Kissel GV, Sullivan AB, teras-Webb SM. Frequent short rest breaks from computer work: effects on productivity and well-being at two field sites. Ergonomics 1997 Jan;40(1):78-91.

(27) Mclean L, Tingley M, Scott RN, Rickards J. Computer terminal work and the benefit of microbreaks. Appl Ergon 2001 Jun;32(3):225-37.

(28) Menendez CC, Amick BC, Chang CHJ, Dennerlein JT, Harrist RB, Jenkins M, et al. Computer use patterns associated with upper extremity musculoskeletal symptoms. J Occup Rehabil 2008 Jun;18(2):166-74.

(29) Norman K, Floderus B, Hagman M, Toomingas A, Tornqvist EW. Musculoskeletal symptoms in relation to work exposures at call centre companies in Sweden. Work 2008;30(2):201-14.

(30) Sharan D, Parijat P, Sasidharan AP, Ranganathan R, Mohandoss M, Jose J. Workstyle risk factors for work related musculoskeletal symptoms among computer professionals in India. J Occup Rehabil 2011 Dec;21(4):520-5.

(31) van den Heuvel SG, de Looze MP, Hildebrandt VH, The KH. Effects of software programs stimulating regular breaks and exercises on work-related neck and upper-limb disorders. Scand J Work Environ Health 2003 Apr;29(2):106-16.

(32) Wang Y, Szeto GP, Chan CC. Effects of physical and mental task demands on cervical and upper limb muscle activity and physiological responses during computer tasks and recovery periods. Eur J Appl Physiol 2011 Mar 16.

(33) Johnston V, Jull G, Souvlis T, Jimmieson NL. Interactive effects from self-reported physical and psychosocial factors in the workplace on neck pain and disability in female office workers. Ergonomics 2010 Apr;53(4):502-13.

(34) Visser B, van Dieen JH. Pathophysiology of upper extremity muscle disorders. J Electromyogr Kinesiol 2006 Feb;16(1):1-16.

(35) Alkjaer T, Pilegaard M, Bakke M, Jensen BR. Effect of aging on performance, muscle activation and perceived stress during mentally demanding computer tasks. Scand J Work Environ Health 2005 Apr;31(2):152-9.

(36) Laursen B, Jensen BR, Garde AH, Jorgensen AH. Effect of mental and physical demands on muscular activity during the use of a computer mouse and a keyboard. Scand J Work Environ Health 2002 Aug;28(4):215-21.

(37) Bloemsaat JG, Meulenbroek RGJ, van Galen GP. Differential effects of mental load on proximal and distal arm muscle activity. Exp Brain Res 2005 Dec;167(4):622-34.

(38) Larsson SE, Larsson R, Zhang Q, Cai H, Oberg PA. Effects of psychophysiological stress on trapezius muscles blood flow and electromyography during static load. Eur J Appl Physiol Occup Physiol 1995;71(6):493-8.

(39) Waersted M, Westgaard RH. Attention-related muscle activity in different body regions during VDU work with minimal physical activity. Ergonomics 1996 Apr;39(4):661-76.

(40) Waersted M. Human muscle activity related to non-biomechanical factors in the workplace. Eur J Appl Physiol 2000 Oct;83(2-3):151-8.

(41) Visser B, de Looze M, De Graaff M, van Dieen J. Effects of precision demands and mental pressure on muscle activation and hand forces in computer mouse tasks. Ergonomics 2004 Feb 5;47(2):202-17.

(42) Selen LPJ, Beek PJ, van Dieen JH. Can co-activation reduce kinematic variability? A simulation study. Biol Cybern 2005 Nov;93(5):373-81.

(43) Van Gemmert AW, Van Galen GP. Stress, neuromotor noise, and human performance: a theoretical perspective. J Exp Psychol Hum Percept Perform 1997 Oct;23(5): 1299-313.

(44) Hagg GM. Comparison of different estimators of electromyographic spectral shifts during work when applied on short test contractions. Med Biol Eng Comput 1991 Sep;29(5):511-6.

(45) Henneman E, Somjen G, Carpenter DO. Excitability and inhibitability of motoneurons of different sizes. J Neurophysiol 1965 May;28(3):599-620.

(46) Bruno Garza JL, Eijckelhof BHW, Johnson PW, Raina SM, Rynell PW, Huysmans MA, et al. Observed differences in upper extremity forces, muscle efforts, postures, velocities and accelerations across computer activities in a field study of office workers. Ergonomics 2012 Jun;55(6):670-81.

(47) Dennerlein JT, Johnson PW. Changes in upper extremity biomechanics across different mouse positions in a computer workstation. Ergonomics 2006 Nov 15;49(14):1456-69.

(48) Simoneau GG, Marklin RW, Berman JE. Effect of computer keyboard slope on wrist position and forearm electromyography of typists without musculoskeletal disorders. Phys Ther 2003 Sep;83(9):816-30.

(49) Homan MM, Armstrong TJ. Evaluation of three methodologies for assessing work activity during computer use. AIHA J (Fairfax , Va) 2003 Jan;64(1):48-55.

(50) IJmker S, Leijssen JNM, Blatter BM, van der Beek AJ, van Mechelen W, Bongers PM. Test-retest reliability and validity of self-reported duration of computer use at work. Scand J Work Environ Health 2008 Apr;34(2):113-9.

(51) David GC. Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders. Occup Med (Lond) 2005 May;55(3):190-9.

(52) van der Beek AJ, Frings-Dresen MH. Assessment of mechanical exposure in ergonomic epidemiology. Occup Environ Med 1998 May;55(5):291-9.

(53) Mathiassen SE. Diversity and variation in biomechanical exposure: what is it, and why would we like to know? Appl Ergon 2006 Jul;37(4):419-27.

(54) Asundi K, Johnson PW, Dennerlein JT. Inertia artefacts and their effect on the parameterisation of keyboard reaction forces. Ergonomics 2009 Oct;52(10):1259-64.

(55) Bruno Garza JL, Catalano PJ, Katz JN, Huysmans MA, Dennerlein JT. Developing a framework for predicting upper extremity muscle activities, postures, velocities, and accelerations during computer use: the effect of keyboard use, mouse use, and individual factors on physical exposures. J Occup Environ Hyg 2012;9(12):691-8.

(56) Dennerlein JT, Johnson PW. Different computer tasks affect the exposure of the upper extremity to biomechanical risk factors. Ergonomics 2006 Jan 15;49(1):45-61.

(57) Asundi K, Johnson PW, Dennerlein JT. Variance in direct exposure measures of typing force and wrist kinematics across hours and days among office computer workers. Ergonomics 2012;55(8):874-84.

(58) Liv P, Mathiassen SE, Svendsen SW. Theoretical and empirical efficiency of sampling strategies for estimating upper arm elevation. Ann Occup Hyg 2011 May;55(4):436-49.

(59) Liv P, Mathiassen SE, Svendsen SW. Accuracy and precision of variance components in occupational posture recordings: a simulation study of different data collection strategies. BMC Med Res Methodol 2012;12:58.

(60) Mathiassen SE, Burdorf A, van der Beek AJ. Statistical power and measurement allocation in ergonomic intervention studies assessing upper trapezius EMG amplitude. A case study of assembly work. J Electromyogr Kinesiol 2002 Feb;12(1):45-57.

(61) Chen JC, Chang WR, Shih TS, Chen CJ, Chang WP, Dennerlein JT, et al. Using exposure prediction rules for exposure assessment: an example on whole-body vibration in taxi drivers. Epidemiology 2004 May;15(3):293-9.