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## Rationalisation in public dental care – impact on clinical work tasks and mechanical exposure for dentists – a prospective study

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**Rationalisation in public dental care – impact on clinical work tasks and mechanical exposure for dentists – a prospective study**

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3 Rationalisation in public dental care – impact on clinical work tasks  
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5 and mechanical exposure for dentists – a prospective study  
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## Abstract

Swedish dentistry has been exposed to frequent rationalisation initiatives during the last half century. Previous research has shown that rationalisation often results in increased risk of developing work-related musculoskeletal disorders, thus reducing sustainability in the production system.

In the present prospective study we assessed mechanical exposures among Swedish dentists in relation to specific rationalisations of clinical dental work during a six-year period. Body postures and movements of 12 dentists were assessed by inclinometry synchronised to video recordings of their work.

No rationalisation effects could be shown in terms of a reduction in non-Value-Adding Work ('waste'); and at job level no major differences in mechanical exposure could be shown between baseline and follow-up.

Conclusion: the present rationalisation measures in dentistry do not seem to result in rationalisation at job level, but may potentially be more successful at the overall dental system level.

Keywords: Loss analysis; Sustainable production system; Inclinometry; Video analysis

## Statement of relevance

In contrast to many previous investigations of the mechanical exposure implications of rationalisation, the present rationalisation measures did not increase the level of risk for dentists. It is highlighted that all occupations involved in the production system should be investigated in order to assess production system sustainability.

## 1. Introduction

Work-related Musculo-Skeletal Disorders (WMSD) are a main occupational health issue for dentists in modern dentistry (Finsen *et al.* 1998, Akesson *et al.* 1999). The complaints are mainly localised to the shoulder/neck and back regions (Ratzon *et al.* 2000, Leggat *et al.* 2007, Hayes *et al.* 2009).

In a recent review by Westgaard and Winkel (2011) it is concluded that "... the potential of rationalisations to cause health problems is large, contrasting the overall assessment of ergonomic interventions that seem to have limited health effects in a long range perspective". The authors therefore emphasise that there is a need to understand the health effects of rationalisation to ensure "sustainable production systems", which they define as "the joint consideration of competitive performance and working conditions in a long term perspective". The term "rationalisation" was defined at the World Economic Conference in Geneva in 1927 as "... the methods of technique and of organisation designed to secure the minimum waste of either effort or material. ...".

Accordingly, it has been suggested that WMSD among dentists in Sweden are partly related to the rationalisation of dentistry, starting in the 1960s based on Tayloristic principles (Bjorkman 1996, Winkel and Westgaard 1996). Different rationalisation principles have dominated over time (e.g. Bejerot *et al.* 1999, Westgaard and Winkel 2011), but all include the general aim of improving performance by reducing duration of tasks considered as waste.

In a recent study, we showed reduced mechanical risk factors for WMSD during tasks characterised as "waste", compared with so-called "Value-Adding Work (VAW) (Jonker *et al.* 2011). VAW is here defined as the portion of process time the worker spends on actions that create value as perceived by the customer (Keyte and Locher 2004). This suggests that further rationalisation where VAW activities are increased may also lead to an increase in

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3 mechanical risk factors for developing WMSD among dentists. However, mechanical risk  
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5 factors may also arise during tasks typically considered as non-VAW for dentists, such as  
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7 administrative work tasks (Tornqvist *et al.* 2009).  
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10 A Swedish government report presented in 2002 recommended that the Public Dental  
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12 Service should be reorganised to obtain a more efficient mix of tasks between the  
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14 occupational groups (SOU 2002:53). Through task reallocation, dental hygienists and dental  
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16 nurses should now perform some of the work performed by dentists.  
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19 Due to these recommendations, which stemmed from a problematic financial situation, but  
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21 are also brought about by recent developments in information technology, the public dental  
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23 care system of Jönköping County Council decided to implement a number of organisational  
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25 and technical rationalisations starting in autumn 2003 (Munvädret 2003:9).  
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28 In the present study, we evaluate changes at both the organisational and the technical level  
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30 made between 2003 and 2009. The following changes were implemented in work  
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32 organisation: some of the dentist's tasks were delegated to lower-level professions with  
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34 appropriate education; small clinics were merged with larger ones in the same region;  
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36 financial feedback was given to each clinic on a monthly basis; dentists' salaries were  
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38 increased from below the national average to slightly above; an extra management level was  
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40 implemented between top management and the directors of the clinics.  
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43 The technical changes comprised introduction of: a SMS reminder system to patients, with the  
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45 aim of preventing loss of patients' visits to the clinics; digital X-ray at the clinics; a new IT  
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47 system to enable online communication between healthcare providers and insurance funds; a  
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49 self-registration system for patients on arrival for both receptionist and dental teams.  
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52 The aim of the present study was to investigate the impact of the above-mentioned  
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54 rationalisations in dentistry at both job and task level, of dentists regarding changes in i)  
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56 duration of "waste", and ii) mechanical exposures in the neck, shoulder, and back.  
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## 2. Material and methods

### 2.1.1. Methods

The study is a prospective cohort study. In 2003 the public dental care system of Jönköping County Council decided to implement a number of organisational and technical rationalisations (Munvädret 2003:9). These were then implemented during the following five years. Data were collected in 2003 and 2009 at dentists' normal workplaces, with the same type of regular work being conducted on both occasions. Four hours of direct technical measurements of mechanical exposure were recorded, starting with the first patient in the morning and ending at lunchtime. During the first 45 minutes of the measurement period, video recordings were also made, synchronised to the direct technical measurements. Work tasks were assessed from the video recordings and corresponding task-specific exposures obtained, as described below.

### 2.1.2. Classification of work tasks and assessment of their duration

The work performed by the dentists was videotaped during the first 45 minutes for each investigated dentist, using a digital camera (Canon MVX30i). The work tasks were classified according to Table 1 with the assistance of an experienced dentist. The duration of these work tasks was then assessed from the video recordings with a sampling frequency of 1Hz, by using a video analysis system ("Videolys" system: Chalmers University of Technology, Engström and Medbo 1997) and further classified into VAW and non-VAW (Table 1). One experienced researcher analysed the video recordings according to Kazmierczak *et al* (2006).

In the present study, VAW was operationalised according to Neumann *et al* (2006). This is an engineering approach used in assembly work and includes any assembly work and acquisition of components or tools that can be completed without the operators having to move from their assembly position. According to this approach, all intra-oral patient work and

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3 all treatment-related dialogue with the patient without leaving the working position were  
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5 considered as VAW.  
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8 Periods of disturbances caused by the researchers were identified and excluded from further  
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10 analyses. The video recording was stopped during scheduled breaks. Baseline data were  
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12 obtained from Jonker *et al.* (2011). In that study, the job as a dentist was classified into six  
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14 work tasks. “Patient treatment” and “Dental information” were classified as VAW, and the  
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16 remaining four tasks, i.e. “X-ray handling”, “administration”, “handling of parts and  
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18 materials”, and “disturbances”, were classified as non-VAW (i.e. “waste”).  
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### 21 22 23 2.1.3. Mechanical exposure

24  
25 Inclinometers based on triaxial accelerometers were used to record the flexion/extension of  
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27 the head, trunk and upper arm elevation relative to the line of gravity. Data were sampled at  
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29 20Hz using a datalogger (the inclinometers and datalogger were manufactured by Logger  
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31 Teknologi HB, Åkarp, Sweden) (Hansson *et al.* 2001). The analogue signals from the  
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33 accelerometers were anti-alias filtered, using a Butterworth filter with a 3dB point at 10Hz  
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35 and a slope of 24dB per octave. A 12-bit analogue-to-digital converter was used, with a span  
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37 corresponding to roughly 4g; i.e., the resolution was approximately 0.002g per least  
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39 significant bit (AD unit). The first step in the data processing was the filtering of the sampled  
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41 accelerometer data using a low-pass, finite-duration impulse response filter with a cut-off  
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43 frequency of 5.0Hz.  
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47 Postures and angular velocities were calculated for each activity category obtained, by  
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49 synchronising the video and inclinometer recordings (Forsman *et al.* 2002).  
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52 One inclinometer was placed on the forehead, another on the upper back to the right of the  
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54 cervical-thoracic spine at the level of C7 and Th1. For the upper arms, the inclinometers were  
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56 fixed to plastic plates (55 x 27 mm) that were placed along the upper arm, with the lateral  
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3 edge along the line from the lateral posterior corner of the acromion to the lateral epicondyle,  
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5 and with the upper edge at the insertion of the deltoid muscle (Hansson *et al.* 2006).  
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7 All recordings started with a calibration procedure where a reference position was  
8 established and recorded for the head, upper back and upper arms respectively for 5 seconds.  
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10 The reference position for the head and upper back (zero degrees flexion) was defined as the  
11 position obtained when the subject was standing, looking at a mark at eye level. The forward  
12 direction of the head and back was defined with the subject sitting, leaning straight forward,  
13 looking at the floor (Hansson *et al.* 2006). For the reference position of the upper arms, an  
14 elevation of zero degrees was recorded with the side of the body leaning against the backrest  
15 of a chair, the arm hanging perpendicular over the backrest of the chair with a dumbbell of  
16 2kg in the hand.  
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#### 29 2.1.4. Job and task exposures

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31 “Job exposures” were estimated based on the four hours of inclinometry recordings. For  
32 comparison, job exposure was also estimated for the 45 minutes when video recordings were  
33 performed. “Task exposures”, i.e. the exposures obtained for the six different tasks were  
34 based on the 45 minutes of recording when the dentists were video-filmed. Specific “task  
35 exposures” were calculated for the tasks indicated in Table 1 according to the periods  
36 assessed by the Videolys and the corresponding inclinometer recordings. By assessing task  
37 exposures, we calculated the exposures during VAW and non-VAW.  
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## 2.2. Subjects

In 2003, 16 dentists participated in the study (Jonker *et al.* 2011). Twelve of these 16 dentists were still available in 2009. In 2003, these 12 dentists (5 male and 7 female) had a mean age of 51 (sd = 6.4, range: 39-59) years and had worked as dentists for an average of 22 (sd= 7.4, range: 9-37) years. All were right-handed and employed in dental clinics in Jönköping County, Sweden.

## 2.3. Data analysis

Descriptive statistics are presented as means (m), and 95 percent confidence intervals (CI 95%). For the inclinometry data, we used group means of the 50<sup>th</sup> percentile, group means of differences between the 90<sup>th</sup> and 10<sup>th</sup> percentiles, and 95 percent confidence interval (CI 95%). Paired t-tests were used in order to analyse changes between year 2003 and 2009 for postures and movement velocities during the same kind of work tasks, job exposure during both 45 minutes and four hours, and time distribution of observed time for VAW and non-VAW during clinical dental work. Paired t-tests were also used in order to detect differences in job exposures based on 45 minutes and four hours of recordings, in 2003 as well as 2009.

The Kolmogorov-Smirnov test of normality showed that the time distributions for VAW and non-VAW activities were significantly separated from normality ( $p < 0.05$ ). Those variables were tested with the Wilcoxon signed-rank test for related samples.

Differences in postures, movement velocities and time consumption of 10%, are assumed to be of clinical relevance. With a statistical power of 80% and a calculated CV of 0.28 and 0.24 for measured workload and VAW time consumption respectively, a sample size of 10 persons is required (Balogh *et al.* 1999).

Significance was assumed at  $\alpha = 0.05$  level. All statistical calculations have been performed using SPSS (Chicago, Illinois 60606 version 16.0).

### 3. Results

#### 3.1. Changes in time distribution of work tasks

The average duration of non-VAW in relation to the total recording time tended to increase from 43% at baseline in 2003 to 55% in 2009 ( $p=0.10$ ). The average duration of “patient treatment” (part of VAW) tended to decrease from 47% in 2003 to 34% in 2009 ( $p=0.14$ ), and “handling of parts and materials” (part of non-VAW) tended to increase from 14% to 18% of the recording time ( $p=0.10$ ) (Table 1).

[Table 1]

#### 3.2. Performance during the video recordings

The performance in terms of average number of patients treated during the video recordings was 2.25 in both 2003 and 2009. The average duration of uninterrupted periods of non-VAW, which can be seen as a measure of porosity of the work, tended to increase by 41 seconds, from 65 seconds in 2003 to 106 seconds in 2009 ( $p=0.09$ ) (Table 2).

[Table 2]

#### 3.3. Mechanical exposure during VAW tasks

The median head inclination during “patient treatment” increased from  $40^\circ$  in 2003 to  $46^\circ$  in 2009 ( $p=0.007$ ). The range of postures and movement velocities (90th – 10th percentiles) for the head were reduced by  $10^\circ$  and  $5^\circ/\text{s}$  respectively at follow-up. The range in movement velocities (90th – 10th percentiles) for the right upper arm was also significantly decreased in 2009, by  $11^\circ/\text{s}$  (Tables 3 and 4).

In general, during “dental information” no changes in mechanical exposure values, either for postures or movement velocities, were found at follow-up.

### 3.4. Mechanical exposure during non-VAW tasks

During “X-ray handling”, the median elevation of the left upper arm was reduced from 35° in 2003 to 23° in 2009; the range of both right and left upper arm postures (90th – 10th percentiles) was reduced by 10° ( $0.005 < p < 0.04$ ) (Table 3). A tendency towards a 6°/s reduction in median movement velocities was found at follow-up for the dominant upper arm ( $p=0.08$ ), and the movement velocity range (90th – 10th percentiles) was reduced by 15°/s ( $p=0.01$ ) (Table 4).

During “administration”, the median movement velocities and the range of movement velocities were in general reduced for all the studied body segments in 2009 compared with 2003. Also, a tendency to a narrower posture range (90th – 10th percentiles) was found for back and upper extremities in 2009 compared with 2003.

“Handling of parts and materials” demanded increased median movement velocities for the head (2.9°/s,  $p=0.02$ ) and the left upper arm (9°/s,  $p=0.03$ ) in 2009 compared with 2003. In 2009, the velocity ranges (90th – 10th percentiles) for both upper arms and back movements were significantly increased, compared with 2003 (23-29°,  $0.02 < p < 0.05$ ) (Tables 3 and 4).

### 3.5. Mechanical exposure during pooled VAW compared with pooled non-VAW

No major exposure changes were found, except for a 4° increase in head inclination during VAW, from 2003 to 2009.

In both 2003 and 2009, VAW compared with non-VAW implied more forward-flexed postures for the head and back, and lower median movement velocities and movement velocity ranges (90th – 10th percentiles) of the head, back and upper arm (Tables 3 and 4).

### 3.6. Job exposure

Estimation of job exposures showed no major differences between baseline and follow-up, neither based on evaluation of the 45 minutes synchronised to the video recordings nor on the full four hours of recording from the first patient in the morning through to lunch. Details are given in Tables 3 and 4.

[Table 3] and [Table 4]

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## 4. Discussion

In spite of several rationalisation initiatives during the investigated period (2003 to 2009) the duration of non-VAW (waste) at follow-up in 2009 was not reduced, but rather showed a trend towards an increase. Accordingly, no major changes in mechanical exposure at job level could be shown. At task level, however, mechanical exposure during VAW became more constrained, while one in four of the non-VAW tasks became more varied.

### 4.1. Methodological considerations

#### 4.1.1. Exposure assessments

In the present study, detailed information on mechanical exposure has been evaluated by combining direct posture and movement measurements with video-based observations of work-task distribution according to previously described procedures (Jonker *et al.* 2011). This allows us to study aspects of exposures rarely considered in epidemiology and intervention studies. Furthermore, it allows studies of the potential effects of rationalisation when reducing the amount of waste/non-VAW. However, our assessments were confined to dentists, while the performed rationalisations aimed to reduce waste at system level. Thus, the lack of waste reduction among the dentists may not be valid at system level.

The method used for measurement of mechanical exposure has shown good precision and high reliability (Hansson *et al.* 2006). In addition, the data were obtained during normal work and at the regular workplace to improve validity.

The representativity of 45 minutes of video recordings may be questioned. Mathiassen and Svendsen (2009) showed, when studying right upper arm movements among house painters, that sample duration longer than 40 minutes is needed to reduce mechanical exposure bias in 10<sup>th</sup> and 90<sup>th</sup> percentiles to below 25% of true whole-day exposure. However, the investigated exposure ranges among dentists are presumed to be smaller compared with the range of movements among housepainters. This suggests a small overall mechanical job exposure bias

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3 in the present study. In line with this, we found only minor differences between job exposure  
4 data obtained from 45 minutes and four hours of recording. However, a larger inter-day  
5 variation in exposures may still occur.  
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9 Only working postures and movements of the neck and upper extremities were measured  
10 with the inclinometer in the present study. Dong *et al.* (2007) have shown a significant  
11 interaction between differently designed dental tools and measured physical workload in the  
12 lower arms during simulated dental work. In a more recent study of dental hygienists, high  
13 muscular load in the trapezius and forearm extensors was found during manual scaling  
14 (Akesson *et al.* 2012). The effect of such forces during dental work has not been considered in  
15 this study.  
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25 In order to consider inter-individual variation in mechanical exposure while performing  
26 identical tasks, the same dentists were studied in both 2003 and 2009. This allowed the use of  
27 paired tests. However, we have no detailed information about the specific treatments carried  
28 out during the observations. This may potentially hide differences in waste between 2003 and  
29 2009.  
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#### 38 4.1.2. Operationalisation of the concept of rationalisation

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40 Rationalisation is defined as “the methods of technique and organisation designed to secure  
41 the minimum of waste of either effort or material” (World Economic Conference in Geneva,  
42 1927 cited in Westgaard and Winkel (2011)). The analysis system used in the present study  
43 was developed for industrial use, and work tasks were classified according to an engineering  
44 and Lean Production approach (Liker 2004). During recent years, the concept of Lean  
45 Production has to an increasing extent been adopted by the service sector, including  
46 healthcare (e.g. Keyte and Locher 2004). The assessment of waste, as performed in the  
47 present study, implies that all activities which can be completed without the dentist having to  
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3 move away from the patient are considered as VAW (cf. Engström and Medbo 1997). This  
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5 approach may be too rough an operationalisation in healthcare, where the aim is to provide  
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7 service to a patient. It has for example been suggested by Grönroos and Ojasalo (2004) that  
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9 contributions from the patient should also be considered.  
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## 11 12 13 14 **4.2. General discussion**

### 15 16 *4.2.1. Duration of VAW and non-VAW*

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18 The proportion of VAW was 57% in 2003 and 45% in 2009. Compared with studies using  
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20 the same system for task analysis, Kazmierczak *et al.* (2005) assessed VAW to about 30% in  
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22 traditional car disassembly. Bao *et al.* (1996) and Neumann *et al.* (2006) recorded about 70%  
23  
24 VAW during industrialised sewing machine and motor assembly. Studies of the Finnish  
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26 Public Dental Service and the Dental Service in the UK concluded that work organisation  
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28 efficiency must be enhanced in order to achieve an overall minimisation of costs (Widstrom *et*  
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30 *al.* 2004, Cottingham and Toy 2009). Thus, in the present study an increase in the proportion  
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32 of VAW during follow-up was expected. A Swedish Government Official Report (SOU 2002)  
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34 and Abelsen and Olsen (2008) emphasise that dental care teams need to be more efficient in  
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36 order to meet increased demands for dental care. Allocation of work tasks to dental hygienists  
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38 and dental assistants is part of this rationalisation. More time may therefore have been made  
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40 available for dentists to carry out other tasks, but seemingly not for more VAW as defined in  
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42 this study. At the investigated job level, i.e. the dentist level, the rationalisation seems not to  
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44 have been successful in terms of waste reduction. However, in a parallel study of the same  
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46 organisation an increase in productivity was found at the overall dental system level  
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48 (Rolander *et al.* Submitted). This may be due to rationalisation effects at other professional  
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50 levels of the investigated organisation, e.g. dental nurses, administrators etc. This emphasises  
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3 the importance of including all occupational groups of a production system in the evaluation  
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5 of changes in system sustainability during a period of rationalisation.  
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#### 8 9 10 4.2.2. Mechanical exposures during VAW and non-VAW tasks

11 Changes in mechanical exposures during “patient treatment” (VAW) indicate more  
12 constrained head postures in 2009 compared with 2003. A forward head inclination of more  
13 than 15°-20° during “an extended period”, may increase the risk of developing neck pain  
14 (Ohlsson *et al.* 1994, Ohlsson *et al.* 1995, Bernard 1997, Ariens *et al.* 2001). However, the  
15 increase in forward flexion of the head from 40° to 46° may be marginal in terms of increased  
16 risk. Using virtual reality simulation, Suebnukarn *et al.* (2009) showed that experienced  
17 dentists (aged 35-45 years) had a more dynamic force pattern in dental hand tool operations  
18 and faster task completion during dental crown preparation compared with dentist students  
19 (aged 20-23 years). This may be explained by a higher level of “motor learning”, implying  
20 faster performance among the more experienced dentists. Our studies showed the opposite  
21 effect: i.e. a decreased range in movement velocities of the dominant arm during “patient  
22 treatment”. Our group of dentists was 15 years older at follow-up compared with the  
23 experienced dentists above; the investigated follow-up period was only six years; and the  
24 measurements were performed during real work. In our study, the decreased range in  
25 movement velocities of the dominant arm during “patient treatment” may be due to a  
26 combination of an age effect and an effect of the implemented rationalisations. Further studies  
27 are needed to clarify this.  
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49 During “X-ray handling” (non-VAW), median elevation of the non-dominant upper arm  
50 was reduced from 35° in 2003 to 23° in 2009. Upper arm elevation more than 30° has been  
51 shown to obstruct blood flow to the supraspinatus muscle (Jarvholm *et al.* 1988). Thus, the  
52 present change in arm elevation between 2003 and 2009 may imply a significant risk  
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3 reduction. However, for the right upper arm we found reduced movement velocities,  
4 indicating a more constrained posture for the dominant arm. This is probably due to the  
5 introduction of computerised routines during the follow-up period.  
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9 During “administration” (non-VAW), decreased movement velocities and narrower velocity  
10 ranges also indicate a more constrained working posture, possibly due to more intensive use  
11 of VDU. Similar results were found by Arvidsson *et al.* (2006) when evaluating physical  
12 workload of air traffic controllers following the computerisation of air traffic control systems.  
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14  
15 In contrast to “X-ray handling” and “administration”, “handling of parts and materials”  
16 (non-VAW) was more dynamic in 2009 compared with 2003, estimated as increased median  
17 head movement velocity and wider range of velocities for both arms. This change towards  
18 more dynamic working conditions may imply less hazardous mechanical exposures  
19 (Madeleine 2010).  
20  
21

22  
23 The duration of individual work tasks is short and thus the risk implications with regard to  
24 WMSDs may be small. When pooling all separate non-VAW tasks, a better risk estimation  
25 due to mechanical exposures may be provided. Compared with pooled VAW, pooled non-  
26 VAW shows more upright postures for the head and back, as well as a wider range of  
27 movements for both upper arms. Thus, non-VAW seems to imply a lower risk of developing  
28 WMSD. This is in accordance with previous studies comparing mechanical exposures in  
29 VAW and non-VAW (Kazmierczak 2005, Ostensvik *et al.* 2008, Jonker *et al.* 2011).  
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#### 47 4.2.3. Mechanical exposure at job level

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49 The arm and head velocities (50<sup>th</sup> percentiles) in the present study are low compared with  
50 industrial assembly work (Christmansson *et al.* 2002, Balogh *et al.* 2006). The low velocities  
51 reflect constrained postures that are typical of dental work, and our results thus seem to have  
52 good face validity. According to Hansson *et al.* (2010), a dentist’s work may be classified as  
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3 “repetitive non-industrial work” when compared with previously investigated occupational  
4  
5 groups using the same methods and procedures. This repetitive work seems to imply an  
6  
7 elevated risk of WMSD in comparison with jobs involving varied mobile work, such as  
8  
9 nursing and home service (Nordander *et al.* 2009).  
10

11  
12 Since the mechanical exposure level in the present study did not change from 2003 to 2009,  
13  
14 the risk level with regard to WMSD still seems to be high compared with occupational groups  
15  
16 whose work is more varied (Bernard 1997, N.R.C. 2001, da Costa and Vieira 2010).  
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#### 20 21 4.2.4. Conclusion

22  
23 A set of organisational and technical changes was introduced in a public dental care system  
24  
25 in Sweden to improve performance. Based on previous investigations of relations between  
26  
27 rationalisation and exposures (Westgaard and Winkel 2011), it was hypothesised that this  
28  
29 would lead to an increased risk of developing WMSD for dentists. However, this could not be  
30  
31 shown at the dentist level of the dental system.  
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34  
35 A parallel study of the same organisations demonstrated an increase in their productivity  
36  
37 (Rolander *et al.* Submitted). This may be due to rationalisation effects at other levels of  
38  
39 dentistry in the investigated organisations, e.g. among other occupational groups. Thus, all  
40  
41 occupational groups in a production system need to be investigated to ensure a sustainable  
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43 production system.  
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Table 1. Description and classification of the investigated work tasks and the proportion of time spent on them in mean percent and CI 95% [in brackets], based on 45 minutes of video registration of observed work activities in 2003 and 2009, n=12 .

Classification	Work tasks	Description	Proportion of time in 2003	Proportion of time in 2009	p=
VAW	Patient treatment	Principal activities during patient dental treatment, e.g. dental examination, dental filling therapy, tooth extraction, assessing X-ray pictures and reading patient's journal during dental treatment, reaching for tools and materials during dental patient treatment	47.2 [36.3-58.1]	34.4 [22.2-46.5]	0.14
	Dental information	Dentist's information about treatment during the dental treatment Conversation about dental treatment with patient or relatives to the patient during treatment	10.1 [5.8-14.4]	10.4 [5.2-15.7]	0.64
Non-VAW	X-ray handling	Taking X-ray pictures, assessing and storing	5.9 [2.4-9.4]	9.2 [3.5-14.9]	0.31
	Administration	Writing/reading and dictation to the patient file	14.1 [11.5-16.7]	15.9 [9.7-22.2]	0.92
	Handling of parts and materials	Adjusting patient and/or operator chair, handling tools and materials, hand hygiene Transfers of the dentist in the dental practice Walking to the next patient	14.3 [9.8-18.9]	18.4 [13.4-23.5]	0.10
	Disturbances	Short spontaneous breaks during treatment lasting for more than one second Social communication with patients or colleagues Short spontaneous breaks Waiting	8.2 [1.8-14.6]	11.7 [6.3-17.0]	0.14
Total VAW			57.3 [49.5-65.2]	44.8 [32.2-57.4]	0.12
Total non-VAW			42.6 [34.7-50.4]	55.2 [42.6-67.8]	0.10

Wilcoxon signed-rank tests for differences in time distribution during the different work activities in 2003 and 2009.

Table 2. Mean frequency ( $h^{-1}$ ) of changes between work tasks and mean duration (s) of uninterrupted periods of VAW and non-VAW activities [min-max] in 2003 and 2009, n=12.

	Year 2003	Year 2009	p=
Frequency /hour	54 [20-106]	41 [15-72]	0.12
Duration of VAW	91 [40-172]	85 [46-182]	0.62
Duration of non-VAW	65 [23-161]	106 [25-234]	0.09

Paired t-test for differences between years 2003 and 2009.

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Table 3. Postures (deg) assessed for each of the investigated tasks and the job as a whole. Positive angles denote forward flexion for both head and back, n=12.

*Pooled and specific VAW and non-VAW tasks:* Group means of 50<sup>th</sup> percentile and of differences between 90<sup>th</sup> and 10<sup>th</sup> percentiles [CI 95% in brackets] for the head, back and upper arms, during the 45 minutes of video recording.

*Job:* Group means of 50<sup>th</sup> percentile [CI 95% in brackets] for the head, back and upper arms, during the 45 minutes of video recording and four hours of dental work.

	Head angle (sagittal plane)			Back angle (sagittal plane)			Dominant upper arm elevation			Non-dominant upper arm elevation		
	2003	2009	p=	2003	2009	p=	2003	2009	p=	2003	2009	p=
<b>VAW</b>												
<b>work tasks</b>												
Patient treatment												
<i>m</i> 50 <sup>th</sup>	40 [33-46]	46 [41-51]*	0.007	20 [14-25]	22 [17-27]	0.432	28 [24-33]	26 [22-30]	0.301	34 [26-43]	34 [29-38]	0.953
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	32 [28-36]	22 [19-25]*	0.001	19 [17-21]	16 [14-19]	0.165	32 [24-40]	29 [22-35]	0.521	25 [20-30]	31 [26-37]	0.055
Dental information												
<i>m</i> 50 <sup>th</sup>	24 [16-33]	27 [19-34]	0.635	17 [12-23]	15 [10-21]	0.464	28 [23-33]	24 [19-29]	0.253	31 [24-39]	24 [20-27]	0.108
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	36 [29-43]	39 [32-47]	0.420	23 [19-28]	18 [14-22]*	0.035	34 [24-45]	24 [21-28]	0.085	23 [19-26]	24 [18-30]	0.690
<b>Non-VAW</b>												
<b>work tasks</b>												
X-ray handling												
<i>m</i> 50 <sup>th</sup>	23 [11-35]	19 [15-23]	0.461	14 [8-20]	19 [11-27]	0.249	30 [25-35]	30 [24-35]	0.918	35 [26-43]	23 [19-27]*	0.019
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	40 [36-44]	31 [21-40]	0.068	29 [21-37]	25 [15-35]	0.563	31 [28-35]	21 [15-28]*	0.005	30 [23-37]	20 [13-27]*	0.044
Administration												
<i>m</i> 50 <sup>th</sup>	22 [14-29]	18 [11-26]	0.288	16 [10-22]	16 [10-22]	0.893	30 [25-36]	28 [23-33]	0.496	28 [21-36]	21 [17-26]	0.075
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	40 [33-46]	37 [30-43]	0.372	19 [12-27]	14 [7-21] <sup>1</sup>	0.073	21 [17-26]	16 [11-21]	0.067	20 [13-26]	15 [10-19]	0.089
Handling parts and materials												
<i>m</i> 50 <sup>th</sup>	23 [16-30]	26 [22-29]	0.450	15 [10-20]	12 [7-15]	0.130	28 [24-33]	29 [26-33]	0.684	29 [21-36]	27 [24-30]	0.600
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	44 [39-50]	43 [38-48]	0.572	28 [22-33]	30 [25-35]	0.517	35 [31-40]	40 [34-45]	0.182	31 [26-36]	33 [28-37]	0.613
Disturbances												
<i>m</i> 50 <sup>th</sup>	21 [12-31]	12 [6.3-18]	0.074	14 [8-19]	7.4 [4-11]	0.065	26 [21-31]	26 [21-30]	0.919	28 [21-36]	24 [20-27]	0.305
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	44 [38-49]	37 [31-43]	0.122	27 [19-36]	22 [16-27]	0.172	27 [21-32]	23 [17-30]	0.312	25 [21-29]	25 [17-33]	0.999
<b>Pooled VAW</b>												
<i>m</i> 50 <sup>th</sup>	38 [31-44]	42 [38-47]*	0.04	19 [14-25]	20 [15-25]	0.76	28 [23-32]	26 [22-30]	0.41	33 [24-42]	30 [27-34]	0.57
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	36 [31-41]	37 [30-44]	0.78	20 [17-22]	19 [16-22]	0.70	32 [24-40]	28 [23-34]	0.43	25 [20-30]	32 [26-38]	0.42
<b>Pooled non-VAW</b>												
<i>m</i> 50 <sup>th</sup>	22 [15-31] <sup>1</sup>	19 [15-23] <sup>2</sup>	0.27	15 [10-21] <sup>1</sup>	12 [7.6-17] <sup>2</sup>	0.21	28 [24-33]	27 [23-33]	0.90	29 [21-36]	24 [20-27] <sup>2</sup>	0.25
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	43 [39-47] <sup>1</sup>	43 [40-45] <sup>2</sup>	0.63	28 [21-35] <sup>1</sup>	28 [24-33] <sup>2</sup>	0.92	29 [25-33]	27 [23-30]	0.42	28 [24-33]	27 [22-32]	0.63
<b>Job exposure</b>												
4 h												
<i>m</i> 50 <sup>th</sup>	29 [22-36] <sup>a</sup>	28 [23-32]	0.70	16 [11-22]	16 [12-21]	0.97	27 [23-31]	28 [24-31]	0.73	28 [23-34]	28 [24-31]	0.79
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	47 [44-51] <sup>a</sup>	48 [44-52]	0.97	27 [24-30]	28 [24-32]	0.74	35 [30-39]	31 [27-35] <sup>a</sup>	0.15	31 [26-36]	31 [27-35]	0.78
45 min												
<i>m</i> 50 <sup>th</sup>	32 [25-39]	30 [25-35]	0.45	17 [12-21]	17 [12-22]	0.88	26 [22-30]	27 [23-30]	0.88	30 [24-37]	26 [22-30]	0.32
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	43 [39-46]	47 [42-52]	0.08	25 [21-29]	25 [21-30]	0.92	33 [28-38]	28 [24-32] <sup>*</sup>	0.04	29 [24-33]	31 [27-35]	0.35

\* Significance for paired t-test for differences between the same work activities in 2003 and 2009, p<0.05.

1. Significance for paired t-test for differences between VAW and non-VAW in 2003, p<0.05.

2. Significance for paired t-test for differences between VAW and non-VAW in 2009, p<0.05.

a Paired t-test for differences between four hours of inclinometry registration and 45 minutes of video recordings, p<0.05.

Table 4. Velocities (deg/s) assessed for each of the investigated tasks and the job as a whole, n=12.

*Pooled and specific VAW and non-VAW tasks:* Group means of 50<sup>th</sup> percentile and of differences between 90<sup>th</sup> and 10<sup>th</sup> percentiles [CI 95% in brackets] for the head, back and upper arms, during the 45 minutes of video recording.

*Job:* Group means of 50<sup>th</sup> percentile [CI 95% in brackets] for the head, back and upper arms, during the 45 minutes of video recording and four hours of dental work.

	Head angle (sagittal plane)			Back angle (sagittal plane)			Dominant upper arm elevation			Non-dominant upper arm elevation		
	2003	2009	p=	2003	2009	p=	2003	2009	p=	2003	2009	p=
<b>VAW</b>												
<b>work tasks</b>												
Patient treatment												
<i>m</i> 50 <sup>th</sup>	3.9 [3.3-4.5]	3.5 [2.8-4.3]	0.18	2.8 [2.4-3.2]	2.6 [2.1-3.0]	0.38	8.2 [6.6-9.8]	7.3 [5.8-8.8]	0.36	5.7 [4.7-6.7]	5.9 [4.6-7.2]	0.99
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	25 [22-29]	20 [16-24]*	0.01	17 [15-19]	14 [12-16]	0.06	45 [38-53]	34[30-39]*	0.01	30 [26-36]	29 [24-34]	0.57
Dental information												
<i>m</i> 50 <sup>th</sup>	6.8 [4.5-9.1]	8.3 [5.9-11]	0.28	4.8 [3.1-6.4]	5.3 [3.9-6.7]	0.64	11 [7.5-15]	12 [9.2-16]	0.73	9.8 [6.3-13]	11 [8.4-14]	0.61
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	41 [28-53]	44 [30-59]	0.58	26 [19-34]	27 [21-34]	0.89	61 [45-76]	59 [48-70]	0.87	49 [35-63]	51 [40-63]	0.80
<b>Non-VAW</b>												
<b>work tasks</b>												
X-ray handling												
<i>m</i> 50 <sup>th</sup>	6.8 [4.6-9.1]	5.6 [4.0-7.3]	0.28	5.2 [3.2-7.3]	3.7 [2.3-5.0]	0.22	15 [10-21]	9 [4.7-13]	0.08	13 [6.7-19]	8 [4.5-12]	0.23
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	39 [30-49]	36 [26-46]	0.41	33 [25-41]	27 [17-37]	0.35	78 [62-95]	63 [40-86]*	0.01	70 [52-88]	60 [40-82]	0.48
Administration												
<i>m</i> 50 <sup>th</sup>	4.9 [4.1-5.7]	4.1 [3.0-5.2]	0.07	3.4 [2.7-4.1]	2.6 [1.8-3.5]*	0.03	9.3 [7.3-11]	6.6 [4.3-9.0]*	0.01	7.4 [5.5-9.3]	5.7 [3.5-8.0]*	0.01
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	34 [28-40]	24 [17-31]*	0.01	23 [19-28]	33 [26-39]*	0.008	58 [47-69]	32 [26-39]*	0.001	46 [37-55]	29 [21-36]*	0.001
Handling parts and materials												
<i>m</i> 50 <sup>th</sup>	9.1 [5.8-12]	12 [9.8-14]*	0.03	6.4 [3.6-9.2]	9.0 [7.7-10]	0.12	19 [11-27]	27 [24-31]	0.09	16 [8.8-23]	25 [22-29]*	0.03
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	51 [37-64]	58 [50-67]	0.12	36 [25-46]	47 [41-53]*	0.06	84 [64-104]	107[95-120]*	0.05	70 [53-88]	99 [86-112]*	0.02
Disturbances												
<i>m</i> 50 <sup>th</sup>	8.9 [5.0-13]	9.7 [6.7-13]	0.72	6.2 [3.1-9.2]	6.5 [3.8-9.3]	0.84	18 [7.5-27]	16 [7.7-24]	0.75	15 [7.3-23]	15 [8.0-22]	0.99
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	47 [32-63]	39 [27-51]	0.40	35 [21-49]	14 [10-18]	0.55	80 [51-109]	78 [54-103]	0.90	70 [45-95]	73 [52-95]	0.77
<b>Pooled VAW</b>												
<i>m</i> 50 <sup>th</sup>	4.2 [3.3-5.0]	4.3 [3.1-5.5]	0.71	2.9 [2.5-3.4]	3.0 [2.3-3.7]	0.76	8.4 [6.8-10]	8.2 [6.6-9.8]	0.84	6.0 [5.0-7.1]	6.8 [5.3-8.3]	0.36
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	28 [23-33]	28 [20-35]	0.93	18 [24-40]	18 [14-22]	0.83	48 [41-55]	42 [35-49]	0.19	34 [29-39]	36 [29-43]	0.64
<b>Pooled non-VAW</b>												
<i>m</i> 50 <sup>th</sup>	6.6 [5.1-8.1] <sup>1</sup>	7.1 [5.6-8.5] <sup>2</sup>	0.39	4.6 [3.5-5.7] <sup>1</sup>	4.8 [3.6-5.9] <sup>2</sup>	0.83	13 [10-17]	13 [9.5-16] <sup>1</sup>	0.79	11 [8.1-14] <sup>1</sup>	12 [8.4-15] <sup>1</sup>	0.70
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	43 [35-52] <sup>1</sup>	47 [39-55] <sup>2</sup>	0.15	32 [25-39] <sup>1</sup>	34 [28-40] <sup>2</sup>	0.60	77 [62-92] <sup>1</sup>	78 [63-92] <sup>2</sup>	0.91	66 [52-79] <sup>1</sup>	72 [58-86] <sup>2</sup>	0.38
<b>Job exposure</b>												
4h												
<i>m</i> 50 <sup>th</sup>	5.4 [4.4-6.5]	5.1 [4.1-6.1]	0.18	3.7[2.9-4.5]	3.4 [2.8-4.1]	0.13	9.9[7.9-12]	8.9 [7.3-10] *	0.04	8.0[6.1-9.9]	7.6 [6.0-9.2]	0.23
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	40 [33-46] <sup>1</sup>	37 [31-43]	0.15	27 [23-31]	27 [23-30]	0.80	65 [56-74]	62 [54-70]	0.26	54 [46-62]	56 [49-64]	0.26
45 min												
<i>m</i> 50 <sup>th</sup>	5.1 [4.1-6.1]	5.5 [4.2-6.8]	0.29	3.5[2.8-4.2]	3.7 [2.9-4.6]	0.33	9.7[7.7-12]	9.9 [7.8-12]	0.70	7.8[5.9-9.3]	8.5 [6.5-11]	0.09
<i>m diff</i> 90 <sup>th</sup> 10 <sup>th</sup>	35 [29-42]	38 [31-46]	0.28	25 [20-29]	27[22-32]	0.29	62 [52-72]	63 [52-75]	0.83	49 [40-58]	57 [45-68]	0.09

\* Significance for paired t-test for differences between same work activities in 2003 and 2009, p<0.05.

1. Significance for paired t-test for differences between VAW and non-VAW in 2003, p<0.05.

2. Significance for paired t-test for differences between VAW and non-VAW in 2009, p<0.05.

a Paired t-test for differences between 4h inclinometry registration and 45 minutes of video recordings, p<0.05.