ERGONOMIC PREVENTION OF MUSCULOSKELETAL DISORDERS OF MAINTENANCE WORKERS IN THE STEEL INDUSTRY

Guidelines for the optimum working height of selected maintenance operations

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CONTENTS

	page
PREFACE	i
SUMMARY	iii
1. INTRODUCTION	1
2. A HEALTH SURVEY OF MAINTENANCE WORKERS IN THE STEEL INDUSTRY	3
2.1 Summary	3
2.2 Introduction	4
2.3 Methods	5
2.3.1 Questionnaire	5
2.3.2 Study population	5
2.3.3 Analysis	6
2.4 Results	7
2.4.1 Description of the study population	7
2.4.2 Health complaints in general	8
2.4.3 Musculoskeletal complaints in all departments	10
2.4.4 Muscoloskeletal complaints in each department	11
2.4.5 Muscoloskeletal complaints in specific tasks	14
2.4.6 Work load profiles of high-risk tasks	17
2.5 Discussion	22
2.6 Conclusions	24
2.7 Acknowledgement	24
3. WORK LOAD SURVEY OF MAINTENANCE WORKERS IN THE STEEL INDUSTRY	25
3.1 Summary	25
3.2 Introduction	25

page

3.3 Methods 26

3.3.1 The MAT system 26
3.3.2 The MTT system 28
3.3.3 Selection of heavy maintenance tasks 30

3.4 Results 30
3.5 Conclusions 33

4. SELECTION OF HEAVY AND HIGH RISK MAINTENANCE TASKS, AND A WORK VARIABLE FOR EXPERIMENTAL STUDY IN THE STEEL INDUSTRY 34

4.1 Summary 34
4.2 Introduction 35
4.3 Methods 35

4.3.1 Selection of tasks 35
4.3.2 Ergonomic evaluation of selected tasks 35
4.3.3 Selection of work variable(s) for experimental ergonomic study 36

4.4 Results 36

4.4.1 Selection of tasks 36
4.4.2 Ergonomic evaluation of tasks 38
4.4.3 Selection of work variable(s) for experimental ergonomic study 43

5. ERGONOMIC GUIDELINES ON THE OPTIMUM WORKING HEIGHT FOR PNEUMATIC WRENCHING, OXY-GAS CUTTING, AND GRINDING DURING MAINTENANCE WORK IN THE STEEL INDUSTRY 45

5.1 Summary 45
5.2 Introduction 46

5.2.1 General background 46
5.2.2 Research background 47

page

5.3 Methods 49

5.3.1 General experimental set-up 49
5.3.2 Subjects 49
5.3.3 Description of experimental operations 50
5.3.4 Independent variable 52
5.3.5 Dependent variables and measuring methods 53
5.3.6 Procedure 59
5.3.7 Data analysis 62
5.3.8 Formulation of guidelines 63

5.4 Results 65

5.4.1 Pneumatic wrenching 66
5.4.2 Oxy-gas cutting 81
5.4.3 Grinding 98

5.5 Discussion 113
5.6 Conclusions 115
5.7 Acknowledgements 116

6. CONCLUSIONS AND RECOMMENDATIONS 118

REFERENCES 121

APPENDICES 123

Appendix I Questionnaire on health and work at the Technical Department of Hoogovens (in Dutch) 125

Appendix II Medical Task Analysis (MAT) of maintenance tasks at Hoogovens 157

Appendix III Additional work site and task observation 163

Appendix IV Questionnaire on subjective experiences (in Dutch) 167

PREFACE*

In the steel industry musculoskeletal disorders are important determinants of sickness and absenteeism. Prevention of 'biomechanical risk' is therefore of utmost importance, both for industry and the workers themselves.
In this research project, ergonomic guidelines have been developed to reduce high musculoskeletal work load for a number of maintenance tasks in the steel industry. The project was aimed at maintenance work because of the supposed high prevalence of complaints in this type of work.
This report gives an overview of the magnitude and nature of musculoskeletal morbidity in various maintenance departments and maintenance tasks followed by useful recommendations on optimum working heights for oxy-gas cutting, pneumatic wrenching and grinding. The work load is reduced by implementing these recommendations and improvements of worker's health are to be expected.
The work was sponsored by the European Coal and Steel Community and carried out by a project team drawn from Hoogovens and the TNO Institute of Preventive Health Care.
The project team comprised:

A.J. Bolijn (project leader):	Hoogovens
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J. Dul	: TNO Institute of Preventive Health Care
V.H. Hildebrandt	: TNO Institute of Preventive Health Care

The project team would like to thank the maintenance workers, management and staff of five maintenance departments at Hoogovens for all the help which they have given during the course of this study. Without their help this work would not have been possible.

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SUMMARY

The aim of this research project was to develop validated ergonomic guidelines to reduce the 'biomechanical risk' for selected heavy, high risk maintenance tasks in the steel industry. To select these tasks, first a health survey and a work load survey were carried out.

In the health survey (chapter 2), the size and nature of musculoskeletal complaints of maintenance workers from five departments at Hoogovens were studied (the five departments were: Mobiele Vaklieden (MOB-department), Ovenbouw (OB-department), Walsenonderhoud (WO-department), Elektrotechnische Dienst (EWS-department) and Centrale Werkplaats (CW-department). The aim was to identify groups with a high prevalence of musculoskeletal problems, possibly indicating high levels of musculoskeletal work load. All workers of these departments were asked to complete a standardized questionnaire on musculoskeletal complaints and musculoskeletal work load. In all, 440 workers participated. In particular the prevalence of complaints of the low back (50% of the workers had experienced complaints during the past 12 months) and neck-hand (41%) were high. Also, complaints of the knees (22%) were substantial. Complaints of other regions of the body were less important (about 10%). These findings appeared to be comparable with prevalences found in other high risk groups. In order to identify high-risk subgroups, it was analyzed to what extent these complaints were associated with specific departments or tasks within these departments. The prevalence of complaints was highest at the EWS-department, followed by the WO-department. However, the other departments showed high prevalences too, in particular with regard to the low back and the neck-hand region. It was difficult to compose groups of workers with a homogeneous set of tasks within these five departments. At the EWS-department and WO-department, there were no tasks which were performed predominantly or even often by groups of workers of sufficient size. This implicated that at these departments, no high-risk groups could be identified. At the three other departments, the prevalence of 20 tasks was just sufficient for the analysis (between 18 and 61 persons for a given task). Twelve tasks could be identified as being associated with a relatively high prevalence of musculoskeletal complaints.

In the work load survey (chapter 3) existing Hoogovens data on work load associated with maintenance tasks were analyzed to select the heaviest tasks. These

data were derived from a system for Medical Analysis of Tasks (MAT), which contains, among others, an assessment by experts of the demands that a certain task places on the worker with respect to his back and muscles. All maintenance tasks in the five maintenance departments selected were identified and task loads were classified according to their heaviness for back and muscles. From the 76 maintenance tasks, 25 were selected on being the heaviest (12 at MOB-department, 5 at the OB-department, 4 at the CW-department, 3 at the EWS-department and 1 at the WO-department).

On the basis of the health survey and the work load survey high risk, heavy tasks and the corresponding most relevant work variable(s) for an experimental ergonomic study were selected in chapter 4.

The main criterium to select tasks for an experimental ergonomic study was directly deduced from the selection criteria used for both surveys accomplished: tasks had to be identified as heavy and high risk by the work load and the health survey, respectively. Five such tasks were selected and evaluated in more detail by visiting relevant work sites. Three tasks were carried out in the CW-department and 2 tasks in the OB-department.

Within the selected tasks, work variables for the experimental ergonomic study were selected, which possibly are related to the high work load and health complaints found. These work variables also had to match the following other requirements:

1. it must be possible to intervene on the work variable in the actual everyday work situation,
2. it must be possible to study the work variable in an experimental setting,
3. no reliable guidelines for the work variable had to be available already, and
4. it must be possible to generalize research results for the work variable to other work situations.

The evaluations of the five tasks led to the conclusion that executing tool-based operations on relatively small objects at a fixed workplace (workbench, trestles) was most suited for an experimental study. On the basis of research volume restrictions, preferences of the management of the maintenance departments involved, and practical reasons, **working height** was chosen as the work variable, and **pneumatic wrenching, oxy-cutting,** and **grinding** as the operations for the experimental study. These tasks are primarily carried out in the CW-department (central maintenance department).

The purpose of the experimental ergonomic study of chapter 5 was to formulate ergonomic guidelines on optimum working height for the three operations mentioned, in order to obtain the best possible working posture and to minimize the load on the musculoskeletal system.
Professional test subjects executed an operation for about 5 minutes (corresponds to the actual operation time) on several different heights. The effects of working height on working posture and on the worker's experiences were measured by a computer assisted video system and a questionnaire, respectively.
The research approach chosen turned out to be valuable and successful. For all three operations studied supportive and non-conflicting information was obtained from working posture and subjective experiences. In general, the three operations studied are executed standing at the same workbench. For pneumatic wrenching a working height between 10 cm below and 10 cm above elbow height is recommended, while a working height of 5 to 10 cm below elbow height is to be preferred. For oxy-gas cutting a strong preference exists for a working height on elbow height, while a working height range between 10 cm below and 10 cm above elbow height is recommended. For grinding a working height 35 cm below elbow height, i.e. approximately knuckle height for average males, is recommended.
Optimum working heights for the operations, object heights, and workers' body height all show moderate to large variation. This means that an optimum working height during task execution can solely be created by height adjustable workbenches (or other height adjustable means). To guarantee optimum use, the adjustment of working height during task execution should be fast and easy. The process of implementation of height adjustable workbenches (or other means) should be given special attention.
It is recommended that height-adjustable workbenches (at least 65-130 cm.) are used for oxy-gas cutting, pneumatic wrenching and grinding. The workers should be informed about their individual optimum working height for these maintenance operations. The individual working height depends on the operation, the object height and the worker's elbow height. These preventive measures can improve the worker's posture and reduce the work load considerably. The scope of the musculoskeletal problems of maintenance workers justify these relatively simple improvements.

1. INTRODUCTION*

In most industrialized countries musculoskeletal disorders is the major reason of sick leave and disability. In the Netherlands, about 25% of the workers regularly suffer from low back pain (Hildebrandt & Van der Valk, 1990). Neck-shoulder-arm problems are common as well. Industries and governments are increasingly concerned with the problem and are looking for ways to reduce it, in particular through preventive approaches.

The prevention of work related musculoskeletal disorders has traditionally been attempted by three approaches:

1. ergonomic (re)design of the task or workplace;
2. education and training of workers in work methods and posture and movement behaviour;

and

3. selection of workers with sufficient capacity, and guidance of workers with (temporary) reduced capacity.

It is generally accepted that the ergonomic approach is the most structural and effective preventive approach.

In the European coal and steel industry, work-related musculoskeletal problems and the need for ergonomic prevention are recognized as well. In the Fifth Ergonomics Programme of the European Coal and Steel Communities, national coal and steel industries are asked to pay attention to the need for measures to reduce the 'biomechanical risk' of workers in this branch of industry (ECSC, 1987). A working group of experts has concluded that 'internal transport', 'maintenance work', repetitive work', and 'fixed work stations' are four areas were research is needed most. The research should lead to valid ergonomic recommendations for the reduction of the 'biomechanical risk' in these areas. The need for the development of valid ergonomic guidelines for specific work situations was also stressed in earlier studies. Dul and Hildebrandt (1987) have shown that the validity of general ergonomic recommendations from handbooks for application to specific work situations can be questioned. They concluded that for specific work situations, specific guidelines should be developed.

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In the Netherlands, Hoogovens IJmuiden has started a collaborative research programme in cooperation with the TNO Institute of Preventive Health Care, Leiden. The aim of this programme is:

1. to develop a method for formulating valid ergonomic guidelines on reduction of the load on the musculoskeletal system

and

2. to apply the method for specific operations during heavy, high risk tasks in the steel industry.

The research approach consist of four phases:

1. a health survey for identification of relatively 'high risk' maintenance tasks;
2. a work load survey for identification of relatively 'heavy' maintenance tasks;
3. selection of high risk, heavy tasks, and work variables;
4. development of valid ergonomic guidelines for specific work variables.

The research presented in this report can be seen as a first project in which the method is developed and applied for specific operations during maintenance work (oxy-gas cutting, pneumatic wrenching and grinding). This project was partially financed by the European Coal and Steel Community. In chapters 2 and 3, the results of a health survey for identification of relatively 'high risk' maintenance tasks and a work load survey for identification of relatively 'heavy' maintenance tasks will be presented, respectively. Chapter 4 deals with the selection of heavy, high risk maintenance operations. Chapter 5 presents the results of the development of valid ergonomic guidelines for these operations. This report ends with conclusions and recommendations for further actions and research.

2. A HEALTH SURVEY OF MAINTENANCE WORKERS IN THE STEEL INDUSTRY*

2.1 Summary

In the health survey, the size and nature of musculoskeletal complaints of maintenance workers from five departments at Hoogovens were studied. The aim was to identify groups with a high prevalence of musculoskeletal problems, possibly indicating high levels of musculoskeletal work load. All workers of these departments were asked to complete a standardized questionnaire on musculoskeletal complaints and musculoskeletal work load. In all, 440 workers participated. In particular prevalence of complaints of the low back (50% of the workers had experienced complaints during the past 12 months) and neck-hand (41%) were high. Also, complaints of the knees (22%) were substantial. Complaints of other regions of the body were less important (about 10%). These findings appeared to be comparable with prevalences found in other high risk groups. In order to identify high-risk subgroups, it was analyzed to what extent these complaints were associated with specific departments or tasks within these departments. Prevalence of complaints was highest at the EWS-department, followed by the WO-department. However, the other departments showed high prevalences too, in particular with regard to the low back and the neck-hand region. It was difficult to compose groups of workers with a homogeneous set of tasks within these five departments. At the EWS-department and WO-department, there were no tasks which were performed predominantly or even often by groups of workers of sufficient size. This implicated that at these departments, no high-risk groups could be identified. At the three other departments, the prevalence of 20 tasks was just sufficient for the analysis (between 18 and 61 persons for a given task). Twelve tasks could be identified as being associated with a relatively high prevalence of musculoskeletal complaints. Table 2.1 gives an overview of these tasks.

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Table 2.1 Tasks characterized by a relatively high prevalence of musculoskeletal complaints

department	body region 'at risk'	task, official Dutch names*
OB	neck-hand	1. werkzaamheden CWO
		2. werkzaamheden Centraal
		3. pannenonderhoud ox1/ox2
MOB	knee	4. onderhoud bankwerken RND
		5. onderhoud bankwerken CEN/CTD
		6. pijpbewerken/P.O. ketels CEN
CW	low back	7. aftekenen
		8. richten
		9. constructie bankwerken algemeen
		10. constructie bankwerken zwaar
		11. lassen werkplaats
	low back + knee	12. constructie bankwerken wagons

* specific company-bound names, cannot be translated

Therefore, from the viewpoint of health these tasks deserve priority when planning ergonomical preventive activities. An analysis of musculoskeletal work load on the basis of questions about exposure to high-risk postures, movements and force-exertions, did confirm this conclusion: it appeared that musculoskeletal load was generally high in these groups, absolute as well as relative to the relating means of the departments in general. Development of guidelines for the prevention of these problems seems therefore important to control and reduce musculoskeletal problems of maintenance workers.

2.2 Introduction

The goal of the health survey was to determine high-risk groups within the maintenance worker population with regard to musculoskeletal disorders, pointing to possible high musculoskeletal work loads. The question of the survey was: What is the nature and size of musculoskeletal problems of different groups of maintenance workers within Hoogovens.

2.3 Methods

2.3.1 Questionnaire

A cross-sectional questionnaire-survey was carried out to collect data on health and work in different groups of maintenance workers.
The NIPG-TNO 'questionnaire on musculoskeletal disorders' was used (Appendix I). This questionnaire contains questions on the following subjects:

- general background data (e.g. age, sex);
- health;
  - general complaints
  - standardised questions on complaints of musculoskeletal system, based on the co-called 'Nordic-questionnaire on musculoskeletal disorders', which is often applied in their kind of surveys and which has been proven to give reliable and valid measurements (Johnsson & Ideborg, 1985);
- tasks (screening of individual exposure to tasks performed in the department concerned);
- work load and working circumstances, involving (among others) questions on exposure to high-risk postures, movements and exertions as well as perceived physical and mental work load;
- suggestions of workers with regard to causes of the problems and possibilities for improvements.

Details on this questionnaire have been published elsewhere (Hildebrandt, 1989).

2.3.2 Study population

Five departments participated in the survey: Mobiele Vaklieden (MOB-department), Ovenbouw (OB-department), Walsenonderhoud (WO-department), Elektrotechnische Dienst (EWS-department) and Centrale Werkplaats (CW-department). All workers of those departments were asked to participate. Due to the cooperation of the management of these departments, questionnaires could be filled-in by the workers at the departments during working time. Those who were ill or absent were asked to complete the questionnaire later.

The analysis was aimed to the identification of groups within the maintenance workers with a relatively high prevalence of musculoskeletal complaints. At the first instance, the data of the five departments were analyzed as a whole. For the ergonomic analysis, more detailed information of high-risk jobs or tasks was essential for the identification of the specific work-situations which need improvement. To obtain that information, groups of workers within the five departments involved were composed which all perform the same tasks. By comparing those groups with regard to the prevalence of musculoskeletal complaints, indications could be obtained about high-risk tasks or working situations. Two possibilities were available to compose such groups: grouping on jobs or grouping on tasks. It appeared to be impossible to compare groups of workers with the same job, because the number of jobs was very large and on the other hand the number of jobs performed by a sufficient number of workers was very small. Although still arbitrary, we required on the basis of earlier experience, that at least 15 workers had to be present in a specific group to obtain more or less 'general' results.

It was also difficult to compose groups of a sufficient size according to *tasks*. Most workers had a rather heterogeneous set of tasks. This made it impossible to compile groups of workers who perform a particular task or combination of tasks predominantly. Instead, groups of workers were compiled performing tasks *often* or *predominantly*. As a result of the way these tasks had to be composed, workers which carry out different tasks regularly, will be represented in different tasks. This could result in a dilution of the comparisons between tasks, since there is a overlap between those groups. However, it may be assumed that high risks associated with certain tasks, should be manifest despite this dilution (see 2.5).

2.3.3 Analysis

Six analysis were carried out.

- First, general work-related health problems reported by the workers themselves are analyzed (2.4.2).

- Then, the musculoskeletal complaints are analyzed, in all departments (2.4.3), in each department separately (2.4.4) and in the tasks (2.4.5).

Musculoskeletal complaints are differentiated into complaints of neck, upper and lower back, upper extremities (shoulder, elbow and wrists/hands) and lower extremities (hips, knees, ankles/foots). Complaints of neck, shoulder, elbow and wrist/hand are also summated, since the close correlation between complaints of these regions. Corrections are made, if relevant, for lefthandedness. The prevalence of complaints are presented as the percentage of workers having had complaints during the last 12 months. To interpret results, comparisons are made with other occupational groups in the Netherlands on which comparable data are available with regard to musculoskeletal morbidity (2.4.3). To identify high-risk groups, the prevalences of musculoskeletal complaints of a specific group are always compared to the prevalence of musculoskeletal complaints among all workers studied. Groups with relatively high prevalences are considered to be at risk, being possibly exposed to hazardous working conditions.

Finally, of the high-risk tasks identified, profiles of work load have been made based on the related questionnaire-data (2.4.6). The selection of relevant work load variables has been made on the basis of available epidemiological knowledge on work related risk factors of musculoskeletal disorders (Hagberg, 1984; Hildebrandt, 1987). The aim of these profiles was to facilitate the choice of work-variables in the ergonomical study presented in chapter 5.

Since this analysis is primarily descriptive and no samples of populations were involved, differences among groups have not been statistically tested. On the basis of earlier research experiences (Hildebrandt et al., 1989), it was decided that a difference between a specific group and the total study population greater or equal to 10% of the mean would be considered as important.

2.4 Results

2.4.1 Description of the study population

The study population consisted of 440 male workers, working at the departments WO (n=47), OB (n=103), EWS (n=34), MOB (n=127) and CW (n=129). Due to limited possibilities, the actual staffing of the departments could not be computed; it was estimated response-rate varied between 60 and 80%, depending on the department involved. This is a satisfactory result in this type of research projects.

Table 2.2 presents some important background data on these groups: mean age, mean of years of employment at Hoogovens (time of exposure) and the prevalence of shiftwork in each department.

Table 2.2 Background-data of study population

department	WO (n=47)	OB (n=103)	EWS (n=34)	MOB (n=27)	CW (n=129)	A (n=440)
mean age (years)	36	40	38	39	36	38
mean length of employment	11	14	13	14	16	14
percentage shift workers	68	88	6	9	46	54

WO = Walsenonderhoud; OB = Ovenbouw; EWS = Elektrotechniek; MOB = Mobiele Vaklieden; CW = Centrale Werkplaats; A = all workers

Differences between departments concerning age and length of employment are less than five years. Shiftwork is common in the WO-department, OB-department and MOB-department.

2.4.2 Health complaints in general

All participants were asked (by an open, non-prestructured question) whether they had had health complaints caused by their work. Most workers indicated one particular complaint. Only a few workers reported several complaints. Table 2.3 gives the results.

Musculoskeletal complaints are mentioned most. Most workers indicate heavy work and climate as related working aspects.

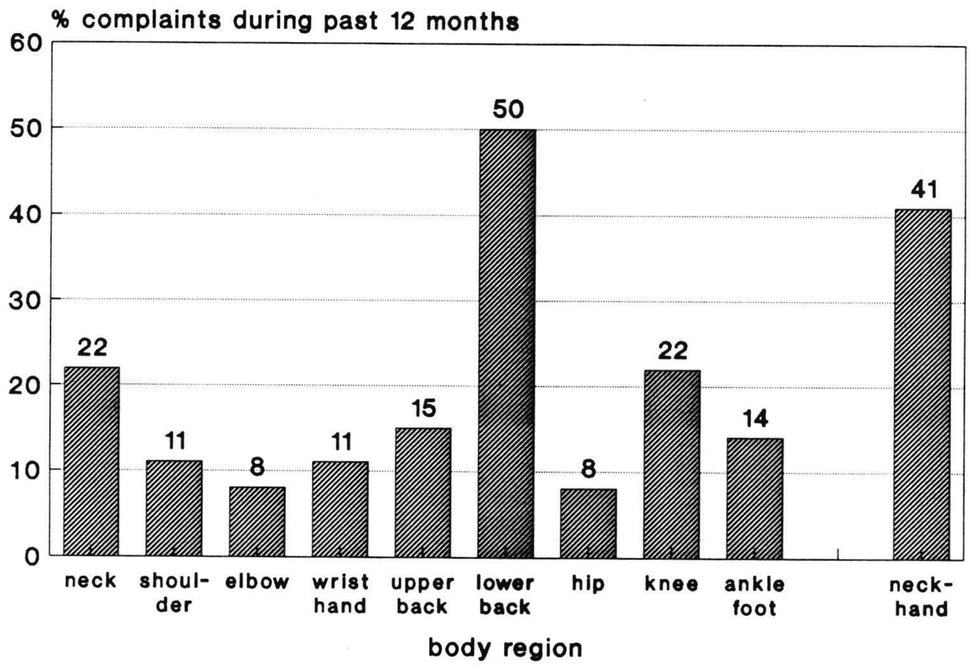
Table 2.3 Number of people having health complaints caused by the work, as reported by themselves, including corresponding causal working aspects

	departments 1 (47) n	2 (103) n	3 (34) n	4 (27) n	5 (129) n	A (440) n	A %	percentage of all complaints (n=142) in all departments	causes 1	2	3	4	5	A*
back trouble	6	9	5	19	19	58	13,2	- (heavy) lifting	2	-	1	10	8	21
								- cold, draught	-	-	-	2	5	7
								- heavy work	1	1	-	2	2	6
								- bending	-	2	-	2	2	6
								- bricklaying	-	2	-	-	-	2
knees trouble	-	2	3	7	2	14	3,2	- sitting on knee	-	2	-	4	-	6
cold, flu	1	4	-	4	4	13	3,0	- draught	1	3	-	2	4	10
								- change of temperature	-	-	-	2	-	2
shoulder trouble	1	4	1	2	3	11	2,5	- lifting	-	-	-	2	-	2
								- bricklaying	-	2	-	-	-	2
headache	-	4	-	2	2	8	1,8	- green mortel	-	3	-	-	-	3
								- noise	-	-	-	2	-	2
neck trouble	-	3	1	1	3	8	1,8	- draught	-	1	-	-	2	3
upper respitory system	1	2	-	1	3	7	1,6	- dust	-	-	-	1	3	4
elbow/fore-arm trouble	-	-	1	1	3	5	1,1	- (heavy) work/lifting	-	-	-	1	-	1
								- knocking with hammer	-	-	-	1	-	1
psychological problems stress, high blood pressure	-	1	1	1	2	5	1,1	- workpace, agitated	-	1	1	-	-	2
ankle/foot trouble	-	-	1	1	2	4	0,9	- walking, standing	-	-	-	1	1	2
								- broken floor	-	-	-	-	1	1
wrist trouble	1	2	-	-	-	3	0,7							
eczema	-	2	-	-	-	2	0,5	- dust	-	1	-	-	-	1
peptic complaints	-	-	1	-	1	2	0,5		-	-	-	-	-	-
malaise, tiredness	-	-	1	-	1	2	0,5		-	-	-	-	-	-

2.4.3 Musculoskeletal complaints in all departments

First, size and nature of complaints at the five departments as a whole are described and compared with data of other occupational groups. For every body region, workers were asked separately to indicate whether they had had trouble of this region during a defined period. Therefore, a worker could report complaints in more than one body region.
In all, 71% of all workers have had complaints of the musculoskeletal system during the last 12 months. Figure 2.1 gives the data on size and nature of those complaints.

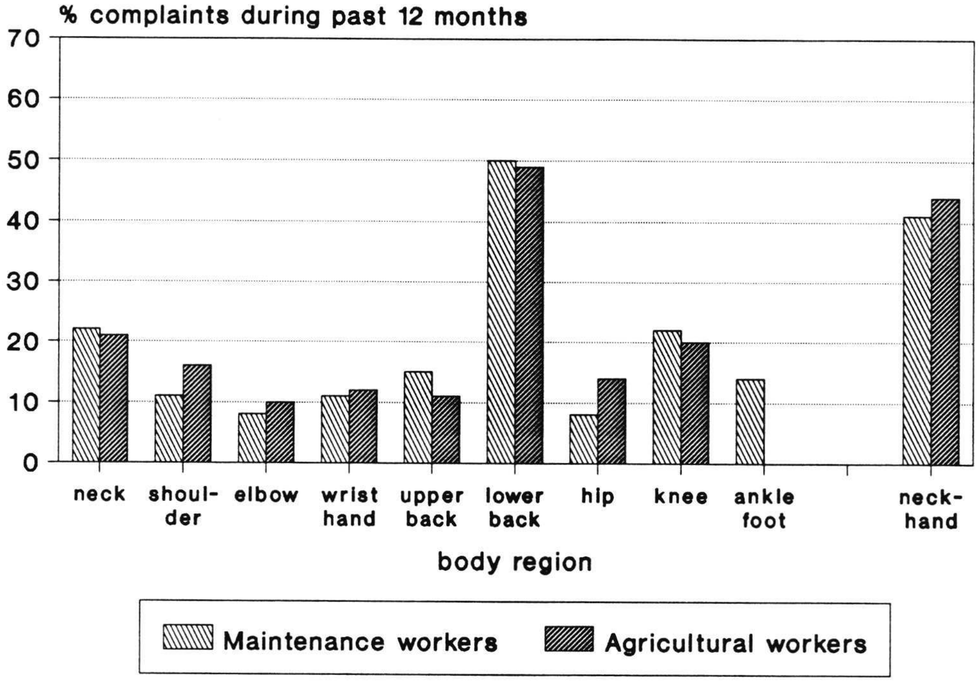
Figure 2.1 Prevalence (%) of musculoskeletal complaints of maintenance workers



Complaints-rates of the low back (50%) and the neck-shoulder-arm region (41%) are particularly high. Also, complaints of the knees (22%) are substantially prevalent. Complaints of other regions are relatively less common.
To interpret these results, it would have been interesting to have comparable data on all production-workers of Hoogovens. However, these data were not available. Instead, figure 2.2 shows a comparison with agricultural workers in the Netherlands on which comparable data are available with regard to musculo-

skeletal morbidity. Agricultural workers are known to be exposed to high work loads and to have high musculoskeletal complaints rates (Hildebrandt, 1989) and thus contribute an interesting reference-group for other groups with high work loads.

Figure 2.2 Prevalence (%) of musculoskeletal complaints maintenance workers in comparison with agricultural workers



This comparison indicates that the prevalences found in this study are as high as prevalences found in an other occupational group know to be a risk group for musculoskeletal problems, indicating the level of complaints is relatively high.

2.4.4 Musculoskeletal complaints in each department

Figures 2.3-2.5 show the prevalences of musculoskeletal complaints in each of the five departments separately. Complaints of the low back and lower extremity are shown in figure 2.3, complaints of the upper extremity are shown in figure 2.4 and complaints of all regions and neck-hand regions together are shown in figure 2.5.

Prevalences are the highest at the EWS-department, followed by the WO-department.

The prevalence of **low back complaints** is high at all departments: at least 2 in 5 workers have had back complaints during the past 12 months. Between departments, differences are relatively marked, the EWS-department having a relatively high prevalence (68%) and the OB-department a relatively low prevalence (39%).

Concerning **lower extremity complaints**, the EWS-department and MOB-department show relatively high prevalences.

Concerning **upper extremity complaints**, differences between departments are not very large. When considering these complaints together, the EWS-department has a relatively high prevalence (50%), the CW-department a relatively low prevalence (38%).

Figure 2.3 Prevalence of complaints of neck, upper back and upper extremities in five maintenance departments

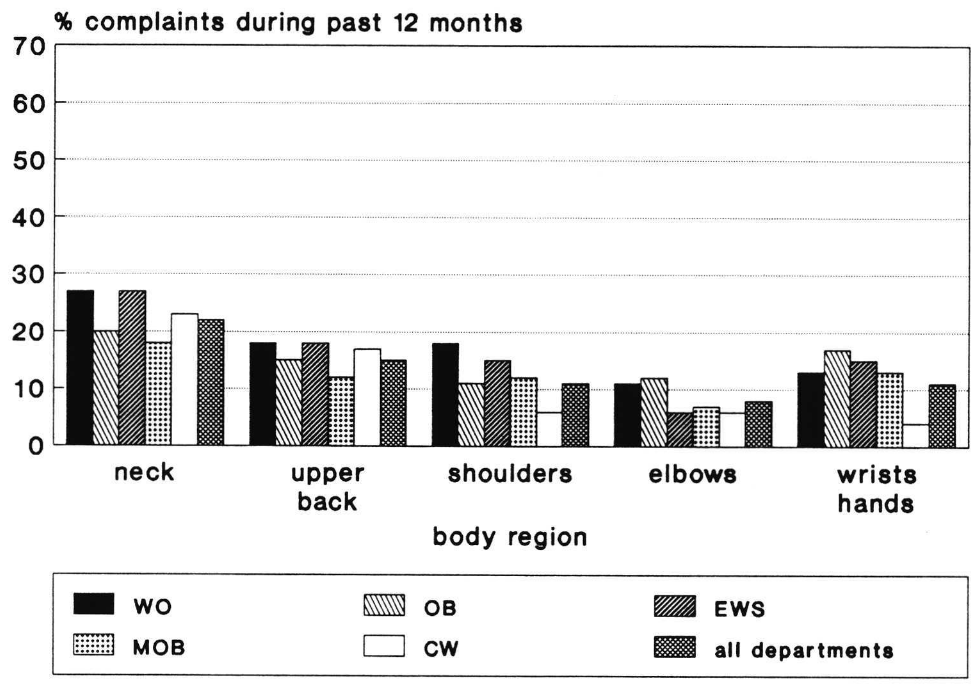


Figure 2.4 Prevalence of complaints of low back, hips and lower extremities in five maintenance departments

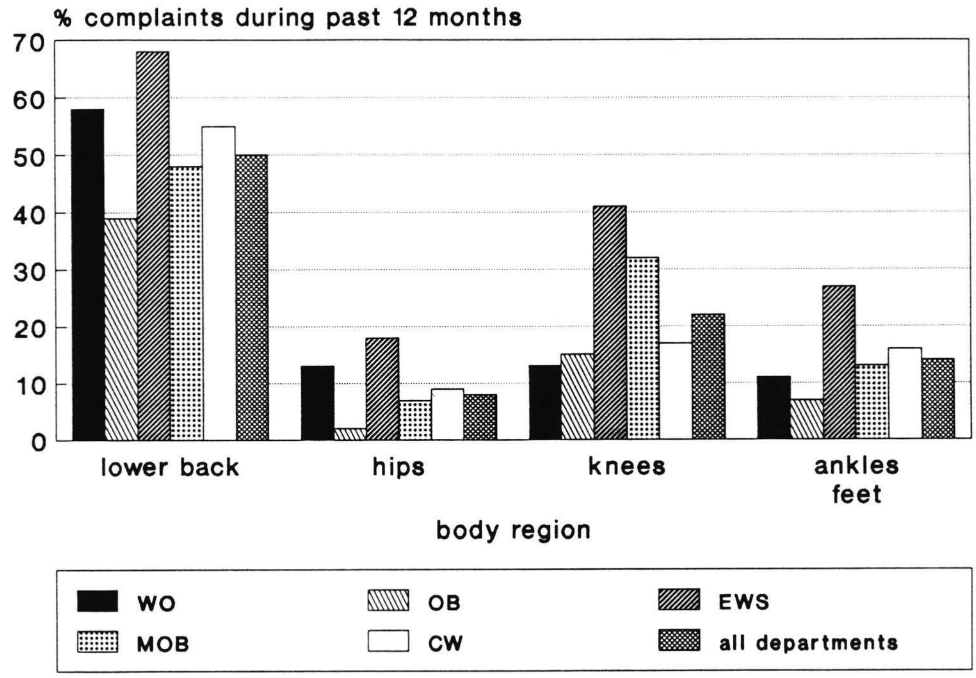
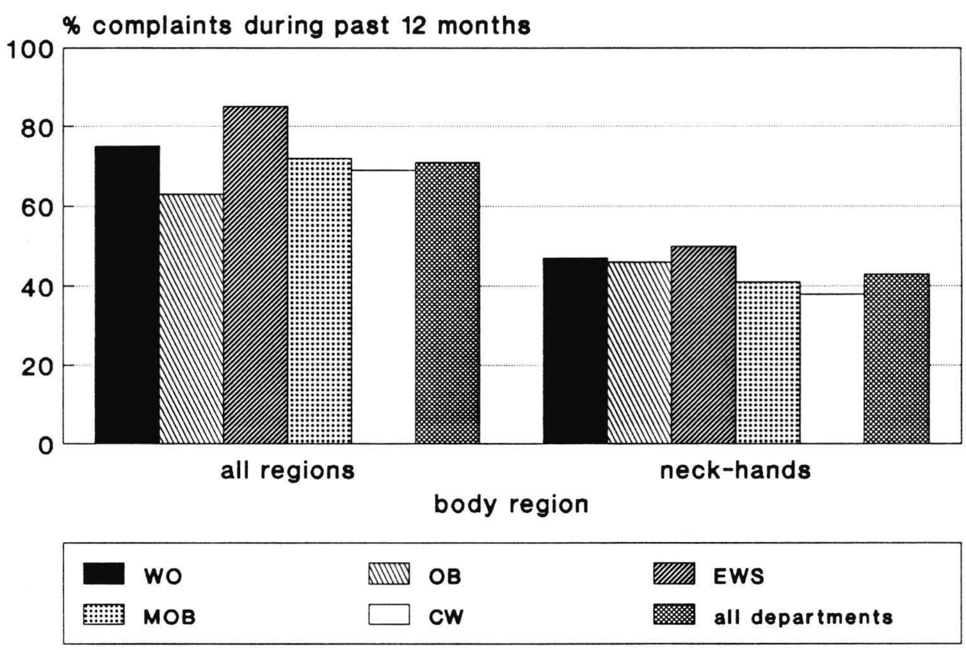


Figure 2.5 Prevalence of complaints of all regions and neck-hand regions together in five maintenance departments



In conclusion, although some differences are present between the departments involved, these differences are not very marked or specific. In particular complaints of the low back and the neck-hand are substantial at all departments.

2.4.5 Musculoskeletal complaints in specific tasks

Only at the departments OB, MOB and CW larger groups of workers (varying between 18 and 61 workers) could be identified performing task often or predominant. The following analysis thus only involves these tasks within the OB-department, MOB-department and CW-department.

The official Dutch names of these tasks, which are difficult to translate, are listed below:

OB-department

a. Werkzaamheden CWO
b. Werkzaamheden Centraal
c. Pannenonderhoud OX1/OX2
d. Verdeelbakspuiten OX1/OX2

MOB-department

a. Onderhoud Bankwerken RZD
b. Branden werkplaats
c. Onderhoud Bankwerken RND
d. Werkzaamheden werkplaats MOB
e. Pijpbewerken algemeen MOB RCV
f. Onderhoud bankwerken CEN/CTD
g. Onderhouding pompen/motoren
h. Pijpbewerken/P.O. ketels CEN
i. Onderhoud pompen/ventilator RND

CW-department

a. Machine Bankwerken
b. Aftekenen
c. Richten
d. Constructie Bankwerken Algemeen
e. Constructie Bankwerken Zwaar
f. Lassen werkplaats
g. Constructie Bankwerken Wagons.

Figures 2.6-2.8 show the prevalence of complaints for 4 tasks of the OB-department, 7 tasks of the CW-department and 9 tasks of the MOB-department. The figures are restricted to complaints of the low back, the neck-hand and the knees, being the most important sites of complaints identified earlier.

Figure 2.6 Prevalence of neck-hand complaints, specified for different tasks

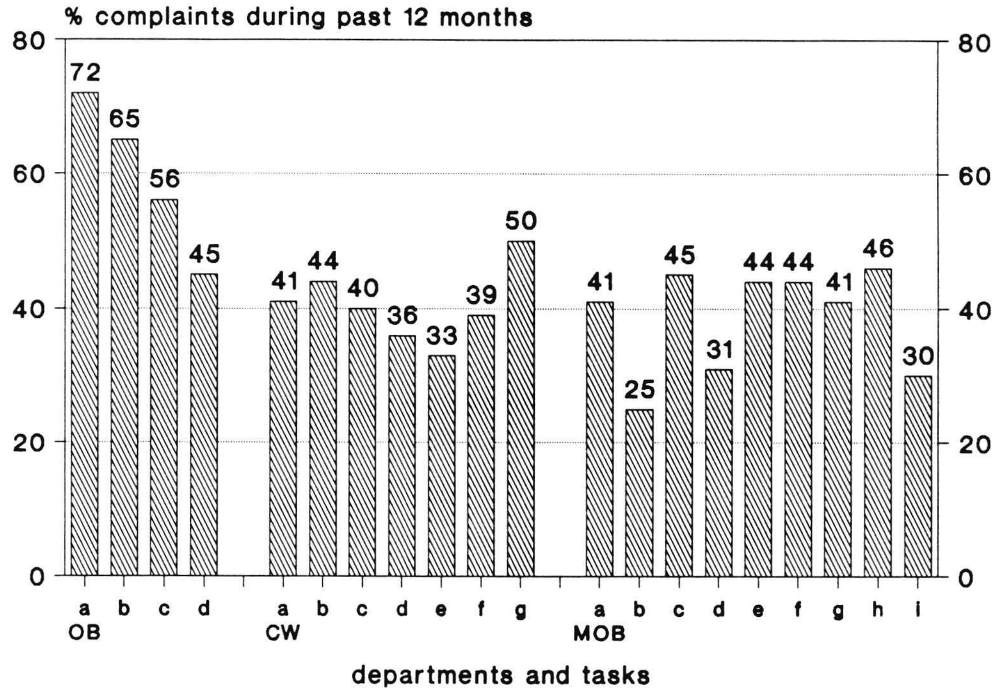


Figure 2.7 Prevalence of low back complaints, specified for different tasks

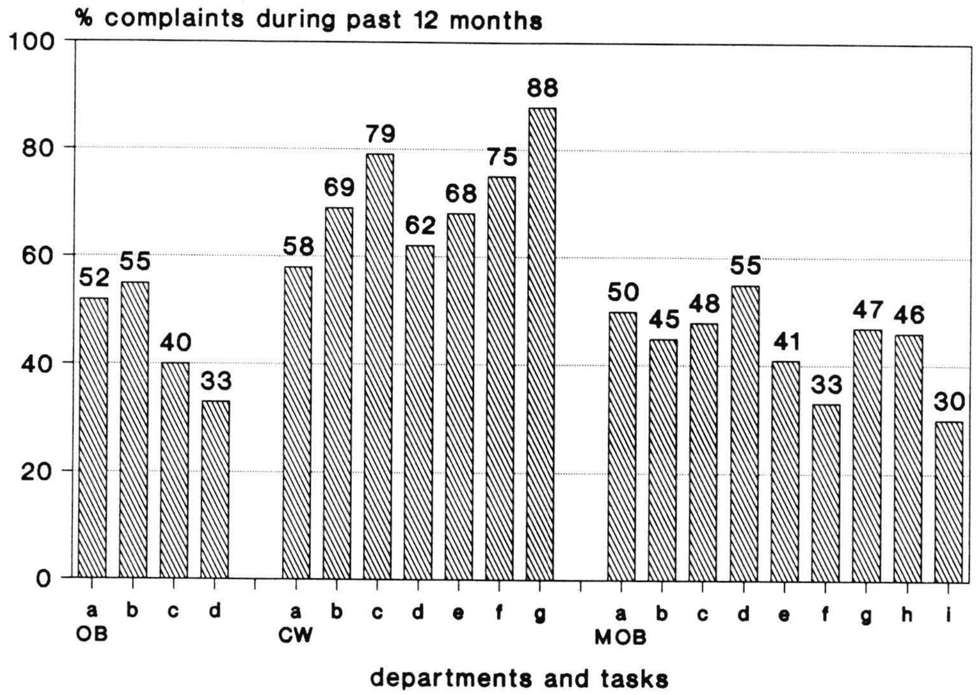
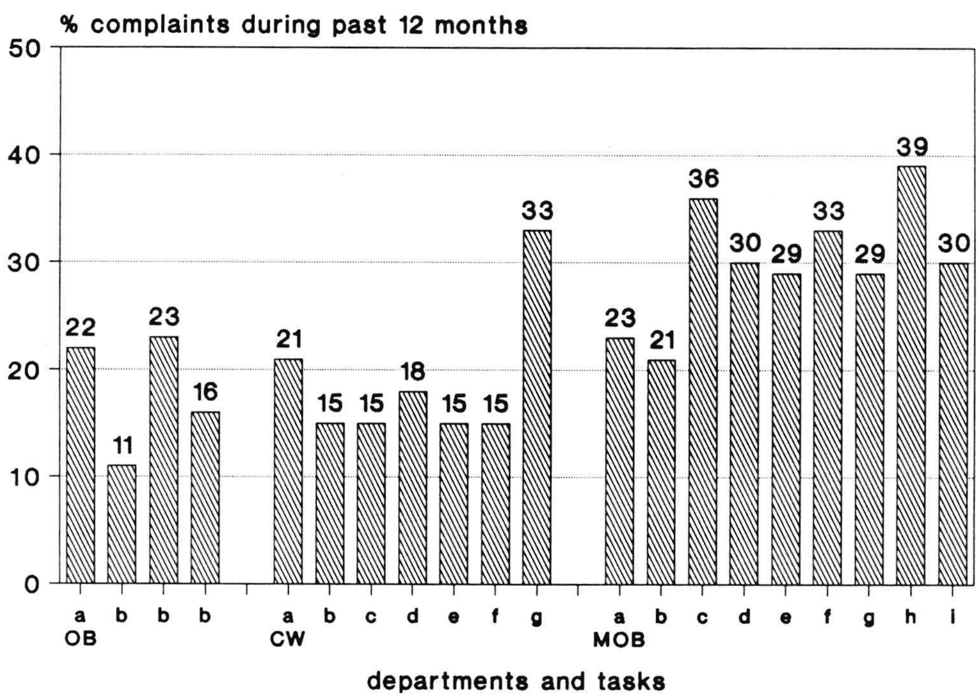


Figure 2.8 Prevalence of complaints of the knees, specified for different tasks



Comparison of prevalences between tasks shows that tasks within each department are characterized by complaints of quite different body regions. A high level (>= 10% higher than the mean) of complaints of the low back is seen at the CW-department, a high level of complaints of the neck-hand at the OB-department and a high level of complaints of the knees at the MOB-department. The tasks involved are mentioned in table 2.4.

Table 2.4 Tasks with a relatively high level of musculoskeletal complaints

department	body region 'at risk'	task, official Dutch name*
OB	neck-hand	1. werkzaamheden CWO
		2. werkzaamheden Centraal
		3. pannenonderhoud ox1/ox2
MOB	knee	4. onderhoud bankwerken RND
		5. onderhoud bankwerken CEN/CTD
		6. pijpbewerken/P.O. ketels CEN
CW	low back	7. aftekenen
		8. richten
		9. constructie bankwerken algemeen
		10. constructie bankwerken zwaar
		11. lassen werkplaats
	low back + knee	12. constructie bankwerken wagons

* specific company-bound names, cannot be translated

It can be concluded that, despite the fact that the tasks are not very homogenous, several tasks are found to be associated with a high level of complaints of specific body regions. This justifies a more detailed ergonomic analysis of these high-risk tasks (chapter 5).

2.4.6 Work load profiles of high-risk tasks

To obtain indications about aspects of the work load within the tasks which could be important to the ergonomic study in chapter 5, 'work load profiles' of these high-risk tasks are presented.

First, it is analyzed to what extent workers in the different tasks perceive their work as being physically heavy in general. Next, differences between groups according to exposure to a high working pace as well as to postures, movements, force-exertions and vibrations will be described. Finally, some data will be given on the extent in which workers find their working situation satisfactory.

Perceived physical exertion in general

Participants were asked whether they perceived their work as physically heavy. Table 2.5 presents the results for the different tasks.

Table 2.5 Perceived physical exertion (percentages)

department	OB			MOB			CW						means			
tasks	1	2	3	4	5	6	7	8	9	10	11	12	OB	MOB	CW	(A)
work is physically heavy	92	90	82	69	83	92	74	85	64	70	73	83	77	78	63	(67)

Description of tasks is given in table 2.4; A= all workers (n=440)

About two-thirds of all workers perceives the work as heavy. It should to be noted that work heaviness is relatively high (compared to the means of the departments) in all tasks involved.

Perceived working pace

Some questions were asked on work pace and perceived trouble because of the latter. Table 2.6 presents the results for the different tasks.

Table 2.6 Perceived work pace and trouble with a high work pace (percentages)

department	OB			MOB			CW						means			
task	1	2	3	4	5	6	7	8	9	10	11	12	OB	MOB	CW	(A)
working pace is rather high regularly	52	65	71	66	83	67	77	75	72	64	53	78	60	67	48	(54)
having trouble with a high working pace regularly	4	10	2	10	17	15	22	20	23	20	18	22	6	12	16	(10)

About half of the workers says work pace is regularly rather high. A small part of that group has trouble with this high work pace. Also work pace is relatively high in all tasks involved compared to the means of the departments.

Reported postures, movements and force-exertions

Below, a description is given of the exposure of the workers to postures and movements as well as force-exertions, as reported by the workers themselves.

Postures

In the following tables, percentages of workers are given who say they have to work in specific postures. First, table 2.7 shows postures which are known to be at risk for the low back (Hildebrandt, 1987).

Table 2.7 Percentage of workers which has to work in specific postures, at risk for the low back, specified for the different tasks

department	OB			MOB			CW						means			
task	1	2	3	4	5	6	7	8	9	10	11	12	OB	MOB	CW	(A)
bent back	28	10	38	28	22	15	37	40	36	40	49	56	27	20	30	(24)
twisted back	13	10	14	0	11	15	15	20	10	17	18	22	14	6	13	(9)
prolonged standing	100	90	98	96	100	100	96	95	97	97	100	100	93	98	96	(93)
prolonged sitting	12	6	16	21	33	18	29	38	22	25	41	38	17	28	26	(30)
prolonged kneeling	86	84	68	88	94	92	78	80	74	73	84	83	73	86	59	(65)

From table 2.7, it can be concluded that prolonged standing is the most prominent working posture in all tasks. About a quarter of the workers has to work in a bent or sitting posture. Almost two third of the workers often has to do work which requires a kneeling posture. Prolonged working with a twisted back does not occur very often. In general, data in different tasks are similar to the means of all departments, with the exception of prolonged kneeling and, in the case of the CW-department, working in bent posture.

Table 2.8 gives data on postures which are known to be at risk for the neck-hand region (Hagberg, 1984).

Table 2.8 Percentage of workers which has to work in specific postures, at risk for the neck-hand region, specified for the different tasks

department	OB			MOB			CW						means			
task	1	2	3	4	5	6	7	8	9	10	11	12	OB	MOB	CW	(A)
bent neck	60	70	65	50	61	85	78	75	69	77	79	83	55	54	53	(53)
twisted neck	30	50	33	43	28	54	46	56	37	43	42	53	32	40	25	(31)
elevated arms:																
- under shoulder-level	79	80	71	71	78	83	69	53	63	55	75	71	65	73	56	(61)
- above shoulder-level	36	58	24	58	59	85	33	35	28	43	52	61	25	26	32	(34)

Typical postures of the neck-hand region in this population involves primarily working with elevated arms: almost two third of the workers reports working often in this posture. About half of the workers do work with bent or twisted neck. Most tasks are reporting more static working postures than average among maintenance personnel.

Movements

Below, percentages of workers are presented who say they have to work in specific dynamic conditions. First, table 2.9 shows movements which are known to be at risk for the low back.

Table 2.9 Percentage of workers which has to work in specific movements, at risk for the low back, specified for the different tasks

department	OB			MOB			CW						means			
task	1	2	3	4	5	6	7	8	9	10	11	12	OB	MOB	CW	(A)
bending	71	80	71	52	61	31	70	80	67	67	73	89	62	42	62	(43)
twisted back	57	65	61	62	61	39	59	75	51	57	61	72	54	54	51	(49)
twisting while bending	26	60	51	38	33	23	44	50	39	50	52	61	44	26	30	(28)

Working while bending or twisting the back is a common feature in the different tasks: about half of them is confronted often with this kind of work. Also, the stressful combination of bending and twisting is reported often. Again, percentages in the tasks are mostly higher than average.

Table 2.10 shows movements at risk for the neck-hand region.

Table 2.10 Percentage of workers which has to work in specific movements, at risk for the neck-hand region, specified for the different tasks

department	OB			MOB			CW						means			
task	1	2	3	4	5	6	7	8	9	10	11	12	OB	MOB	CW	(A)
bending neck	79	85	74	75	67	85	81	79	87	76	81	100	70	75	71	(71)
twisted neck	61	79	61	64	50	92	74	75	64	70	70	83	61	63	58	(60)
repetitive movements with the arm	95	95	93	96	100	85	81	79	79	69	88	82	92	84	81	(82)

Movements of the upper extremities are common: 4 in 5 of the workers have to make repetitive movements with the arms often, 3 in 5 of the workers are often confronted with movements of the neck.

Force exertions

Table 2.11 reports the exposure of workers to work which requires force exertions.

Table 2.11 Percentage of workers with work requiring lifting/carrying or pulling/pushing, specified for the different tasks

department	OB			MOB			CW						means			
task	1	2	3	4	5	6	7	8	9	10	11	12	OB	MOB	CW	(A)
lifting or carrying	46	50	52	52	50	25	33	47	36	38	39	50	44	34	36	(33)
pulling or pushing	72	70	61	79	67	75	67	70	64	83	64	94	53	71	58	(55)

About one third of the workers has to lift regularly, and half of the workers has work which requires pushing and pulling regularly. These figures are again higher than those of the maintenance workers as a whole.

Reported exposure to vibration

Table 2.12 shows exposure to vibration in the different tasks.

Table 2.12 Percentage of workers which reports to be exposed to vibration, specified for the different tasks

department	OB			MOB			CW						means			
task	1	2	3	4	5	6	7	8	9	10	11	12	OB	MOB	CW	(A)
exposed to vibration	68	70	73	69	67	67	70	70	59	73	55	83	70	60	52	(55)

About half of the workers report to be exposed to vibration. Since no distinction was made in the questionnaire between whole body and hand-arm vibrations, these figures cannot be analyzed further in that respect.

2.5 Discussion

The aim of this part of the study was to screen size and nature of the musculoskeletal problems of maintenance workers and to identify high-risk groups. Due to limited possibilities, it was not possible to involve all maintenance workers of Hoogovens in this survey. Instead, five important departments were chosen. As a consequence, the results presented cannot be considered representative of all maintenance work. In Hoogovens, this was not a prerequisite, since the goal of the study was to obtain data on *relative* size and nature of musculoskeletal problems in groups, by comparing departments and tasks. Since the work within these five departments comprises most of the tasks regularly performed by maintenance workers in general, it is likely that size and nature of musculoskeletal problems in other departments performing maintenance jobs will resemble the results obtained very closely. This is also likely since differences concerning prevalence of musculoskeletal complaints between the five departments were, broadly speaking, rather small. Since the work within those departments is very diverse and the work between the departments shows sometimes a rather close resemblance, this is not surprising.

It is difficult to estimate the influence of the non-response on the result of this survey. Since the number of non-respondents was not very large, their influence will have been limited. Nevertheless, one has to keep in mind this possibility when evaluating the results of this survey.

To identify high-risk groups, prevalences of groups have to be compared which are characterised by certain, well-described, musculoskeletal load, e.g. specific tasks. The formation of such groups constituted a major problem in this survey, which became apparent just after data-collection and which is probably specific for maintenance work. It appeared to be impossible to obtain any information from existing data on the specific tasks performed by the workers involved. The MAT-data (chapter 3) contain only descriptions of *possible* tasks on each department, without data on the number of workers who actually performed them. This information thus had to be obtained during the data-collection. From the data collected, it turned out that most workers carried out many tasks with varying frequency and duration. This made it impossible to compose homogeneous groups of workers performing a fixed set of tasks. The only possibility was to form groups of workers who performed a specific task *often*. The resulting overlap of groups, due to the fact that many workers performed several tasks often, will have had a weakening effect on the desired differentiation of groups with regard to the prevalence of musculoskeletal complaints. Nevertheless, it appeared possible to obtain such a differentiation, while the real differences between tasks could even be greater than is indicated by the data presented. Unfortunately, the number of groups which could be formed was very limited due to the low number of workers performing tasks often. This implicates that this survey has probably identified only a small number of all possible high-risk tasks. However, in any case the most prevalent tasks have been involved in the analysis. This is important since one of the criteria for choosing tasks in the ergonomic study of chapter 5 is the prevalence of the task. From the experiences described above, it must be concluded that the limited possibilities to compose groups with a homogeneous set of tasks should receive much attention in future research.

It is striking that the **nature** of the musculoskeletal complaints in the various tasks seems to be associated with the department: back problems at the CW-department, neck-hand problems at the OB-department and knee-problems at the MOB-department. This indicates that each department has a characteristic musculoskeletal profile.

Concerning the **size** of the complaints it is justified to conclude that attention for the prevention of musculoskeletal complaints in this population as a whole is strongly needed: *absolute* prevalences of 1 in 2 workers having back-problems and 2 in 5 workers having neck-hand problems during the past 12 months can be considered (too) high. Also, a comparison with other occupational groups indicates a *relatively* high size. The findings on health in the specific tasks are confirmed by the data on exposure to musculoskeletal load in these groups: in general, workload in these groups appears to be above average, compared to the whole study population. It seems therefore plausible that the reported health problems are at least partly due to a high musculoskeletal workload. In combination with the analysis of the MAT-data (chapter 3) and observations at the work places themselves (chapter 4), these findings could help to identify workplaces that most urgently need guidelines for ergonomical improvements to prevent musculoskeletal trouble.

2.6 Conclusions

Prevalences of musculoskeletal complaints of the maintenance workers studied were relatively high. In all departments workers had a very heterogeneous set of tasks, which made it difficult to compose groups of workers performing the same task. At three departments, in all 20 tasks were performed by a sufficient number of workers. Size and nature of the musculoskeletal complaints of these workers appeared to be related to these tasks. Twelve tasks could be identified as being associated with a relatively high prevalence of complaints of specific body regions. These tasks deserve priority in preventive activities.

2.7 Acknowledgement

The authors wish to thank management and workers of the maintenance departments at Hoogovens, IJmuiden for their co-operation in this study.

3. WORK LOAD SURVEY OF MAINTENANCE WORKERS IN THE STEEL INDUSTRY*

3.1 Summary

Existing Hoogovens data on work load associated with maintenance tasks were analyzed to select the heaviest tasks. These data were derived from a system for Medical Analysis of Tasks (MAT), which contains, among others, an assessment by experts of the demands that a certain task places on the worker with respect to his back and muscles. All maintenance tasks in the five maintenance departments selected were identified and task loads were classified according to their heaviness for back and muscles. From the 76 maintenance tasks, 25 were selected on being the heaviest (12 at the MOB-department, 5 at the OB-department, 4 at the CW-department, 3 at the EWS-department and 1 at the WO-department).

3.2 Introduction

In the past 20 years the Medical Department of Hoogovens IJmuiden has designed a system that serves as an aid in monitoring the work load and occupational health of employees.

Underlying the system is the load versus load capacity concept, which has its root in the principle that the requirements of the work must not exceed human capacity both on short and long term. The principle concerned invites the following questions:

- What does the work require of the employee?
- How much can the employee perform without affecting his/her health?

A system for Medical Analysis of Tasks (MAT) has been developed to arrive at a database on task requirements (i.e. work load), in conjunction with a system for Medical Analysis of Personnel (MAP) which purpose it is to indicate task requirements for which an employee is not suited on medical grounds. Both analyses are confined mainly to aspects involving physical capacity and task require-

* A.J. Bolijn, Hoogovens, IJmuiden, The Netherlands.

ments. A comparison between MAT-data for the (intended) task and the MAP-data for the employee reveals hazardous mismatches.
In designing the system, cognizance has been taken of relevant developments in the Netherlands and in Germany. As regards German literature, reference is made to the AET Survey Procedure for Task Analysis (Rohmert, 1978), to an ECSC study conducted at the Research Institute for Rationalization of the Aachen University of Technology (Hackstein, 1974), and to the publication entitled "Modell eines Werksärtzlichen Informationssystems" (Eggeling, 1973).
In present project the existing MAT data on maintenance work are used to identify maintenance tasks that pose high demands on the musculoskeletal system of the employee.

3.3 Methods

3.3.1 The MAT system

The objective of the MAT-system is to gain an insight into the task requirements imposed on an average, healthy employee by the work, the workplace, the work method and the work environment, i.e. by the work conditions. The system is used by Hoogovens for:

- allocating new employees to a workplace;
- re-allocating employees that have become the subject of medical restrictions, to a suitable workplace;
- assessing the possibility of combining specified tasks into one job;
- formulating research policies on to occupational hygiene and ergonomics.

To identify task requirements, a questionnaire has been developed. Within a task various task aspects are distinguished. These task aspects fall into the categories "energy expenditure", "locomotor system", "senses", "work environment", "work schedule", "safety provisions", and "psychological factors" (the category "chemical-physical factors" has still to be worked out). Examples of task aspects are static load on lower extremities, use of hands, sitting, and noise level. The importance of each task aspect to the fulfilment of a given task is assessed in most cases on its frequency of occurrence (e.g. stair climbing) and in some other cases on its intensity (e.g. required muscle force of the legs). Both frequency and intensity are coded on a 4-point scale (below).

code	frequency	intensity
0	does not occur	insignificant
1	occurs incidentally	light requirements
2	occurs frequently	average requirements
3	occurs predominantly	above average requirements

Task requirements assessment is performed by work experts trained by the plant medical department. An instruction manual provides recommendations and guidelines that assist in aspect interpretation and assessment. Making an inventory of the task requirements within a department comprises the following steps:

- introduction of the MAT system to management and employees;
- general orientation by the work expert in the department;
- assessment of the various tasks and task aspects, as well as assessment of the task requirements for the various aspects with respect to frequency and intensity;
- consultation of management and employees on findings;
- feedback on the final results to management and employees.

When all the tasks in the department have been reviewed, the inventory of task requirements is complete. Subsequently the groups to which the medical department has introduced the MAT system receive a concise report outlining the results obtained.

The full information is recorded in a computer-database on task requirements. To record modifications of task requirements, a follow-up procedure has been designed. In each department a MAT coordinator is appointed, who informs the work experts of any changes that may have consequences for the task requirements. The work expert, in turn, contacts the MAT coordinators once a year to ask whether any update on the department's task requirements data is required.

3.3.2 The MTT system

To identify tasks posing a severe load on given physical systems, a system for Medical Task Typification (MTT) has been developed, based on the task requirements summed up in the MAT-system.

The systems "circulation", "respiration", "back", "muscles", "skin", "ears", and "legs" were selected because these systems are frequently involved in job mutation on medical grounds. In Dutch, the initial letters of these systems form the word CARSHOB. This expression will be used in the following to mention the set of systems.

For each CARSHOB-system, a working group of occupational health officers has identified

1. the MAT task aspects affecting the system,
2. the relationships between MAT codes and MTT intensity codes, and
3. a healthy person with an average working capacity.

The relationship between the MAT-system and the MTT-system will be described in detail below, partly with the help of an example.

First the requirements that each task aspect from the MAT system imposes on each CARSHOB-system are expressed in an MTT intensity code (below).

code	intensity
1	light requirements
2	moderate requirements
3	average requirements
4	above average requirements

The MTT intensity code depends on the MAT code assigned to the task aspects. For example a number of MAT task aspects put demands on the back. One such aspect is the manual handling of loads. For loads between 5 and 20 kg, the demands on the back are assessed by the following relations between MAT code and MTT intensity code:

MAT code 1 results in MTT intensity code 1
MAT code 2 results in MTT intensity code 2
MAT code 3 results in MTT intensity code 3

However, for loads between 20 and 40 kg the demands on the back are higher, so different relations are adopted:

MAT code 1 results in MTT intensity code 2

MAT code 2 results in MTT intensity code 3

MAT code 3 results in MTT intensity code 4

Manual transfer of objects heavier than 40 kg already imposes average requirements on the back when it is only an incidental activity, so that MAT codes 1 and higher result in MTT intensity code 4.

Through the MTT-system it is thus possible to identify tasks that place a considerable load on the CARSHOB-systems. For this identification an MTT score and MTT class is defined.

An MTT score equals the sum of MTT intensity codes assigned to all MAT task aspects of a given task. An MTT score is determined for each CARSHOB-system. The number found is then expressed as a percentage of the maximum possible score. Each CARSHOB-system has a different maximum score (in brackets): circulation (65), respiration (46), back (36), muscles (34), skin (8), ears (7), and legs (38). The resulting percentage is converted in an MTT class. The MTT classes range from 0 to 9 (0 for 1-10%, 1 for 10-20%, ... , 9 for 90-100%). Assume that for a given task the MTT score related to the circulation system equals 31. The circulation system has a maximum possible score of 65. Thus an MTT score 31 corresponds to a percentage of 47.7. This percentage results into an MTT class 4. The same calculation procedure applies to the classification of the other CARSHOB-systems. Below an example of the MTT classes for a task Y is shown:

	C	A	R	S	H	O	B
Task Y:	4	2	5	5	3	2	4

3.3.3 Selection of heavy maintenance tasks

In the present study all maintenance tasks in the five maintenance departments selected in chapter 3 (CW-department, MOB-department, WO-department, OB-department, EWS-department) were identified and each task load was described by the MTT classes for all CARSHOB systems. Heavy maintenance tasks in terms of musculoskeletal load were scheduled as follows.
Only the CARSHOB-systems back (R) en muscles (S) were considered. The MTT classes for these two CARSHOB-systems were summed (MTT class (R + S)), and the number of times an MTT intensity code 4 was assigned to the task aspects related to the back or the muscles were counted (# intensity code 4 (R + S)).
Those tasks having an MTT class (R + S) greater than or equal to 10, or # intensity code 4 (R + S) greater than or equal to 1 were designated as the heaviest tasks.

3.4 Results

In table 3.1 the heaviness of all maintenance tasks for CARSHOB-systems R (back) and S (muscles) is given by their MTT class (R + S) and their # intensity code 4 (R + S). In appendix II the MTT classes for all CARSHOB-systems of all maintenance tasks are given (tables II.1-II.5).

Table 3.1 Task numbers and names for the departments in sequence of heaviness according to MTT class (R + S) and # intensity code 4 (R + S). R = back, S = muscles

task number	task name	MTT class (R + S)	# intensity code 4 (R + S)
department CW:			
1383	constructie bankwerken wagons	12	5
1382	constructie bankwerken zwaar	11	5
1325	machine bankwerken	11	4
1386	lassen werkplaatsen	11	3
1381	constructie bankwerken algemeen	9	-
1384	lassen lasbox	9	-
1385	lassen machinaal	8	-
1326	reparatie hydrauliek en pneumatiek	7	-
1328	pompen reparatie	7	-
1327	testen hydrauliek en pneumatiek	5	-
1332	werkzaamheden schoonmaak machine	5	-
1372	zagen	5	-
1376	aftekenen	5	-
1377	knippen	5	-

Sequence table 3.1

task number	task name	MTT class (R + S)	# intensity code 4 (R + S)
1378	zetten	5	-
1380	richten	5	-
1365	controle constructie werkplaats	4	-
1374	branden automatisch	4	-
1379	walsen	4	-
1338	kraandrijven A kranen	3	-
1339	kraandrijven B kranen	3	-
1340	kraandrijven C kranen	3	-
1364	controle verspor ing/machine bankwerken	3	-
1387	gereedschapbeheer	3	-
department MOB:			
1410	onderhoud bankwerken RZD	13	5
1417	vulcaniseren	13	5
1422	onderhoud pompen/ventilator RND	13	5
1426	pijpbewerken algemeen	13	3
1427	pijpbewerken/P.O. ketels	12	3
1420	onderhoud bankwerken RND	11	3
1411	onderhoud bankwerken RCN	10	1
2595	onderhoud pompen/motoren	10	1
1425	kwaliteit lassen RVC	9	1
1414	kwaliteit lassen RZD	8	1
1421	onderhoud smeersysteem RND	8	1
1424	kwaliteit lassen	8	1
1423	werkzaamheden werkplaats RND	9	-
1429	werkzaamheden werkplaats RCV	9	-
1413	werkzaamheden werkplaats RZD	7	-
2334	best.unimog.vulcaniseerd. RZD	6	-
1433	algemene werkzaamheden smeerdienst	6	-
2596	draaien	5	-
1412	branden werkplaats	4	-
1416	transportband inspectie/ algemene werkzaamheden	3	-
2600	werkzaamheden buizenpost/sprinklers	3	-
department WO:			
1472	steunwals ombouw	12	3
1473	werkwals ombouw	7	-
1477	onderhoud bankwerken	7	-
1471	lassen	5	-
1478	walsen ruwen	5	-
1470	bankwerken storingsdienst	4	-
1475	walsen slijpen	4	-
1476	walsen draaien	4	-
1474	walsen transport	3	-
1482	kraandrijven	3	-
1483	rubberrollen slijpen	3	-
1484	rond en vlak slijpen	3	-
1485	centerdraaien	3	-
1486	werkzaamheden werkplaats controle	1	-
department OB:			
2351	werkzaamheden centraal	10	3
2362	menger spuiten in CWO	9	-
2364	pannenonderhoud OX1/OX2	8	1
2349	werkzaamheden betonwerkplaats	9	1

Sequence table 3.1

task number	task name	MTT class (R + S)	# intensity code 4 (R + S)
2350	werkzaamheden CWO	7	1
2369	verdeelbak.spuiten OX1/OX2	6	1
2348	onderhoud werkzaamheden materiaal werkplaats	4	-
-	conv.spuiten OX1/OX2		
department EWS:			
1986	werkzaamheden buitenploeg	12	1
1982	schoonmaken motoren	10	1
1988	werkzaamheden koppelingenveld	8	1
1983	verfspuitwerkzaamheden	9	-
1984	balanceren/zagen	9	-
1980	demontage- en montagewerkzaamheden	8	-
1987	transportwerkzaamheden	6	-
1981	wikkelen	5	-
1989	draaien	5	-

Table 3.2 shows the heaviest tasks through all departments (cut-off point MTT class (R + S) lower than 10 or no intensity-code 4).

Table 3.2 Numbers, names and departments of the heaviest tasks in sequence of heaviness according to MTT class (R + S) and # intensity code 4 (R + S). R = back, S = muscles

dept.	task number	task name	MTT class (R + S)	# intensity code 4 (R + S)
MOB	1410	onderhoud bankwerken RZD	13	5
MOB	1417	vulcaniseren	13	5
MOB	1422	onderhoud pompen/ventilator RND	13	5
CW	1383	constructie bankwerken wagons	12	5
CW	1382	constructie bankwerken zwaar	11	5
CW	1325	machine bankwerken	11	4
MOB	1426	pijpbewerken algemeen	13	3
WO	1472	steunwals ombouw	12	3
MOB	1427	pijpbewerken/P.O. ketels	12	3
MOB	1420	onderhoud bankwerken RND	11	3
CW	1386	lassen werkplaatsen	11	3
OBD	2351	werkzaamheden centraal	10	3
EWS	1986	werkzaamheden buitenploeg	12	1
EWS	1982	schoonmaken motoren	10	1
MOB	1411	onderhoud bankwerken RCN	10	1
MOB	2595	onderhoud pompen/motoren	10	1
OB	2364	pannenonderhoud OX1/OX2	8	1
OB	2349	werkzaamheden betonwerkplaats	9	1
OB	2350	werkzaamheden CWO	7	1
OB	2369	verdeelbak.spuiten OX1/OX2	6	1
EWS	1988	werkzaamheden koppelingenveld	8	1
MOB	1425	kwaliteit lassen RVC	9	1
MOB	1414	kwaliteit lassen RZD	8	1
MOB	1421	onderhoud smeersystemen RND	8	1
MOB	1423	kwaliteit lassen	8	1

The heaviest tasks appear most at the MOB-department (12), and further at the OB-department (5), CW-department (4), EWS-department (3) and WO-department (1).

3.5 Conclusions

From the 76 tasks in the five maintenance departments 25 were selected as being the heaviest. These results from this analysis of existing work load data at Hoogovens will be combined in the next chapter with the results from the health survey (chapter 2), in order to select heavy and high risks for which ergonomic guidelines will be developed in chapter 5.

4. SELECTION OF HEAVY AND HIGH RISK MAINTENANCE TASKS, AND A WORK VARIABLE FOR EXPERIMENTAL STUDY IN THE STEEL INDUSTRY*

4.1 Summary

On the basis of a work load survey and a health survey, heavy, high risk tasks and the corresponding most relevant work variable(s) for an experimental ergonomic study were selected.

The main criterium to select the tasks for the ergonomic study was directly deduced from the selection criteria used for both surveys accomplished: tasks had to be identified as heavy and high risk by the work load and the health survey, respectively. Five tasks were evaluated by visiting relevant work sites.

Within these selected tasks, work variables for the experimental study were selected, which possibly are related to the high work load and health complaints found. These work variables also had to match the following other requirements:

1. it must be possible to intervene on the work variable in the actual everyday work situation,
2. it must be possible to study the work variable in an experimental setting,
3. no reliable guidelines for the work variable had to be available already, and
4. it must be possible to generalize research results for the work variable to other work situations.

The evaluations of the five tasks led to the conclusion that executing tool-based operations on relatively small objects at a fixed workplace (workbench, trestles) was most suited for an experimental study. On the basis of research volume restrictions, preferences of the management of the maintenance departments involved, and practical reasons, working height was chosen as the work variable and pneumatic wrenching, oxy-cutting, and grinding as the operations for the experimental study.

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4.2 Introduction

On the basis of the surveys described in the preceding chapters, heavy, high risk tasks and the corresponding most relevant work variable(s) for the experimental ergonomic study of chapter 5 were selected. This chapter describes the criteria used for both selections and the actual process of selecting tasks and the most relevant work variable.

4.3 Methods

4.3.1 Selection of tasks

The main criterium to select the tasks for the ergonomic study was directly deduced from the selection criteria used for both surveys accomplished: tasks had to be identified as heavy and high risk by the work load and the health survey, respectively. Since the health survey only involved tasks carried out regularly by a reasonable number of workers (> 15), non-prevalent tasks were automatically excluded.

4.3.2 Ergonomic evaluation of selected tasks

To evaluate the tasks, relevant work sites were visited. The preparation of each task evaluation session was executed by structuring workers' opinions on heavy tasks, inappropriate tools, and possible solutions to improve working conditions. These opinions were gathered in the questionnaire-survey, described in chapter 2. During the evaluation sessions a general impression of the task was formed (objects/installations worked on, operations involved, time spending). Furthermore, explanations for the task-specific musculoskeletal complaints as well as corresponding relevant work variables were looked for. Observations and discussions with employees and floor managers were used to gather relevant information.

Work variables were selected which possibly are related to the high work load and health complaints found. Work variables of interest for the experimental ergonomic study had to match the following other requirements:

- it must be possible to intervene on the work variable in the actual every-day work situation,
- it must be possible to study the work variable in an experimental setting,
- no reliable guidelines for the work variable had to be available already, and
- it must be possible to generalize research results for the work variable to other work situations.

The first three requirements will be discussed for each task in the subsection on corresponding relevant work variables. The requirement on generalization will dealt with in 4.4.3.

4.3.3 Selection of work variable(s) for experimental ergonomic study

Work variables suited for experimental ergonomic study found during task evaluations will be summarized. One work variable will be selected. This selection is carried out on the basis of research volume restrictions, preferences of the management of the maintenance departments involved, and practical reasons. Special attention is given to the possibilities to generalize research results for the work variable to other work situations. Task evaluations identify the tasks where a selected work variable is observed. Discussions with management will reveal other tasks where the selected work variable is also seen.

4.4 Results

4.4.1 Selection of tasks

Table 4.1 shows heavy and/or high risk tasks.

Table 4.1 Tasks characterized as heavy (work load survey), as high risk (health survey), or both as both heavy and high risk (denoted by '+'). Tasks selected for ergonomic evaluation are denoted by an arrow (<-). Tasks involving (pneumatic) wrenching, oxy-gas cutting, grinding, and/or welding at a workbench are denoted by an asteriks (*). An 'x' denotes departments with no tasks performed by groups of workers of sufficient size (15 workers) and for tasks performed by groups of workers of insufficient size (<15 workers)

							at a workbench			
dept.	tasks	< 15	high risk	heavy	both	selected for evalualities	(pneumatic) wrenching	oxy-gas cutting	grinding	welding
OBD	werkzaamheden CWO		+	+	+	<-				
	werkzaamheden Centraal		+	+	+					
	pannenonderhoud OX1/OX2		+	+	+	<-				
	werkzaamheden betonwal	x								
	verdeelbak rep. en spuiten OX1/OX2	x								
MOB	onderhoud bankwerken RZD		-	+	-					
	vulcaniseren		-	+	-					
	onderhoud bankwerken RND		+	+	+					
	pijpbewerken algemeen		-	+	-		*	*	*	*
	onderhoud bankwerken RCN		+	+	+					
	onderhoud pompen/motoren		-	+	-					
	pijpbewerken/P.O. ketels		+	+	+					
	onderhoud pompen/ventilator RND		-	+	-					
	kwaliteit lassen RVC	x								
	kwaliteit lassen RZD	x								
	onderhoud smeersysteem RND	x								
	kwaliteit lassen	x								
CW	machine bankwerken		-	+	-		*			
	aftekenen		+	-	-					
	richten		+	-	-					
	constructie bankwerken algemeen		+	-	-		*	*	*	*
	constructie bankwerken zwaar		+	+	+	<-	*	*	*	*
	lassen werkplaatsen		+	+	+	<-				*
	constructie bankwerken wagons		+	+	+	<-		*	*	*
WO		x								
EWS		x								

Nine tasks are both heavy and high risk. After consultancy of the management of the departments concerned, task 'Werkzaamheden Centraal' at the OB-department was omitted, because of its close resemblance to task 'Werkzaamheden CWO'. Furthermore, all tasks of the MOB-department were excluded, due to the absence of fixed work-units and steady working circumstances. These considerations were verified by work site and task observations (Appendix III). For the MOB-tasks it was considered hardly possible to establish an experimental design that would be representable for every-day work practice. As a consequence, five tasks were selected for ergonomic, i.e. 'Werkzaamheden CWO', 'Pannenonderhoud OX1/OX2 (both OB-department), 'Constructie Bankwerken Wagons', 'Constructie Bankwerken Zwaar', and 'Lassen Werkplaatsen' (all three CW-department) (table 4.1).

4.4.2 Ergonomic evaluation of tasks

Below the results on the evaluations of the five tasks selected are described. For each task first a general description is presented, succeeded by a section on the musculoskeletal complaints and their possible relation to the task, and a section on corresponding relevant work variables. A distinction is made between

1. work variables that can be acted upon by simple interventions or application of existing guidelines, and
2. work variables suited for experimental study. Work variables suited for experimental study are underscored.

'Werkzaamheden CWO' - dept. OB - task number 2350

- Task description

  Two major operations were distinguished, i.e. brick laying and pouring concrete. Both operations serve to give metal objects (e.g. parts of blast-furnaces, tundishes) a new lining. Employees lay bricks and pour concrete each 40 percent of their working time.

  During bricklaying bricks are manipulated intensively to apply mortar. Manipulation of a brick is often difficult due to its weight and shape and due to the fact that the applied mortar may not be touched. Furthermore the (very) heavy bricks have to be positioned precisely at their destined

location and rubbed against previously laid bricks in order to guarantee a close fit without air bubbles. This activity of positioning bricks often has to be done at low locations (at or even tens of centimetres below foot level) or at high locations (at or slightly above shoulder level). Laying bricks at the side (wall) of the object till the sixth layer employees have to kneel or stoop. Above this layer bricks have to be lifted more and more. Brick laying of a floor can in some cases be eased by using a crane. In general, however, unfavourable postures have to be maintained for a certain time period.
The second major operation within the task is pouring of concrete on an object. Especially smoothing and equal distribution of the sticky concrete with a rake is considered physically demanding. In addition, preparation of small raised borders is considered heavy because a forward bend trunk posture has to be taken for a lengthy time period, while high forces have to be applied by hand. Fortunately, moulds are being designed to relieve from both physical demands mentioned.

- Musculoskeletal complaints and relation to the task

  The neck-hand complaints found are most certainly related to manipulation of heavy bricks, working at or above shoulder level, and extreme wrist postures during brick laying as well as to raking of concrete.
- Corresponding relevant work variables

  Brick weight and working height for brick laying are work variables of interest for physical work load. However, these work variables can be acted upon by simple interventions (lighter bricks, use of larger prefabricated parts) and/or by introduction of working aids (small cranes). For the moment no work variables suited for experimental study are present.

'Pannenonderhoud OX1/OX2' - dept. OB - task number 2364

- Task description

  At this task parts of blast-furnaces get a new brick lining. The objects arrive after the old bricks have been removed by a crane.

  At plant OX1 75 percent of the working time is used for brick laying, the rest for removing old bricks that remained on the object by hand-operated power-hammers. Both operations are considered very heavy. Heavy bricks are used to construct floors and walls. The weight, recoil, and vibration of the powerhammer used make manual brick removal heavy. For brick laying the work has more a routine character (short cycle, high pace, similar actions) than at task 'Werkzaamheden CWO' (section 1). However, in accordance with task "Werkzaamheden CWO' bricks are heavy and difficult to manipulate, bricks often have to be positioned precisely at low locations (stooped posture) and at high locations (outside the employee's physical control, body weight cannot be deployed). Employees wish to have height adjustable work floors as at plant OX2 (described below). Working with a crane is considered too slow.

At plant OX2 the work conditions are more or less identical to plant OX1. Fixed height plateaus are stacked to create a reasonable working height range. A fully height adjustable work floor was left unused after mechanical failure. Bricks used are heavy, i.e. at minimum 5 times brick weight seen in out-door building construction.* Furthermore stooped posture is seen very often. Also here removal of old bricks by hand-operated power-hammers is considered heavy.

At plant OX2 two men continuously are busy giving tundishes a new lining by spraying refractory material. This operation is not considered heavy.

- <u>Musculoskeletal complaints and relation to the task</u>

  The neck-hand complaints found most probably are related to the manipulation of heavy bricks, working at or above shoulder level with heavy bricks, manual removal of old bricks by power-hammers, and extreme wrist postures.

- <u>Corresponding relevant work variables</u>

  Working height and brick weight for brick laying are work variables of interest for physical work load. However, these work variables can be acted upon by simple interventions (lighter bricks) and/or by introduction of working aids (height adjustable work floors). Manual removal of bricks can be relieved by using suspended power-hammers. For manipulation of very heavy bricks a crane with a suction-mouth can be a solution. Furthermore

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* The Foundation Arbouw (Dutch organization for improvement of working conditions in building construction) gives the following recommendations (Arbouw, 1989):
- maximum brick weight for one-handed manipulation: 6 kg;
- maximum brick weight for two-handed manipulation: 8 kg; (12 kg for optimum working conditions);
- maximum grip width for bricks: 102 mm.

experimental studies have already been conducted on routine brick-laying for out-door building construction (e.g. on guidelines for optimum working height). The usefulness and validity of those experimental results for brick-laying at the OB-department should be considered first. So, it can be concluded that for the moment no work variables suited for experimental study are present.

'Constructie Bankwerken Wagons' - dept. CW - task number 1383

- Task description

  At this task three major operations were seen, i.e. oxy-gas cutting, grinding, and welding (short courses). These operations are executed on objects that vary enormously on size and accessibility as well as on operation location in or on the object. Two thirds of the task is executed on large and very large objects, like blast-furnace tops, railway wagons, tundishes, etcetera. This means that task execution occurs at all heights from foot level to above shoulder level. In some cases non-stable postures have to be taken, e.g. reaching far out from a ladder. One third of the task is done on small objects at workbenches. These workbenches are not adjustable in height. The objects can be up to 1 meter high. The combination of a fixed workbench height and a variable object height leads in almost all cases to a non-optimum working height.
- Musculoskeletal complaints and relation to the task

  The back complaints found may be related to stooping and/or twisting of the back, twisted and/or bend back postures, lifting (stooped due to confined spaces), reaching far out, etcetera.

  The knee complaints found may be related to kneeling and flexed knee postures.
- Corresponding relevant work variables

  Movable and height adjustable scaffoldings offer the opportunity at large objects to adjust working height to individual anthropometry and to the work location on the object. Height adjustable workbenches can serve the same purpose for small objects. Currently no reliable guidelines for optimum operation-specific working height are available.

'Constructie Bankwerken Zwaar' - dept. CW - task number 1382

- Task description

  The operations executed are oxy-gas cutting, grinding, welding (short courses), and considerable dismounting and mounting ((pneumatic wrenching). A few employees execute their task on middle-sized and large objects as tops of blast-furnaces and iron-ore/coke graspers.

  Most employees work on relatively small objects. Mostly a workbench or trestles are used. Especially oxy-gas cutting is seen a lot. This operation requires high precision, optimum viewing conditions, and stable posture, leading to a wide footed position, trunk support against the workbench, arm support on the object, and a strong forward bend trunk and neck. The workbenches and trestles used are not adjustable in height. The objects can be up to 1 meter high. The combination of a fixed workbench height and a variable object height in most cases creates a non-optimum working height.

- Musculoskeletal complaints and relation to the task

  The back complaints found most probably are related to bending and/or twisting of the back, bend and twisted back postures, reaching far out, etcetera.

- Corresponding relevant work variables

  By height-adjustable workbenches working height can be adjusted to the employee's individual anthropometry and the object height. Currently no reliable guidelines for optimum operation-specific working height are available. The tool characteristics (shape, weight) offer opportunities for improvement, i.e. a better adaptation to the required operation.

'Lassen Werkplaatsen' - dept. CW - task number 1386

- Task description

  Approximately two thirds of the welding operations are executed on large and very large objects. Welding is executed on objects that vary enormously on size and accessibility as well as on location in or on the object. A welder works for lengthy time periods in the same posture. As much as possible support for the trunk and the arms is created, in order to work precisely. A seated position with the arms supported on the upper legs is preferred. Usage of a welding-helmet leaves both hands for stabilization of the welding-torch. Welding with a semi-automat requires additional lifting of cables.

For one third of the operations the object (up to lengths of a couple of meters and up to weights of 5 to 6 tons) can be taken to a welding box. In this box a welding fume extractor and workbenches are present. The workbenches are low (50 to 60 cm) and welding is done sitting forward bend.

- Musculoskeletal complaints and relation to the task

  The back complaints found are most probably related to twisting and/or bending of the back, and bend back postures.

- Corresponding relevant work variables

  For welding on large and very large objects height adjustable scaffoldings ease the operation execution to the employee. For welding in special boxes height adjustable workbenches serve the same purpose. In both cases working height can be adjusted to the employee and the object height. Currently no reliable guideline for optimum welding height is available.

4.4.3 Selection of work variable(s) for experimental ergonomic study

The evaluations of the five tasks described before lead to the conclusion that executing tool-based operations on relatively small objects at a fixed workplace (workbench, trestles) was most suited for an experimental study. Two work variables remained for the experimental study, i.e. working height and tool characteristics (shape, weight). As a consequence the experimental study could focus on

A. optimum working height,

B. optimum tool characteristics, or

C. optimum working height in combination with optimum tool characteristics.

The following operations are executed at a workbench, and can be subject of the experimental study:

1. (pneumatic) wrenching
2. oxy-gas cutting
3. grinding
4. welding.

Table 4.2 shows the options for an experimental study aiming at the development of guidelines for tool-based operations at a workbench, given the work variables and operations mentioned.

Table 4.2 Options for an experimental study aiming at development of guidelines for tool-based operations at a workbench

	A working height	B tool characteristics	C working height and tool characteristics
1. (pneumatic) wrenching	x	x	x
2. oxy-cutting	x	x	x
3. grinding	x	x	x
4. welding	x	x	x

Table 4.1 shows the tasks involving one or more of the four operations at a workbench. All operations reveal sufficient possibility of generalization of research results to other work situations.

Only a limited number of the options above for experimental study could be accomplished within the current study.

Management of the maintenance departments involved preferred to focus on working height within the current project and not on tool characteristics for the moment. This meant that options B and C were set aside.

Operation welding was excluded from the current experimental study for two reasons. First, welding is executed mostly sitting, while operations (pneumatic) wrenching, oxy-gas cutting, and grinding all are executed standing. This common characteristic was expected to ease the set-up of the experiments as well as the conceivable comparison of results. Second, of all four operations welding was considered the least specific for maintenance tasks. It is seen in many more branches of industry (e.g. all kinds of metal construction).

The overall selection process described led to a volume that could be dealt with within the conditions of the overall project.

As a result of the considerations above working height was chosen as the work variable and pneumatic wrenching, oxy-cutting, and grinding as the operations for the experimental study.

5. ERGONOMIC GUIDELINES ON THE OPTIMUM WORKING HEIGHT FOR PNEUMATIC WRENCHING, OXY-GAS CUTTING, AND GRINDING DURING MAINTENANCE WORK IN THE STEEL INDUSTRY*

5.1 Summary

A health survey on musculoskeletal disorders and a work load survey identified high risk and heavy maintenance tasks in the steel industry, respectively. Workers at the central maintenance department showed high percentages of low back complaints. Furthermore, various operations are executed at workbenches of fixed height, which leads to high loads either on the low back or on the neck/shoulder/arm complex. In this study, attention was on the operations pneumatic wrenching, oxy-gas cutting, and grinding upon objects lying on workbenches or on trestles. The purpose of the present study was to formulate ergonomic guidelines on optimum working height for the three operations mentioned, in order to obtain the best possible working posture and to minimize the load on the musculoskeletal system.

Professional test subjects executed an operation for a certain period on several different heights. The effects of working height on working posture and on the worker's experiences were measured by video cameras and a questionnaire, respectively.

The research approach chosen turned out to be valuable and successful. For all three operations studied supportive and non-conflicting information was obtained from working posture and subjective experiences. For pneumatic wrenching a working height between 10 cm below and 10 cm above elbow height is recommended, while a working height of 5 to 10 cm below elbow height is to be preferred. For oxy-gas cutting a strong preference exists for a working height on elbow height, while a working height range between 10 cm below and 10 cm above elbow height is recommended. For grinding a working height 35 cm below

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elbow height, i.e. approximately knuckle height for average males, is recommended.
In general, the three operations studied are executed standing at the same workbench. Optimum working heights for the operations, object heights, and workers' body height all show moderate to large variation. This means that an optimum working height during task execution can solely be created by height adjustable workbenches (or other height adjustable means). To guarantee optimum use the adjustment of working height during task execution should be fast and easy. The process of implementation of height adjustable workbenches (or other means) should be given special attention.

5.2 Introduction

5.2.1 General background

Maintenance work in the steel industry is characterised by an enormous variety of tasks, operations, and settings, as described in the previous chapter. Operations such as welding, oxy-gas cutting, grinding, wrenching, cleaning, and lifting amongst others have to be done inside installations as large as blast-furnaces and rolling-mills as well as on objects ranging in size from iron-ore/coke-graspers and railway wagons to small pistons.
In the mobile and central maintenance groups high percentages of low back complaints are seen. The mobile group mainly works inside the large installations. Confined work spaces, bad visual conditions, and manual lifting of heavy objects reflect the absence of a notion at design that maintenance by humans would be needed. Only rigorous redesign or early introduction of ergonomic knowledge at the design phase of plants will improve physical working conditions and reduce the amount of musculoskeletal complaints for the workers involved.
The central maintenance group mainly works on middle-sized and small objects. If possible, objects are placed on a workbench or on trestles. The heights of these supports are fixed, the worker's own workbench in most cases being roughly adjusted to his preferred fixed height. Due to the varying sizes of the

maintenance objects and the varying operations, working height is hardly ever optimum. Height adjustable tables are a solution to this problem. Optimum working height may reduce musculoskeletal load as well as the percentage of complaints, e.g. of the low back. However, necessary ergonomic guidelines on optimum working heights for specific maintenance operations do not exist.

5.2.2 Research background

In this study attention will be on the operations pneumatic wrenching, oxy-gas cutting, and grinding upon objects lying on workbenches or on trestles.
Maintenance operations all have their specific purpose, and are divers with respect to the demands they place on the worker. Operations can be high/low demanding on vision/precision, force magnitude, and manipulation, demanding stability/mobility (e.g. repetitive movements) of different body parts, and can vary in force direction. Apart from the characteristics of the operation, workplace, and object, the tool characteristics are important with respect to the demands on the worker.

A **pneumatic wrench** (figure 5.1) is a powered tool to tighten or loosen nuts. It is heavy, and therefore it requires a lifting force, mainly of the right shoulder/arm and to a lesser extent of the left shoulder/arm. For bolts directed horizontally towards the operator, an additional slight forwardly directed force has to be applied by the right hand. The left hand and the eyes are only temporarily needed to put the head of the wrench on the nut. Both hands are required to resist counter-rotating moments.

An **oxy-gas cutter** (figure 5.1) is a tool to cut metal objects along a certain course by a high temperature flame. The object is preferably placed flat on the workbench, a little over the edge, in such a way that sparks fall on the floor. Oxy-gas cutting asks for high precision and continuous visual control, and maximum stability of the whole body. Generally, the worker places the left hip and/or upper leg against the table side and supports the left elbow on the table top. The left hand is held close to the front of the cutter, near to the flame, and the right hand at the rear side, close to the oxygen and gas tubes. The flame is moved along the course slowly by rotation of the left hand around the elbow, and small translations of the right hand by upper arm movement and trunk rotation. In case of long cutting courses, after a while the object is moved or a new stable posture is taken.

A **grinding-machine** (figure 5.1) is used to remove roughnesses from metal surfaces. This tool consists of a fast rotating circular-shaped stone plate within a metal house, and two handles to move it. Grinding asks for repetitive movements of both arms, moderate force directed down and forward, and moderate visual control. A slight forward tilt of the tool is needed. Usually the operation control switch is placed in the right handle, which means that there is hardly any way to change the right hand grip. In case of a pneumatic grinding-machine the air tube comes in through the right handle. This requires a lifting force from the right shoulder/arm to balance the grinding-machine. This lifting force is reduced or eliminated by an upwardly directed reaction force from the work surface on the grinding-machine.

The various operation demands on the worker mentioned above, in combination with the physical characteristics of the workplace, tool, and object can lead to non-optimum working postures and complaints of the musculoskeletal system. A working height above the optimum will pose a burden on neck/shoulder/arm complex, a working height below the optimum will stress the low back, the neck and/or the upper legs.

The purpose of the present study was to formulate ergonomic guidelines on optimum working height for maintenance operations pneumatic wrenching, oxy-gas cutting, and grinding in order to obtain the best possible working posture and to minimize the load on the musculoskeletal system.

5.3 Methods

5.3.1 General experimental set-up

In order to formulate guidelines on optimum working height for pneumatic wrenching, oxy-gas cutting, and grinding three separate experiments were set up. The overall approach was identical for all three operations. Deviating methodological approaches will be described for the operation in question. Experiences from an earlier study (Delleman & Dul, 1990) revealed that the research approach to be described below was valuable and successful.
Test subjects executed an operation for a certain period on several different heights. The effects of working height on working posture and on the worker's experiences were measured by video cameras and a questionnaire respectively.

5.3.2 Subjects

Seven male workers from the Fitting department, section Hydraulics/Pneumatics, participated in the experiments on pneumatic wrenching. In each of the experiments on oxy-gas cutting and grinding eight male workers from the Steel Construction and Welding department co-operated. Seven of them were the same for both experiments. For each of these subjects both experiments were executed on separate days. In general subjects were asked to participate according availability. Table 5.1 presents several characteristics of the three experimental subject groups. All workers were right-handed.

Table 5.1 Characteristics of the experimental subject groups for operations pneumatic wrenching, oxy-gas cutting, and grinding. Group averages and ranges (in brackets) are presented

operation	age (years)	stature (cm)	elbow height (cm)	weight (kg)	work experience (years)
pneumatic wrenching	32.1 (26-41)	183.3 (172-186)	113.7 (108-117)	77.7 (64-84.5)	7.7* (4-16)
oxy-gas cutting	31.6 (21-47)	184.1 (176-194)	116.7 (108-125.5)	81.6 (68-99)	11.5 (2-20)
grinding	28.6 (21-40)	184.4 (178-194)	116.1 (108-125.5)	78.5 (68-90)	9.3 (2-18)

* plus on average 6.9 years (range 0-13) in other maintenance departments, tasks, and operations

5.3.3 Description of experimental operations

In general during maintenance tools are used in many ways. In this study the focus was on the correct and intended use of tools.

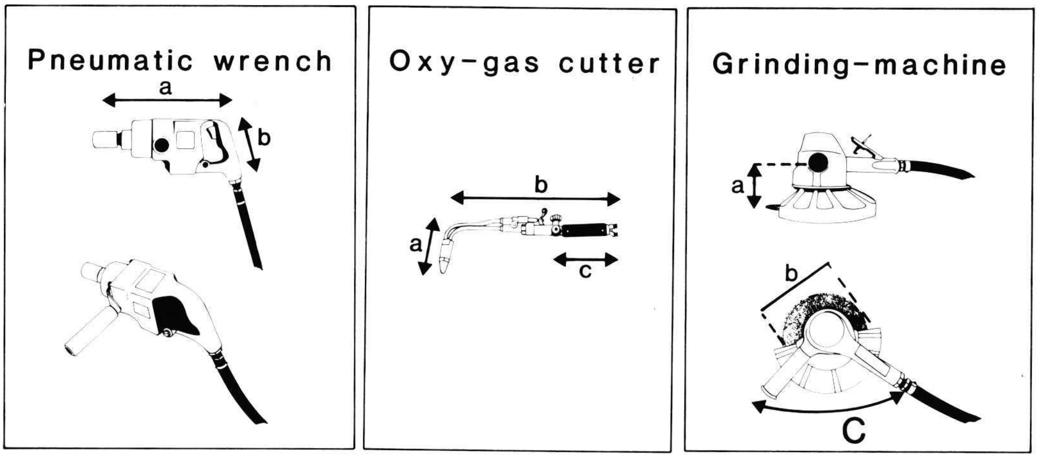
Pneumatic wrenching

The experimental operation consisted of tightening ten nuts on bolts by a pneumatic wrench, followed by loosening the same nuts. This cycle was repeated until the operation period ended. The bolts were fixed on a metal base, in a horizontal row, their centres 10 cm apart, and directed horizontally towards the subject. Table 5.2 shows the dimensions, net weight, and weight in the right and left hand during operation for the pneumatic wrench (figure 5.1), that was used in the experiment.

Oxy-gas cutting

The experimental operation consisted of cutting small strips from a long steel plate (25 cm wide and 2.5 cm thick) until the operation period ended. The plate was positioned in the for/aft and left/right directions by the subject. Table 5.2 shows the dimensions, net weight, and weight in the right and left hand during operation for the oxy-gas cutter (figure 5.1), that was used in the experiment.

Figure 5.1 The pneumatic wrench, oxy-gas cutter, and grinding machine, that were used in the experiments. Dimensions are presented in table 5.2



Grinding

The experimental operation consisted of grinding the top surface of a horizontal steel plate until the operation period ended.

Table 5.2 shows the dimensions, net weight, weight in the right hand and in the left hand during operation for the grinding-machine (figure 5.1), that was used in the experiment.

Table 5.2 The characteristics of the pneumatic wrench, oxy-gas cutter, and grinding machine, that were used in the experiments

tool	dimensions* (cm, DEG)	net weight (kg)	weight (kg) in hand in a typical working posture right	left
pneumatic wrench	a= 31 b= 10	6.0 (+1.0**)	4.5	2.5
oxy-gas cutter	a= 11.5 b= 39.5 c= 10	1.0 (+1.0**)	1.5	0.5
grinding-machine	a= 9 b= 23 C=100	4.5 (+0.75**)	3.75*** (3.25****)	1.5*** (1.0****)

* visualized in figure 5.1
** the weight of the tube(s) at average experimental working height
*** the weight will be reduced or eliminated by the reaction force from the object during operation
**** non-operating grinding machine supported on the object at the contact area

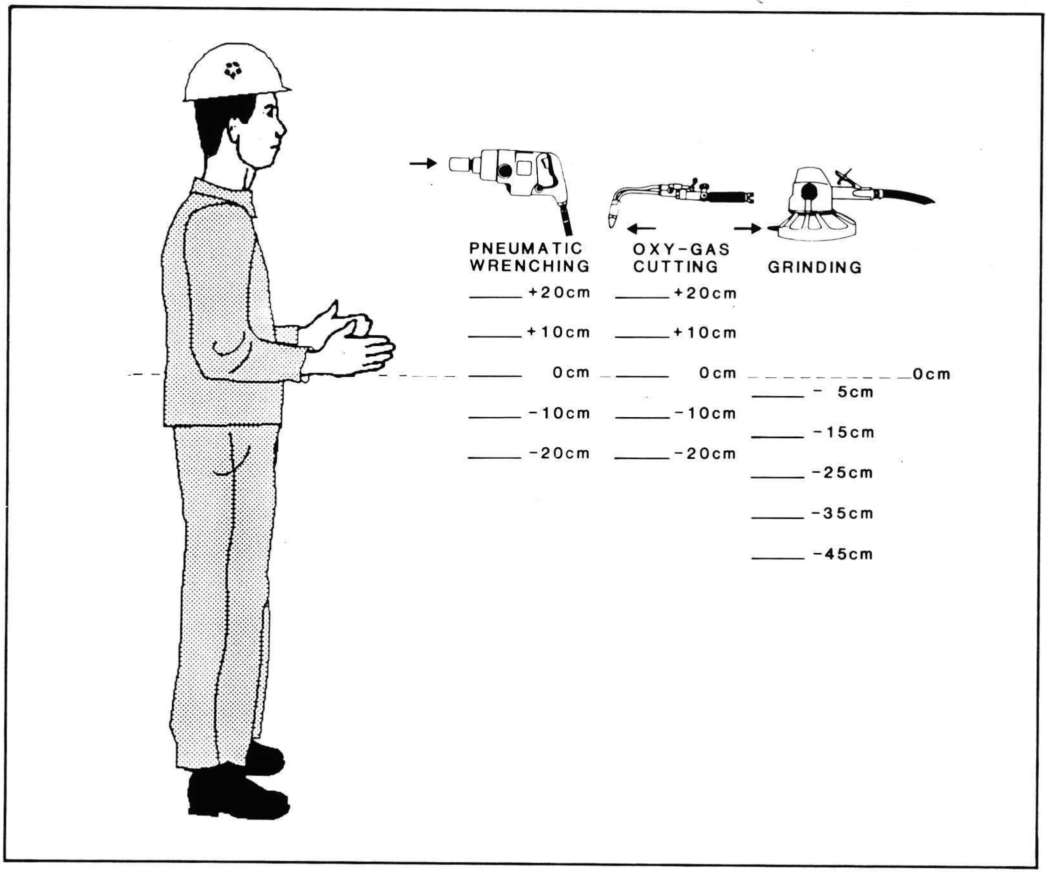
5.3.4 Independent variable

The independent variable of this study was working height. For each operation five levels for working height were selected on basis of a small pilot-study.

For pneumatic wrenching working height was defined as the centre of the bolt and nut. Working height levels -20, -10, 0, +10, and +20 cm relative to elbow height were selected (figure 5.2).

For oxy-gas cutting working height was defined as the height of the cutting surface on the object, i.e. the height of the flame. Working height levels -20, -10, 0, +10, and +20 cm relative to elbow height were selected (figure 5.2).

Figure 5.2 The five experimental working heights for pneumatic wrenching, oxy-gas cutting, and grinding. The elbow height is shown by the horizontal broken line



For grinding working height was defined as surface height of the object, i.e. the height of the contact area of the object surface and the grinding-machine. Working height levels -45, -35, -25, -15, and -5 cm relative to elbow height were selected (figure 5.2).

Elbow height was defined as the distance from the floor to the elbow (underside) with the worker standing upright, looking forward, the upper arms hanging down, and the forearms horizontal (figure 5.2).

5.3.5 Dependent variables and measuring methods

Several dependent variables were measured for each of the five working height conditions. These variables were related to the working posture and to the worker's experiences. These two types of dependent variables are measured together, because both present complementary and essential information. Furthermore, posture information alone can only be evaluated properly if external forces on the body (or body part) are known or absent, and the validity and reliability of measurements of subjective experiences, are still unknown. Therefore, it was decided that the ergonomic guidelines should only be formulated if the information from both types of dependent variables is non-conflicting and supportive. In sections *posture* and *subjective experiences* dependent variables with respect to posture and subjective experiences will be described respectively.

Posture

The working posture of the subject was recorded by the optoelectronic VICON-system with four synchronized video cameras. Retro-reflective markers were put on the skin overlying selected body joints and bones. Two markers were attached on a pelvic rig. Another two markers were placed on a thin rod on top of the grinding-machine as well as on top of the oxy-gas cutter (figure 5.3). After data acquisition the markers were identified semi-automatically.
Based on the three-dimensional positions of markers the following dependent variables were calculated:

1. **Head/trunk inclination**, defined as the difference between the head angle during operation and the head angle in a neutral posture (definition below). The head angle was defined as the angle between the vertical and the line through the markers near the lateral corner of the right eye (marker number 1; M1) and near the lobe of the right ear (M2). Head/trunk inclination can be considered as the sum of inclination of the head relative to the trunk and inclination of the trunk relative to the neutral posture.
   A higher score means more head inclination as well as more head plus trunk inclination.

2. **Trunk inclination**, defined as the difference between the trunk angle during operation and the trunk angle in a neutral posture (definition below). The trunk angle was defined as the angle between the vertical and the line through the markers on the vertebral joint C7/Th1 (in between the two spinal processes) (M3) and on the vertebral joint L5/S1 (in between the two spinal processes) (M4). M4 was an imaginary marker. Its location, defined at the base of the rod on the pelvic rig, was determined mathematically on a line through markers M5 and M6, 8.9 cm away from marker M5, and 17.8 cm away from marker M6.
   A higher score means more trunk inclination.

3. **Elevation of the left upper arm**, defined as the difference between the left upper arm angle during operation and the left upper arm angle in a neutral posture (definition below). The left upper arm angle was defined as the angle between the vertical and the line through the markers on the left acromio-clavicular joint (M7) and on the left elbow (humero-radial) joint (M8).
   A higher score means more elevation of the left upper arm.

4. **Elevation of the right upper arm**, defined as the difference between the right upper arm angle during operation and the right upper arm angle in a neutral posture (definition below). The right upper arm angle was defined as the angle between the vertical and the line through the markers on the right acromio-clavicular joint (M11) and on the right elbow (humero-radial) joint (M12).

A higher score means more elevation of the right upper arm.

5. **Trunk - right upper arm angle** (only for oxy-gas cutting), defined as the difference between (a) the angle between the line through the markers M3 and M4 (trunk), and the line through markers M11 and M12 (right upper arm) during operation and (b) this angle in a neutral posture (definition below).
   A higher score means more abduction and/or ante/retro-flexion of the right arm relative to the trunk.

6. **Neck angle**, defined as head/trunk inclination (definition above, sub 1) minus trunk inclination (definition above, sub 2).
   A higher deviation from 0 means more inclination of the head relative to the trunk.

7. **Left elbow angle** (only for grinding), defined as the angle between the line through the markers on the left acromio-clavicular joint (M7) and on the left elbow (humero-radial) joint (M8), and the line through the markers on the left elbow (humero-radial) joint (M8) and on the dorsal side of the left forearm (M9) during operation minus this angle in a neutral posture (definition below).
   A higher score means more elbow flexion.

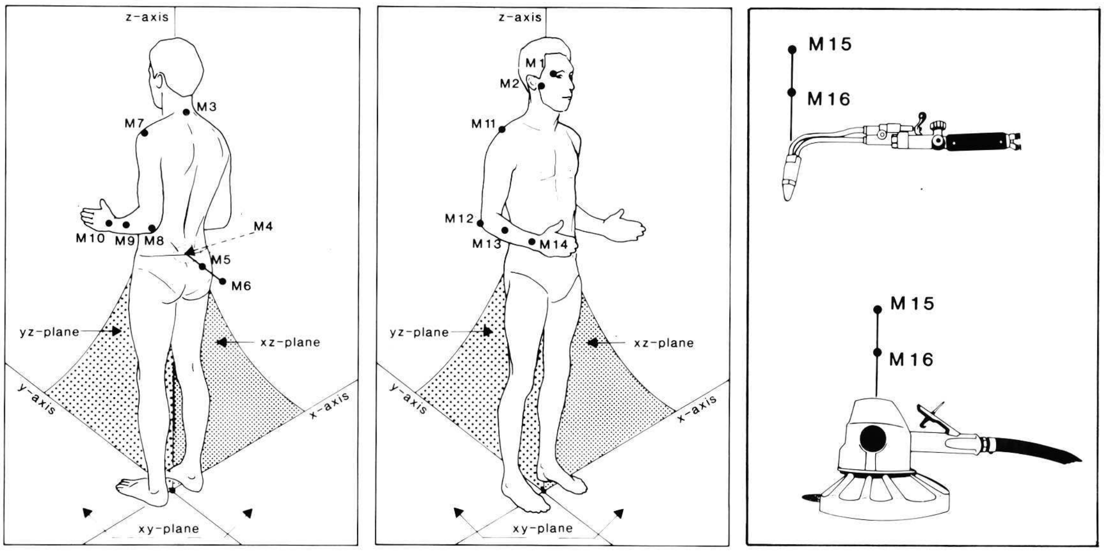
8. **Right elbow angle**, defined as the angle between the line through the markers on the right acromio-clavicular joint (M11) and on the right elbow (humero-radial) joint (M12), and the line through the markers on the right elbow (humero-radial) joint (M12) and on the dorsal side of the right forearm (M13) during operation minus this angle in a neutral posture (definition below). In the pneumatic wrenching experiment the marker on the right wrist (distal radio-ulnar) joint (M14) was used instead of the marker on the dorsal side of the right forearm.
   A higher score means more elbow flexion.

9. **Right grip/wrist angle** (only for oxy-gas cutting and grinding), defined as the angle between the line through the markers M15 and M16 on the rod on

top of the grinding-machine as well as on top of the oxy-gas cutter, and the line through the markers on the right elbow (humero-radial) joint (M12) and on the dorsal side of the right forearm (M13).
Provided that the same way of grip is used, a higher score means more radial/ulnar abduction and/or flexion/extension of the right wrist. Observations from video-tapes can give indication on the character of wrist posture.

The neutral posture was defined as the subject standing, head and trunk upright, looking straight forward, and the arms hanging down.

Figure 5.3 Work space axes and marker positions



Subjective experiences

The subjective experiences were recorded by a questionnaire (appendix IV), containing four questionnaire modules. The modules 'Perceived posture' and 'Local postural discomfort' focus on detailed, local physical experiences. The modules 'Estimated endurance time' and 'Judgement on working height' focus on integral responses, that are based on various kinds of experiences, including physical ones.
The modules (A till D) and the dependent variables will be described below.

A. Perceived posture

The subject was asked to rate his perception of the posture of the **neck, back, left upper leg, right upper leg, left shoulder, left upper arm, left forearm, left wrist, right shoulder, right upper arm, right forearm**, and **right wrist**. The order of presentation of these 12 questions was randomized each time the module was used. Directly after the operation period written responses were given on a seven-point scale (1 = very favourable, 3 = favourable, 5 = unfavourable, 7 = very unfavourable. Scores 2, 4, and 6 were available for intermediate responses).

The perceived postures of all 12 body parts mentioned above were used as dependent variables.

B. Local postural discomfort

The subject was asked to rate his postural discomfort in 40 regions shown on a diagram of the rear view of a human body (figure 5.4). A category-ratio scale ranging from 0 (no discomfort) to 10 (extremely much discomfort (close to maximum)) was used. This method (Van der Grinten, 1990) is a combination of methods described by Corlett and Bishop (1976) and Borg (1982). A verbal response was given at the beginning and at the end of the operation period. For each region the score at the beginning was subtracted from the score at the end.

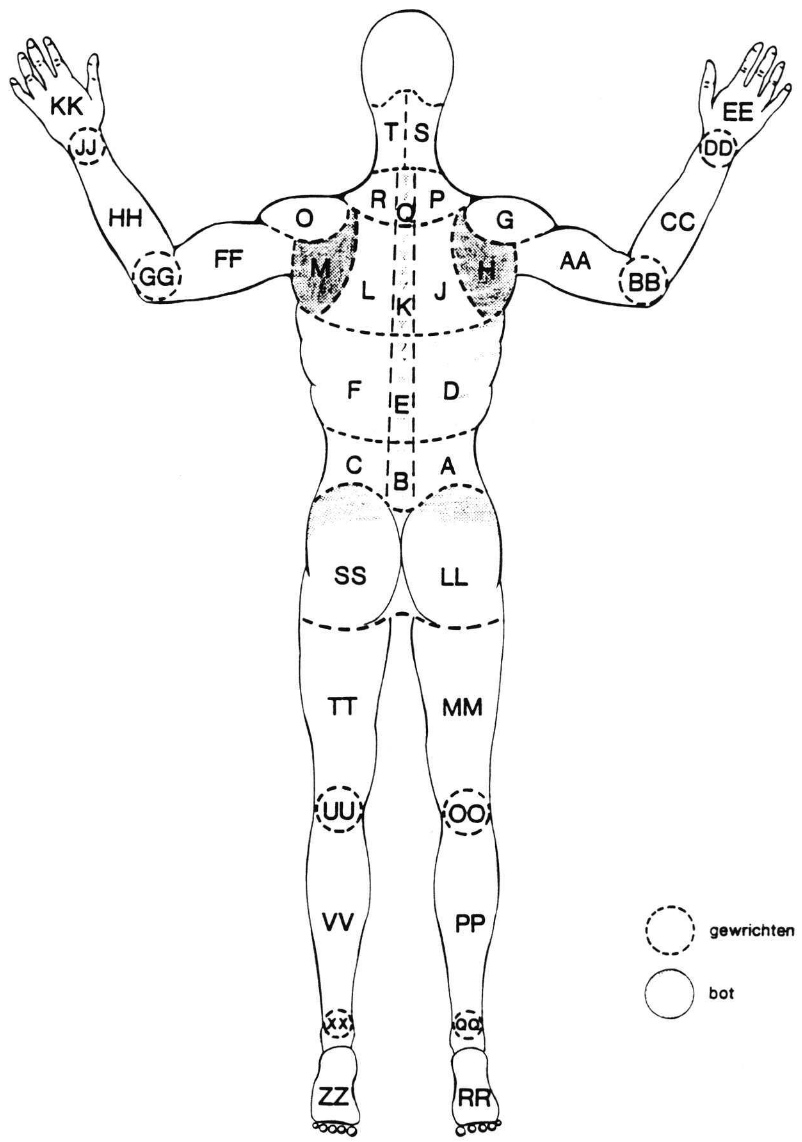
The resulting scores for each region were grouped into larger (functional) units, that were used as dependent variables

The following eight dependent variables were constructed:

1. **Whole body**, defined as the sum of the resulting scores on all 40 body regions.
2. **Neck**, defined as the sum of the resulting scores on the body regions T, S, R, Q, and P.
3. **Left shoulder/arm**, defined as the sum of the resulting scores on the body regions KK, JJ, HH, GG, FF, O, and M.
4. **Right shoulder/arm**, defined as the sum of the resulting scores on the body regions EE, DD, CC, AA, G, and H.
5. **Upper back**, defined as the sum of the resulting scores on the body regions L, K, J, F, E, and D.

6. **Low back**, defined as the sum of the resulting scores on the body regions C, B, and A.
7. **Left leg**, defined as the sum of the resulting scores on the body regions ZZ, XX, VV, UU, TT, and SS.
8. **Right leg**, defined as the sum of the resulting scores on the body regions RR, QQ, PP, OO, MM, and LL.

Figure 5.4 Diagram of the rear view of a human body, that was used in the questionnaire module on local postural discomfort. Forty regions are discriminated and marked by a single or double letter



C. Estimated endurance time

The subject was asked to estimate how much longer he could continue operation without difficulty. Directly after the operation period written responses were given on a nine-point scale (0 = less than 5 minutes, 1 = 5 to 10 minutes, 2 = 10 to 20 minutes, 3 = 20 to 30 minutes, 4 = 30 minutes to 1 hour, 5 = 1 to 2 hours, 6 = 2 hours to 1/2 work day (4 hours), 7 = 1/2 work day (4 hours) to 1 work day (8 hours), and 8 = more than 1 work day (8 hours)).

The estimated endurance time was used as a dependent variable

D. Judgement on working height

The subject was asked to judge the working height. Directly after the operation period written responses were given on a five-point scale (1 = much too low, 2 = a little too low, 3 = right, 4 = a little too high, and 5 = much too high).

The judgement on working height was used as a dependent variable.

5.3.6 Procedure

Pilot studies

For each operation five levels for working height were selected on basis of a small pilot study. In each pilot three subjects were asked to find out an optimum working height during operation by raising or lowering working height. Next, realistic levels for highest and lowest experimental working heights were determined during operation. Working height was increased or decreased by steps of 5 cm until the subject reported distinct local postural discomfort or uncomfortable posture.

Experiments

The subjects carried out the actual experimental operations at the central maintenance building (figure 5.5). Working height was adjustable by a scissor lift table. Each subject participated in five experimental sessions including five minutes of operation, followed by breaks of at least ten minutes. The five-minute period of operation was chosen in accordance with the periods of operation

C. Estimated endurance time

The subject was asked to estimate how much longer he could continue operation without difficulty. Directly after the operation period written responses were given on a nine-point scale (0 = less than 5 minutes, 1 = 5 to 10 minutes, 2 = 10 to 20 minutes, 3 = 20 to 30 minutes, 4 = 30 minutes to 1 hour, 5 = 1 to 2 hours, 6 = 2 hours to 1/2 work day (4 hours), 7 = 1/2 work day (4 hours) to 1 work day (8 hours), and 8 = more than 1 work day (8 hours)).

The estimated endurance time was used as a dependent variable

D. Judgement on working height

The subject was asked to judge the working height. Directly after the operation period written responses were given on a five-point scale (1 = much too low, 2 = a little too low, 3 = right, 4 = a little too high, and 5 = much too high).

The judgement on working height was used as a dependent variable.

5.3.6 Procedure

Pilot studies

For each operation five levels for working height were selected on basis of a small pilot study. In each pilot three subjects were asked to find out an optimum working height during operation by raising or lowering working height. Next, realistic levels for highest and lowest experimental working heights were determined during operation. Working height was increased or decreased by steps of 5 cm until the subject reported distinct local postural discomfort or uncomfortable posture.

Experiments

The subjects carried out the actual experimental operations at the central maintenance building (figure 5.5). Working height was adjustable by a scissor lift table. Each subject participated in five experimental sessions including five minutes of operation, followed by breaks of at least ten minutes. The five-minute period of operation was chosen in accordance with the periods of operation during regular daily task execution. In each session one of the five working heights was presented. The order of presentation of the working heights was balanced as well as possible over subjects and sessions (table 5.3). In total a subject was involved in testing all five experimental working heights for 1½ to 2 hours. Between one and five subjects participated in the experiments on a day. Experiments on the three operations were executed within three distinct research periods.

Figure 5.5 Experimental set-up at the central maintenance building

Prior to the first experimental session an explanation was given to the subjects on the experiments in general, the questionnaire for subjective experiences, and the purpose of the cameras. Next, the markers were put on the selected skin locations, the pelvic rig was attached to the L5/S1 region, and the elbow height was measured.

Each experimental session consisted of (1) the adjustment of the working height, followed by (2) three recordings of the neutral posture, (3) the first verbal response on local postural discomfort, (4) the first two and a half minutes of operation, (5) the second verbal response on local postural discomfort (not used for analysis), (6) the second two and a half minutes of operation, and (7) the third verbal response on local postural discomfort. A diagram of the rear view of a human body (figure 5.4) and the rating scale for local postural discomfort were positioned in front of the subject.

During the break following an experimental session subjects gave a written response on the questionnaire modules with respect to perceived posture, estimated endurance time, and judgement on working height.

Table 5.3 The order of presentation of the experimental working heights over subjects and sessions for the operations pneumatic wrenching, oxy-gas cutting, and grinding

research period operation	06/12/'89-07/12/'89 pneumatic wrenching					14/12/'89-20/12/'89 oxy-gas cutting					21/12/'89-03/01/'90 grinding				
working height (cm to elbow height)	-20	-10	0	10	20	-20	-10	0	10	20	-45	-35	-25	-15	-5
subject number:															
1	2	1	5	3	4										
2	3	5	1	4	2										
3	4	1	3	2	5										
4	5	3	2	1	4										
5	1	2	4	5	3										
6	2	4	5	3	1										
7	3	5	2	4	1										
8						5	2	4	1	3	1	4	3	5	2
9						1	3	5	4	2					
10						2	5	3	4	1	5	2	4	3	1
11						3	5	1	2	4	2	5	3	4	1
12						4	1	2	3	5	1	4	2	5	3
13						3	2	1	5	4	4	3	1	2	5
14						2	4	3	1	5	3	2	5	1	4
15						1	3	4	5	2	5	3	4	1	2
16											2	1	5	3	4

During the second two and a half minutes of operation posture was recorded for one or two periods. For pneumatic wrenching data processing was restricted to the time intervals during which the actual wrenching occurred (time intervals for transport of the wrench from one nut and bolt to another were excluded). Scores on the dependent variables for posture were averaged over two time intervals of actual wrenching. For oxy-gas cutting the scores on the dependent variables for posture were averaged over a period of a second, due to the highly static whole body posture. For grinding the scores on the dependent variables for posture were averaged over a period of five seconds, due to the highly repetitive movements of both arms. For each subject the scores on the dependent variables for the neutral posture were averaged over recordings of a second each, that were obtained prior to the experimental sessions for each operation.

5.3.7 Data analysis

Posture

The overall effect of working height on all dependent variables related to posture was tested by an Analysis of Variance (ANOVA) for Repeated Measures. In case of a significant overall effect of working height the scores on a dependent variable for levels of working height were also compared pair wise. Differences were tested by a T-test. The selected level of significance for both tests mentioned was p=.05. For head/trunk inclination, trunk inclination, left upper arm elevation, right upper arm elevation, and trunk - right upper arm angle pair wise comparisons were done with respect to the optimum working height for the dependent variable. **The optimum working height was defined as the experimental working height that caused the least difference between posture during operation and the neutral posture (average group scores).** For neck angle, left elbow angle, right elbow angle, and right grip/wrist angle pair wise comparisons were done for neighbouring experimental working heights. No criterium for 'optimum' was defined for these four dependent variables.

Subjective experiences

It is assumed that the Borg-scale used for determination of local postural discomfort has ratio properties. Therefore, parametric statistical tests were applied.The overall effect of working height on all dependent variables related to local postural discomfort was tested by an Analysis of Variance (ANOVA) for Repeated Measures. In case of a significant overall effect of working height for each dependent variable the scores for levels of working height were also compared pair wise with the score for their own optimum working height. **The optimum working height was defined as the experimental working height that caused the least local postural discomfort (average group score). Differences were tested by a T-test. The selected level of significance for both tests mentioned was p=.05.**

It is assumed that the scales used for all other determinations of subjective experiences have an ordinal character. Therefore, non-parametric or distribution-free statistical tests were applied. The overall effect of working height on estimated endurance time, judgement on working height, and all dependent variables related to perceived posture was tested by a Friedman Test. In case of a significant overall effect of working height the scores on a dependent variable for levels of working height were also compared pair wise with the score for the optimum working height. Differences were tested by a Wilcoxon Matched-Pairs Signed-Ranks Test. **For each dependent variable its own optimum working height was defined as the experimental working height that caused a perceived posture closest or equal to 'very favourable', the longest estimated endurance time, or a judgement on working height closest or equal to the qualification 'right' (average group scores).** The selected level of significance for both tests mentioned was p=.05.

5.3.8 Formulation of guidelines

The results for the dependent variables on posture, perceived posture, local postural discomfort, estimated endurance time, and judgement on working height together with the characteristics of the operation have to be combined to formulate a guideline for optimum working height or height range for each of the three operations. The guidelines are formulated by a comparison of test-situations (working heights).

The process of formulating a guideline for an operation will be executed by excluding certain working heights for recommendation on basis of significant results (alpha $\leq$ .05, criteria to be described below). At the results section these working heights are underscored. The result of this process is a recommendation for either one specific working height or for a working height range. In case of a recommended working height range, other (non-significant) results (optimum working heights for various dependent variables) are used to establish preferences for a specific working height within the recommended height range.

Biomechanical principles state that a more elevated upper arm as well as a more inclined head and/or trunk increases the load on the body (and can be considered more hazardous for a worker's health). The body has to work against gravity, and consequently the load on various body structures is increased. However, in case of arm support on the work surface (as for oxy-gas cutting) or in case of upwardly directed reaction forces from the work surface on the tool (as for grinding) the negative influence of gravity on the trunk and/or upper arm(s) is reduced or eliminated. The amount of load on the body (and the possible consequences for a worker's health) have to be determined also on basis of the subjective experiences on a working height.

All postural data obtained give insight into postural behaviour, i.e. adaptation to changing working heights, and also can give explanations for subjective experiences. Head/trunk inclination, trunk inclination, left upper arm elevation, right upper arm elevation, and trunk - upper arm angle for a working height are considered optimum if posture is closest or equal to the neutral posture. So, the five variables mentioned can be used to determine musculoskeletal load and possible health consequences for a working height. **In principle, working heights causing scores on one or more posture variables that are significantly worse than for the optimum working height of the variable are not to be recommended.** It is conceivable that results on various posture variables exclude all working heights for recommendation. In that case, the subjective experiences related to the posture of specific body parts indicate their mutual relative loads on the musculoskeletal system on a same continuum. An optimum working height or height range may be found.

For each dependent variable on subjective experiences the scores for working heights are compared to the score for its own optimum working height (for definition see section 5.3.7, subsection *subjective experiences*). **In principle, working heights causing scores on one or more dependent variables that are significantly worse than for the optimum working height of the dependent variable are not to be recommended. Furthermore, working heights causing average group scores higher than 5 (definitely unfavourable) for a dependent variable on perceived posture are considered unacceptable and are not to be recommended.**

As was described earlier in section 5.3.5, it was decided that conclusions with respect to ergonomic guidelines can only be drawn if information from both posture and subjective experiences is non-conflicting and supportive.

In case of a recommended working height range the borders of this range are formed by the lowest and highest experimental working heights that can be recommended on basis of the criteria described before. This excludes working heights outside the recommended range that might be found acceptable if tested experimentally. Theoretically, it can be expected that the actual acceptable range is somewhat larger than the currently recommended range. However, the exact borders of this actual range can not be determined on basis of the present study. Consequently, the smallest possible height range was recommended.

The periods of operation during the experiments were in accordance with the periods seen during a normal working day. Furthermore, subjects were tested all over the day, i.e. after and/or before periods of daily task execution and their accompanying states of fatigue. Therefore, the experimental results are valid for regular daily task execution.

5.4 Results

The experimental results for each operation will be described in a way to facilitate the process of selecting an optimum working height. This selection process contains two steps.

First, a recommended optimum working height or height range will be determined through exclusion of those working heights that show significantly (alpha $\leq .05$) worse scores than for the optimum working height. **These working heights will be underscored at their presentation.** The significance levels (p-values) will not be mentioned.

Second, in case of a recommended optimum working height range other results, that approach significance, will be used to establish a preferred working height within the recommended height range. The exact significance levels (p-values) will be given.

The results for pneumatic wrenching, for oxy-gas cutting, and for grinding are presented each in a separate section (5.4.1 till 5.4.3). Each section contains subsections on the results for *posture*, on the results for *subjective experiences*, and on the *formulation of the guideline.*

The subsections on posture and on subjective experiences are started with a summary, containing short statements on the results that are most important in the process of selecting an optimum working height. The reader who is not interested in details can skip the remainder of the subsection.

In general, far more significant results were found than could be expected on the basis of chance capitalization.

5.4.1 Pneumatic wrenching

Posture

Summary

At all experimental working heights the left upper arm is kept close to the neutral posture. With increasing working height the right upper arm gets slightly more elevated and trunk inclination gets slightly reduced and vice versa. Both small, but significant effects have opposing effects on the total load on the musculoskeletal system.

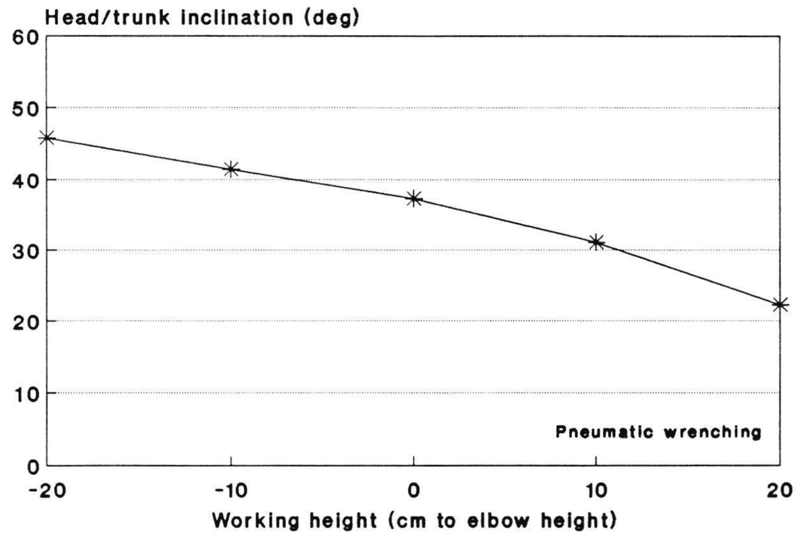
With decreasing working height the head/trunk inclination increases at a faster rate than the trunk inclination. This results in a larger neck angle, i.e an increased inclination of the head relative to the trunk.

The required working height for the wrench is realized mainly by flexion of the elbow joint.

The reader who is not interested in details can go to page 70.

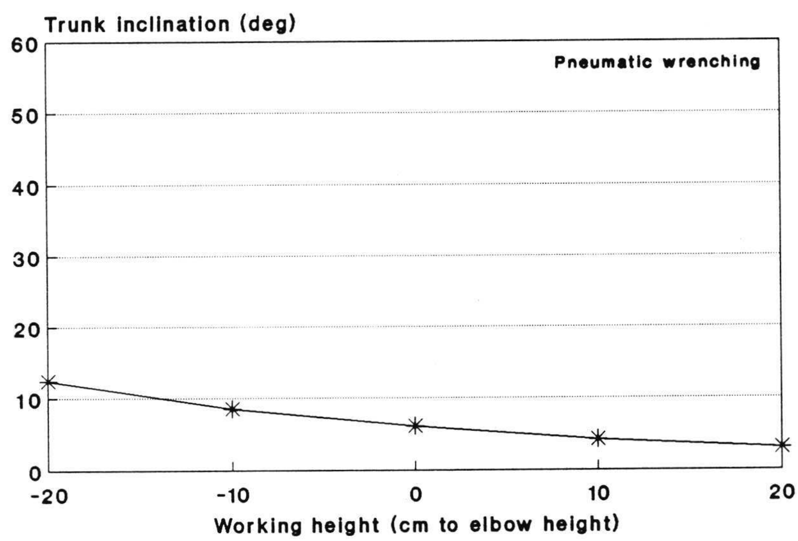
Head/trunk inclination
Figure 5.6 shows the effect of working height on head/trunk inclination. The scores for working heights -20, -10, 0, and +10 cm differed significantly from the score on its optimum working height (+20 cm).

Figure 5.6 Pneumatic wrenching. Average group scores for head/trunk inclination in relation to working height (relative to elbow height)



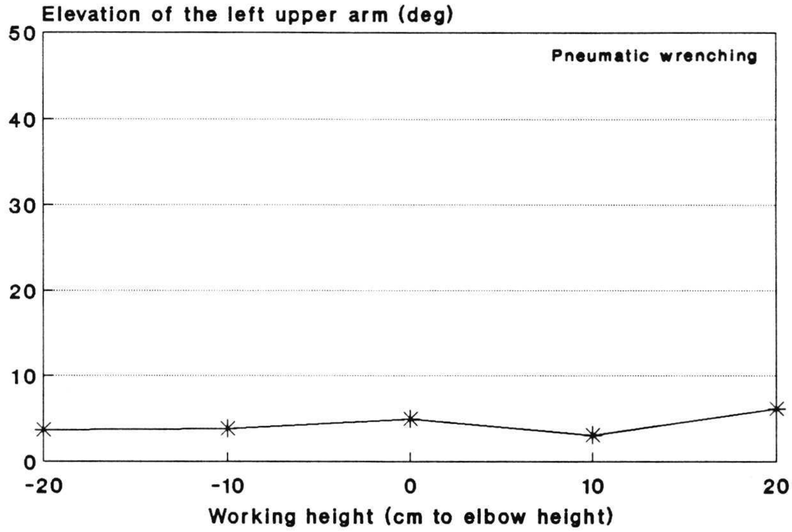
Trunk inclination
Figure 5.7 shows the effect of working height on trunk inclination. The scores for working heights -20, -10, and 0 differed significantly from the score on its optimum working height (+20 cm). The score for working height +10 cm differed not significantly from the score on the optimum working height (p=.09).

Figure 5.7 Pneumatic wrenching. Average group scores for trunk inclination in relation to working height (relative to elbow height)



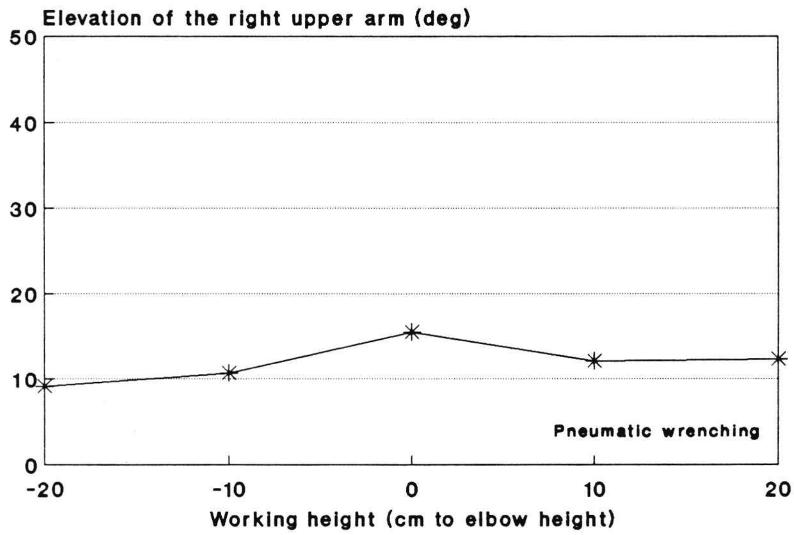
Elevation of the left upper arm
Figure 5.8 shows the effect of working height on the elevation of the left upper arm. The overall effect of working height on this variable was not significant (p=.57).

Figure 5.8 Pneumatic wrenching. Average group scores for elevation of the left upper arm in relation to working height (relative to elbow height)



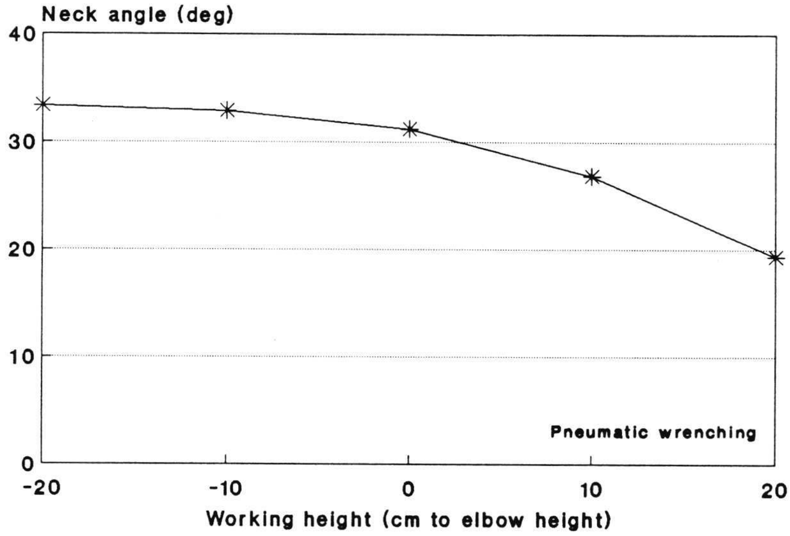
Elevation of the right upper arm
Figure 5.9 shows the effect of working height on the elevation of the right upper arm. The scores for working heights 0 and +20 cm differed significantly from the score on its optimum working height (-20 cm). The scores for working heights -10 cm and +10 cm differed not significantly from the score on the optimum working height (p=.12 and p=.10, respectively).

Figure 5.9 Pneumatic wrenching. Average group scores for elevation of the right upper arm in relation to working height (relative to elbow height)



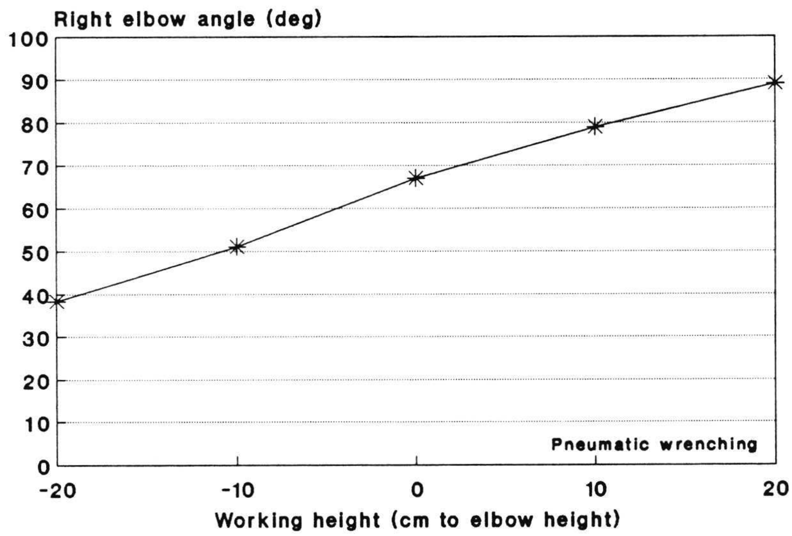
Neck angle
Figure 5.10 shows the effect of working height on the neck angle. The score for working height 0 cm differed significantly from the score for working height +10 cm. The score for working height +10 cm differed significantly from the score for working height +20 cm.

Figure 5.10 Pneumatic wrenching. Average group scores for neck angle in relation to working height (relative to elbow height)



Right elbow angle
Figure 5.11 shows the effect of working height on the right elbow angle. The score for working height -20 cm differed significantly from the score for working height -10 cm. The score for working height -10 cm differed significantly from the score for working height 0 cm. The score for working height 0 cm differed significantly from the score for working height +10 cm. The score for working height +10 cm differed significantly from the score for working height +20 cm. The right elbow shows more flexion with increasing working height.

Figure 5.11 Pneumatic wrenching. Average group scores for the right elbow angle in relation to working height (relative to elbow height)



Summary

Working height -20 cm caused unfavourable posture for the neck.

Working height +20 cm caused definitely unfavourable posture for the right upper arm and for the right wrist.

Furthermore, non-preferences for working heights -20 and +20 cm can be seen on basis of the perceived postures of the back and the left upper arm, respectively.

A preference for a working height below elbow height can be seen for the perceived postures of the right wrist and right upper arm, for postural discomfort of the whole body and the right shoulder/arm, for the estimated endurance time, and for the judgement on working height.

The reader who is not interested in details can go to page 78.

A. Perceived posture

Figures 5.12, 5.13 and 5.14 show the effect of working height on the perceived posture of 12 body parts. Results will be described separately for working height -20 cm, for working height +20 cm, and for working heights -10, 0, and +10 cm. For each of these three cases first a general distinction on the magnitude of the scores for a variable will be made. Three types of qualification are used, i.e. below score 4 (at the favourable side of the favourable/unfavourable border-line), between score 4 and 5 (tending to unfavourable), and above score 5 (definitely unfavourable). Thereafter the results from statistical analyses are presented.

Working height -20 cm.

This working height caused scores higher than 4 (tending to unfavourable) on the perceived posture of the back, neck, and all parts of the right shoulder/arm complex except for the right shoulder.

The score for the neck differed significantly from the score on its optimum working height (+10 cm).
The overall effect of working height for the back was not significant (p=.13). The score for working height -20 cm was the highest seen.
The overall effect of working height for the left upper arm was not significant (p=.08).

Working height +20 cm.

This working height caused scores higher than 4 on the perceived posture of all four parts of the right shoulder/arm complex. The scores for the right upper arm and wrist were even higher than 5 (definitely unfavourable). For the left upper arm a score 4 on the perceived posture was found.

The overall effect of working height for the right upper arm was not significant (p=.08). The score for working height +20 cm was the highest seen.
The overall effect of working height for the left upper arm was not significant (p=.08). The score for working height +20 cm was the highest seen.
The overall effect of working height for the back was not significant (p=.13). The score for working height +20 cm was the second highest seen.

Working heights -10, 0, and +10 cm.

For working heights between -10 and +10 cm the perceived posture of the neck, back, both upper legs, and all parts of the left shoulder/arm complex was at maximum slightly above score 3 (favourable). For all three heights the perceived posture of all parts of the right shoulder/arm complex was nearly always above score 4 (tending to unfavourable). Highest, i.e. worst, scores were for right upper arm and the right wrist. These parts of the right shoulder/arm complex were more critical than the right shoulder and the right forearm. The score for the right upper arm was lowest, i.e. best, at working height -10 cm. The score for the right wrist was lowest at working height 0 cm.

The overall effect of working height for the left upper arm was not significant (p=.08).

Figure 5.12 Pneumatic wrenching. Average group scores for perceived posture of the neck, back, left upper leg, and right upper leg in relation to working height (relative to elbow height). 1 = very favourable, 3 = favourable, 5 = unfavourable, and 7 = very unfavourable

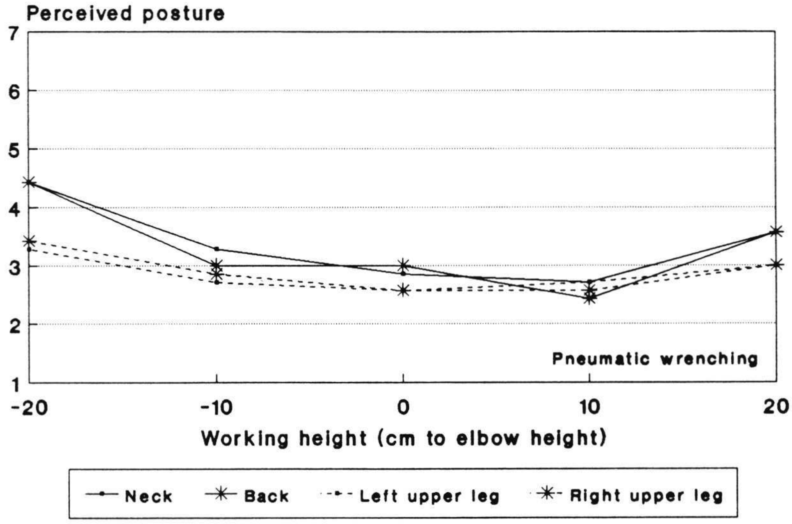


Figure 5.13 Pneumatic wrenching. Average group scores for perceived posture of the left shoulder, left upper arm, left forearm, and left wrist in relation to working height (relative to elbow height). 1 = very favourable, 3 = favourable, 5 = unfavourable, and 7 = very unfavourable

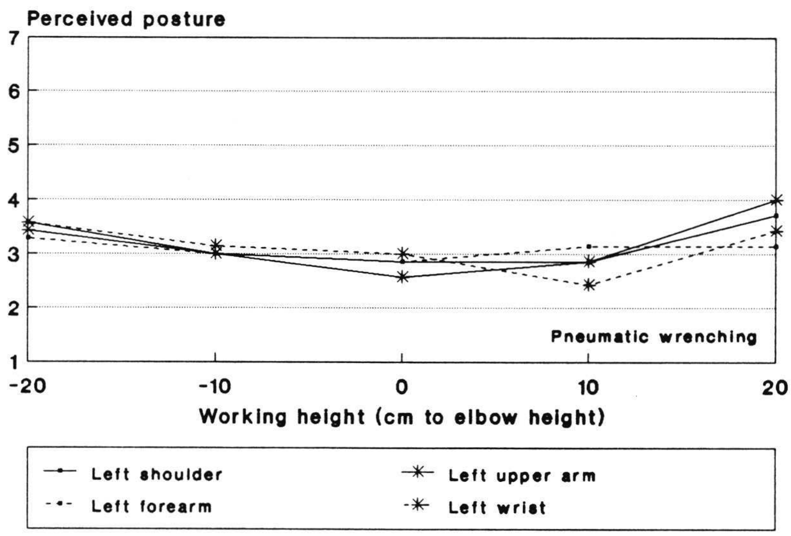
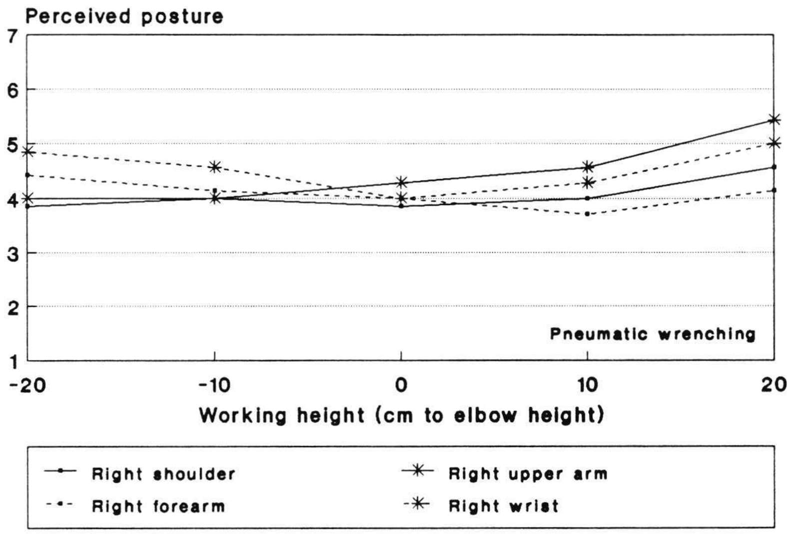


Figure 5.14 Pneumatic wrenching. Average group scores for perceived posture of the right shoulder, right upper arm, right forearm, and right wrist in relation to working height (relative to elbow height). 1 = very favourable, 3 = favourable, 5 = unfavourable, and 7 = very unfavourable



B. Local postural discomfort

Figures 5.15 and 5.16 show the effect of working height on local postural discomfort of the whole body, neck, both shoulder/arms, upper back, low back, and both legs.
No single optimum working height or height range could be distinguished on basis of the scores for postural discomfort of the whole body. Postural discomfort of the whole body was determined mainly by local postural discomfort of the right shoulder/arm, and to a lesser extent by local postural discomfort of the neck and low back. Except for the neck, all scores on postural discomfort were lowest for working height -10 cm. The score on postural discomfort for the neck was lowest for working height +10 cm.

For all eight dependent variables the overall effect of working height on the postural discomfort was not significant (.17< p <.50)

Figure 5.15 Pneumatic wrenching. Average group scores for local postural discomfort of the whole body, neck, left shoulder/arm, and right shoulder/arm in relation to working height (relative to elbow height). Positive and negative scores reflect the amount of increase and decrease in postural discomfort during the time of operation, respectively

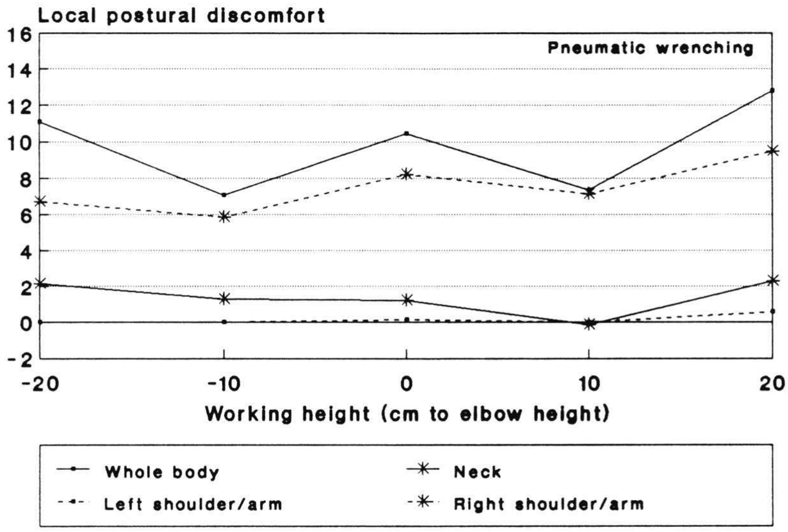
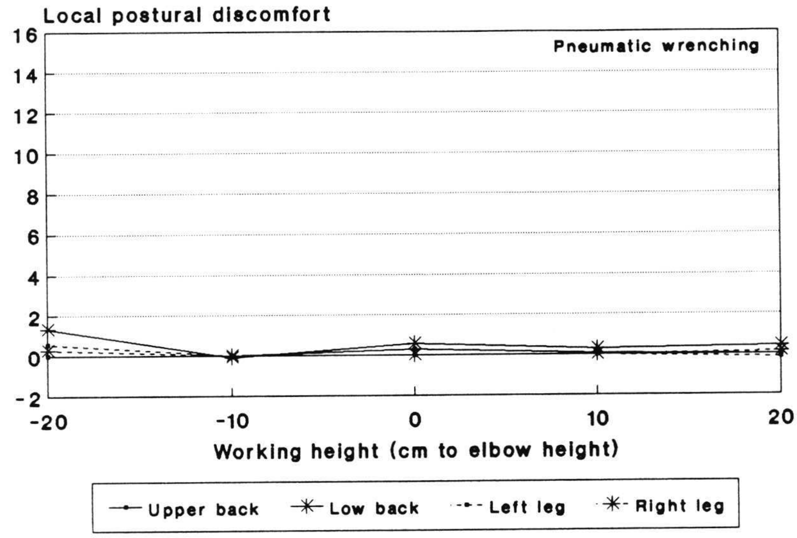


Figure 5.16 Pneumatic wrenching. Average group scores for local postural discomfort of the upper back, low back, left leg, and right leg in relation to working height (relative to elbow height). Positive and negative scores reflect the amount of increase and decrease in postural discomfort during the time of operation, respectively

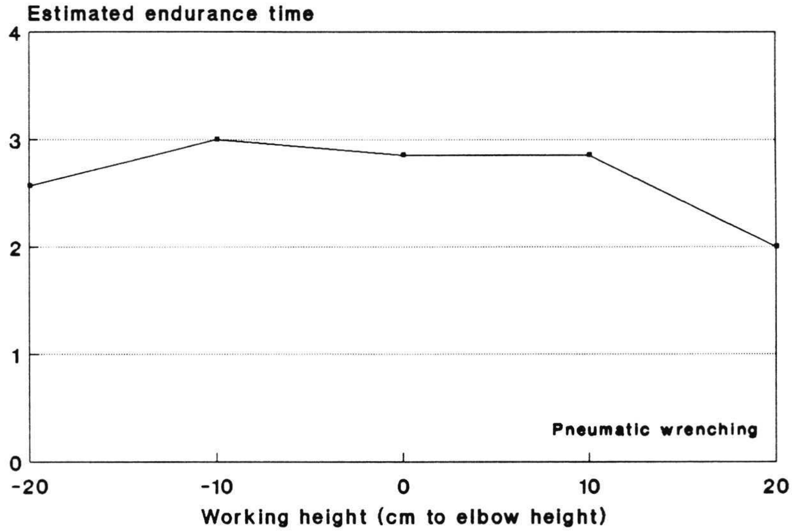


C. Estimated endurance time

Figure 5.17 shows the effect of working height on estimated endurance time.
The scores for working heights -10, 0, and 10 cm were highest, i.e. best. Estimated endurance time was slightly longer for working height -10 cm than for working heights 0 and +10 cm.

The overall effect of working height on the estimated endurance time was not significant (p=.17).

Figure 5.17 Pneumatic wrenching. Average group scores for estimated endurance time in relation to working height (relative to elbow height). 0 = less than 5 minutes, 1 = 5 to 10 minutes, 2 = 10 to 20 minutes, 3 = 20 to 30 minutes, and 4 = 30 minutes to 1 hour

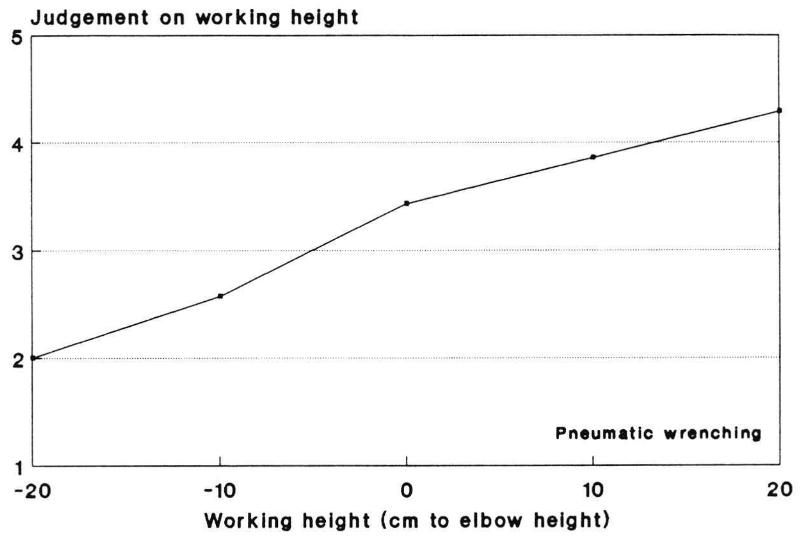


D. Judgement on working height

Figure 5.18 shows the effect of working height on judgement on working height. The scores for working height -10 and 0 cm were closest to score 3 ('right'). The judgement of working height -10 cm tended to 'a little too low'. The judgement for working height -0 cm tended to 'a little too high'. Judgement 'right' fell between working heights -10 and 0 cm.

The score on working height +20 cm differed not significantly from the score on working height 0 cm (p=.07).

Figure 5.18 Pneumatic wrenching. Average group scores for judgement on working height in relation to working height (relative to elbow height). 1 = much too low, 2 = a little too low, 3 = right, 4 = a little too high, and 5 = much too high



Formulation of guideline

Postural data reveal that during pneumatic wrenching at all experimental working heights the left upper arm is kept close to the neutral posture and the right upper arm is slightly more elevated. The required working height for the wrench is realized mainly by flexion of the elbow joint. With increasing working height the trunk inclination is reduced. At the same time the head/trunk inclination is reduced at a faster rate, resulting in a smaller neck angle, i.e a reduced inclination of the head relative to the trunk.

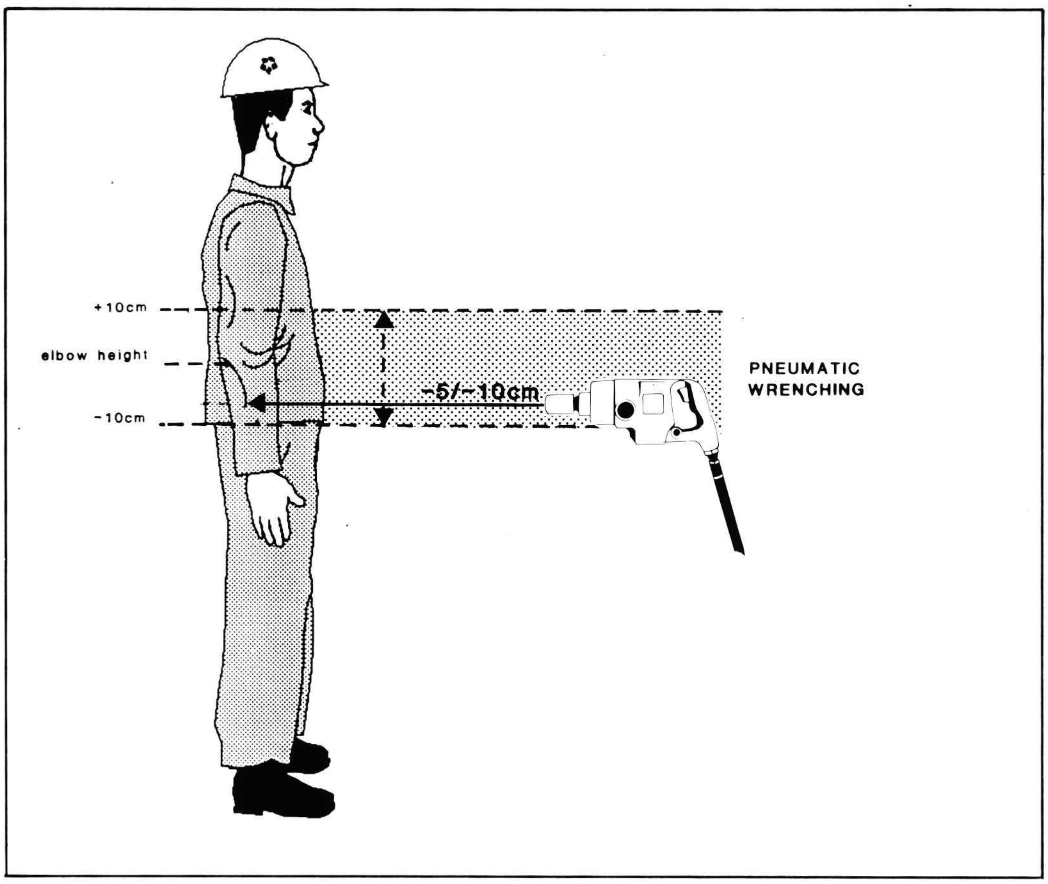
The perceived posture and local postural discomfort with respect to the right shoulder/arm complex, the (low) back, and the neck are most pronounced in pneumatic wrenching. These subjective experiences, related to the (relative) posture of specific body segments, depend on working height.
Working height -20 cm caused unfavourable posture for the neck and to a lesser extent (close to significance) for the (low) back. This can be explained by the inclination of the trunk and of the head. Due to the absence of support for the head and the trunk the load on the low back and the neck increases with inclination of both body segments. In addition the momentum due to the weight and position of the pneumatic wrench makes any inclination of the trunk feel more unfavourable.
Working height +20 cm caused unfavourable posture for the right upper arm and wrist, and to a lesser extent (close to significance) for the left upper arm. For both upper arms this can be explained by their increased elevation relative to lower working heights. It may be that the unfavourable right wrist posture is caused by the fact that the forearm was not positioned in line with the wrench, as was observed from video-tapes.

The results discussed above lead to the conclusion that working heights -20 and +20 cm should not be worked on. This is supported by the highest scores on postural discomfort of the whole body, lowest scores on estimated endurance time, and judgements on working height furthest away from the qualification 'right' for both extreme experimental working heights. Therefore, a working height range from 10 cm below to 10 cm above elbow height is recommended.

From the remaining working heights -10, 0, and +10 cm no specific height can be recommended with certainty. These working heights solely caused unfavourable posture of the right wrist and upper arm. For the wrist this may again be caused by the fact that the forearm is not positioned in line with the wrench. For the right upper arm this can be explained by its increased elevation relative to lower working heights. Perceived posture of the wrist and of the upper arm was best at working heights 0 cm and -10 cm respectively. On basis of the results for perceived posture a working height -5 cm seems indicated.
Results on postural discomfort of the whole body and right shoulder/arm disfavour working height 0 cm. For the right shoulder/arm an explanation can be found in the higher elevation of the right upper arm relative to the other two heights. Therefore, on basis of local postural discomfort a working height 0 cm seems not indicated. A working height either towards -10 cm or towards +10 cm is more appropriate.
The judgements on working heights -10 and 0 cm were closest to the qualification 'right'. The judgements on working heights -10 and 0 cm tended to qualifications 'a little too low' and 'a little too high' respectively. Judgement 'right' fell between working heights -10 and 0 cm.

The results discussed above lead to the conclusion that within the recommended work height range from 10 cm below to 10 cm above elbow height, a working height of 5 to 10 cm below elbow height is to be preferred. Figure 5.19 visualizes this guideline.

Figure 5.19 Recommended working height range and preferred working height for pneumatic wrenching



5.4.2 Oxy-gas cutting

Posture

Summary

With increasing working height the trunk gets less inclined. Furthermore, an increase of the left upper arm elevation (mainly at working heights above elbow height), and the trunk - right upper arm angle (above working height -10 cm) is seen. In general, these large significant effects on the trunk and on the arms oppose each other with respect to the total load on the musculoskeletal system.

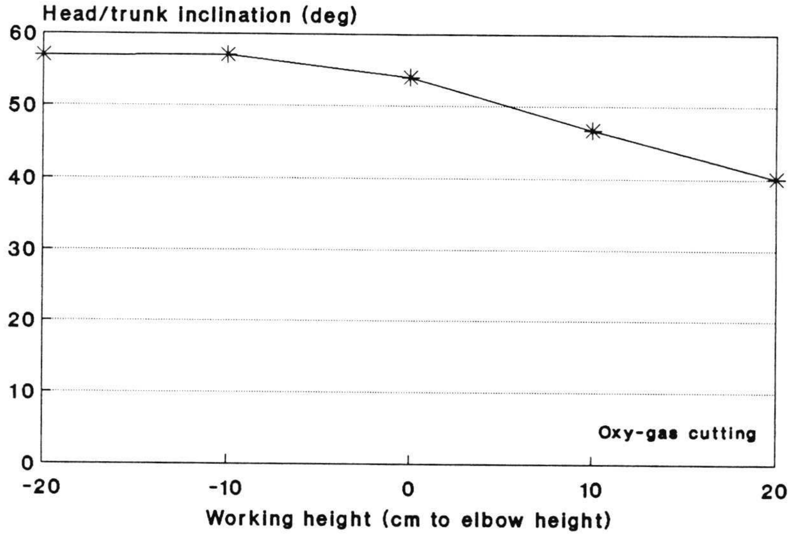
The left arm and the trunk are (partly) supported on the work surface directly and indirectly, respectively.

Surprisingly, it was found that the right upper arm does not get more elevated with increasing working height.

The reader who is not interested in details can go to page 86.

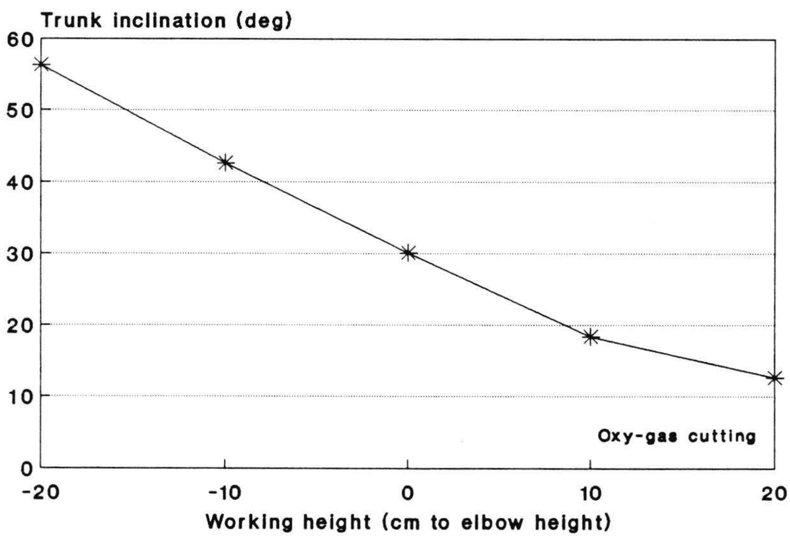
Head/trunk inclination
Figure 5.20 shows the effect of working height on head/trunk inclination. The scores for working heights -20, -10, 0, and +10 cm differed significantly from the score on its optimum working height (+20 cm).

Figure 5.20 Oxy-gas cutting. Average group scores for head/trunk inclination in relation to working height (relative to elbow height)



Trunk inclination
Figure 5.21 shows the effect of working height on trunk inclination. The scores for working heights -20, -10, 0, and +10 cm differed significantly from the score on its optimum working height (+20 cm).

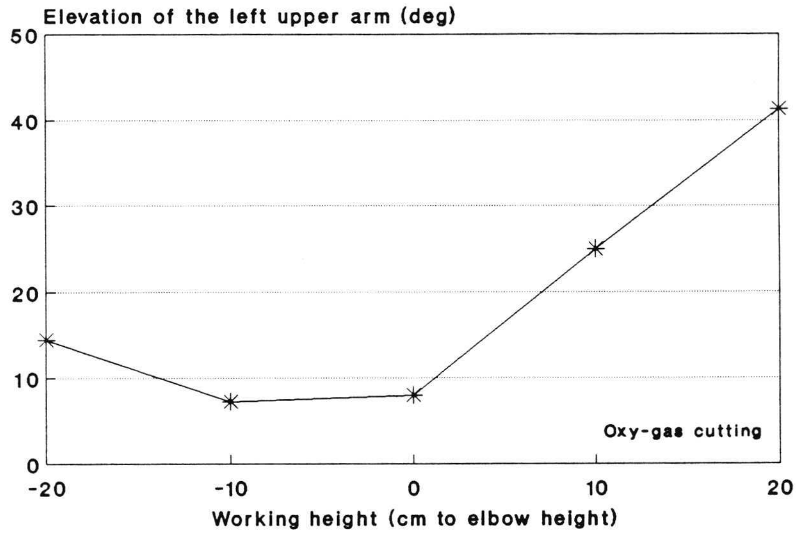
Figure 5.21 Oxy-gas cutting. Average group scores for trunk inclination in relation to working height (relative to elbow height)



Elevation of the left upper arm

Figure 5.22 shows the effect of working height on the elevation of the left upper arm. The scores for working heights +20 and +10 cm differed significantly from the score on its optimum working height (-10 cm). The score for working height -20 cm differed not significantly from the score on its optimum working height ($p=.14$). The high average group score for working height -20 cm is caused mainly by two subjects showing a relatively large elevation.

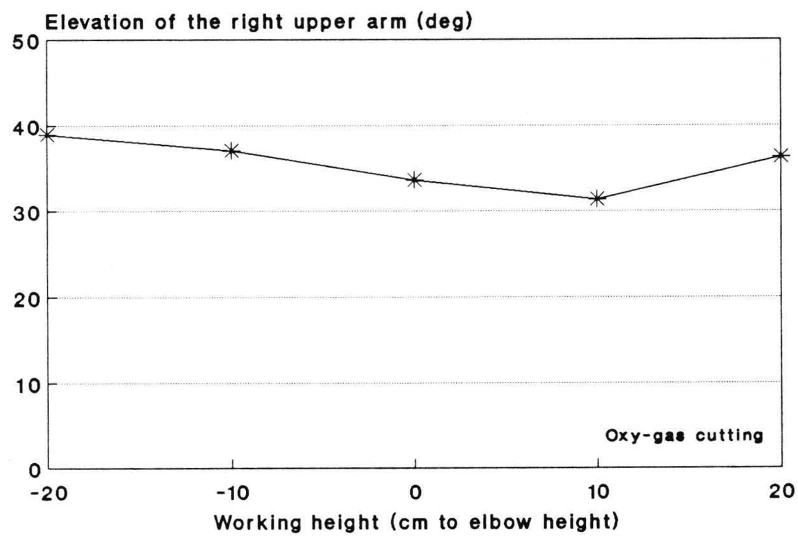
Figure 5.22 Oxy-gas cutting. Average group scores for elevation of the left upper arm in relation to working height (relative to elbow height)



Elevation of the right upper arm

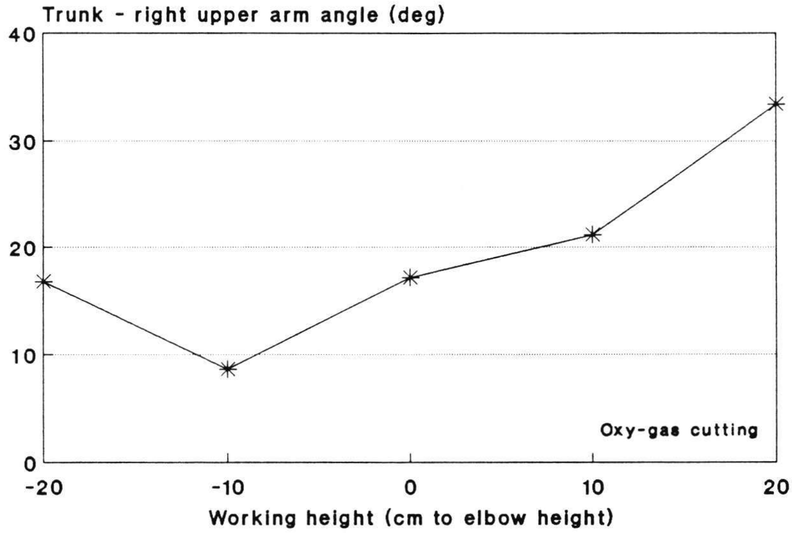
Figure 5.23 shows the effect of working height on the elevation of the right upper arm. The overall effect of working height on this dependent variable was not significant ($p=.39$).

Figure 5.23 Oxy-gas cutting.Average group scores for elevation of the right upper arm in relation to working height (relative to elbow height)



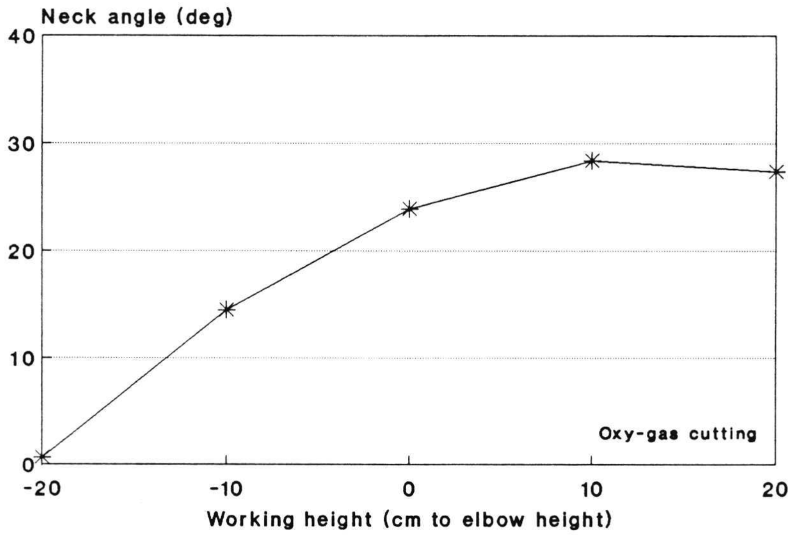
Trunk - right upper arm angle
Figure 5.24 shows the effect of working height on the trunk - right upper arm angle. The scores for working heights 0, +10, and +20 cm differed significantly from the score on its optimum working height (-10 cm). The score for working height -20 cm differed not significantly from the score on the optimum working height (p=.08).

Figure 5.24 Oxy-gas cutting. Average group scores for the trunk-right upper arm angle in relation to working height (relative to elbow height)



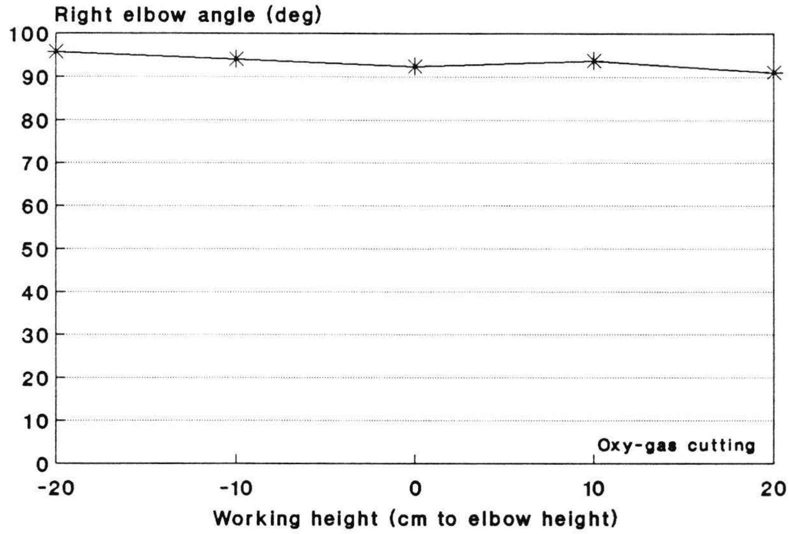
Neck angle
Figure 5.25 shows the effect of working height on the neck angle. The score for working height -20 cm differed significantly from the score for working height -10 cm. The score for working height -10 cm differed significantly from the score for working height 0 cm.

Figure 5.25 Oxy-gas cutting. Average group scores for neck angle in relation to working height (relative to elbow height)



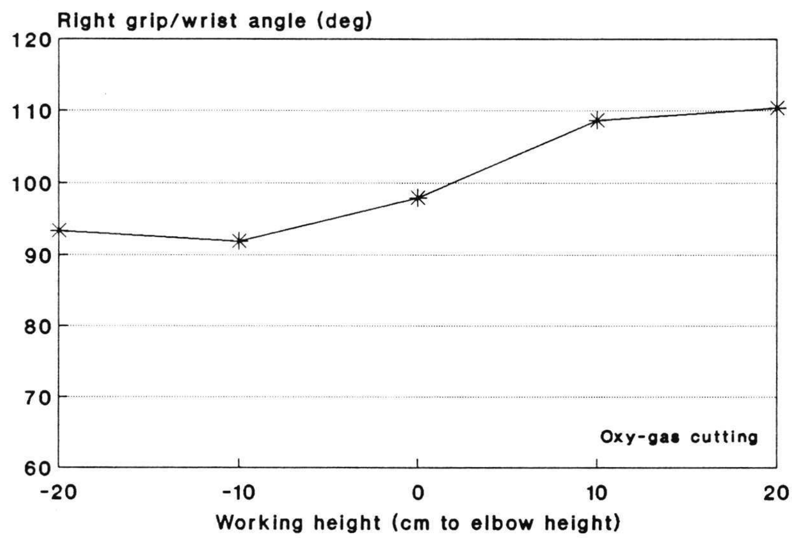
Right elbow angle
Figure 5.26 shows the effect of working height on the right elbow angle. The overall effect of working height on this dependent variable was not significant (p=.42).

Figure 5.26 Oxy-gas cutting. Average group scores for the right elbow angle in relation to working height (relative to elbow height)



Right grip/wrist angle
Figure 5.27 shows the effect of working height on the right grip/wrist angle. The score for working height -10 cm differed significantly from the score for working height 0 cm. The score for working height 0 cm differed significantly from the score for working height +10 cm. Observations from video-tapes show that the wrist is increasingly abducted in the ulnar direction at higher work surfaces. It seems that at working heights +10 cm and higher an extreme position is reached.

Figure 5.27 Oxy-gas cutting. Average group scores for the right grip/wrist angle in relation to working height (relative to elbow height)



Summary
Working height -20 cm caused unfavourable posture for the back and for the right upper arm.

Working height +20 cm caused unfavourable posture for the whole right and left shoulder/arm complex. These unfavourable postures are substantiated by the highest postural discomfort for the whole body, the left shoulder/arm, and to a lesser extent for the right shoulder/arm.

Working heights -20 and +20 cm both have shortest estimated endurance times, and are judged much too low and much too high, respectively.

Furthermore, a preference for working height 0 cm can be seen for the perceived postures of almost all body parts, for postural discomfort of the whole body, for the estimated endurance time, and for the judgement on working height.

The reader who is not interested in details can go to page 94.

A. Perceived posture

Figures 5.28, 5.29, and 5.30 show the effect of working height on the perceived posture of 12 body parts. Results will be described separately for working heights -20 cm, for working height +20 cm, and for working heights -10, 0, and +10 cm. For each of these three cases first a general distinction on the magnitude of the scores for a dependent variable will be made. Three types of qualification are used, i.e. below score 4 (at the favourable side of the favourable/unfavourable border-line), between score 4 and 5 (tending to unfavourable), and above score 5 (definitely unfavourable). Thereafter the results from statistical analyses are presented.

Working height -20 cm.

This working height caused scores higher than 4 (tending to unfavourable) on the perceived posture of the left upper leg and the right shoulder, and a score higher than 5 (definitely unfavourable) for the back.

The score for the back differed significantly from the score on its optimum working height (+10 cm).
The score for the right shoulder differed from the score on its optimum working height (0 cm) (p=.07). The score for the right upper arm differed significantly from the score on its optimum working height (0 cm).
The score for the left shoulder differed not significantly from the score on its optimum working height (0 cm) (p=.07). The score for the left forearm differed not significantly from the score on its optimum working height (0 cm) (p=.07). The overall effect of working height for the left wrist was not significant (p=.07). The score for working height -20 cm was the second highest seen.

Working height +20 cm.

This working height caused scores higher than 4 on the perceived posture of the neck, all four parts of the left shoulder/arm complex, and all four parts of the right shoulder/arm complex. The scores for the left and right shoulder were even higher than 5.

The scores for the left shoulder and the left forearm differed significantly from the score on their optimum working height (0 cm). The overall effect of working height for the left upper arm was not significant (p=.08). The score for working height +20 cm was the highest seen. The overall effect of working height for the left wrist was not significant (p=.07). The score for working height +20 cm was the highest seen.
The scores for the right shoulder, the right upper arm, and the right forearm differed significantly from the score on their optimum working height (0 cm). The overall effect of working height for the right wrist was not significant (p=.052). The score for working height +20 cm was the highest seen.

Working heights -10, 0, and +10 cm.

The working heights between -10 and +10 cm caused scores between 3 and 4 (between favourable and favourable/unfavourable) on the perceived posture of nearly all body parts. For scores within this range, at working height +10 cm the perceived posture is lowest, i.e. best, for the back. All other body parts showed their lowest scores at working height 0 cm.

The score for the right upper arm on working height +10 cm differed not significantly from the score on its optimum working height (0 cm) (p=.07).

Figure 5.28 Oxy-gas cutting. Average group scores for perceived posture of the neck, back, left upper leg, and right upper leg in relation to working height (relative to elbow height). 1 = very favourable, 3 = favourable, 5 = unfavourable, and 7 = very unfavourable

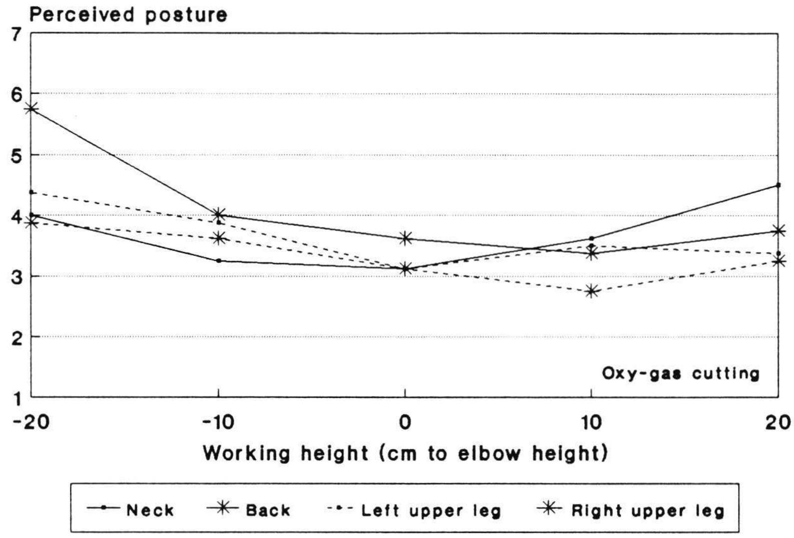


Figure 5.29 Oxy-gas cutting. Average group scores for perceived posture of the left shoulder, left upper arm, left forearm, and left wrist in relation to working height (relative to elbow height). 1 = very favourable, 3 = favourable, 5 = unfavourable, and 7 = very unfavourable

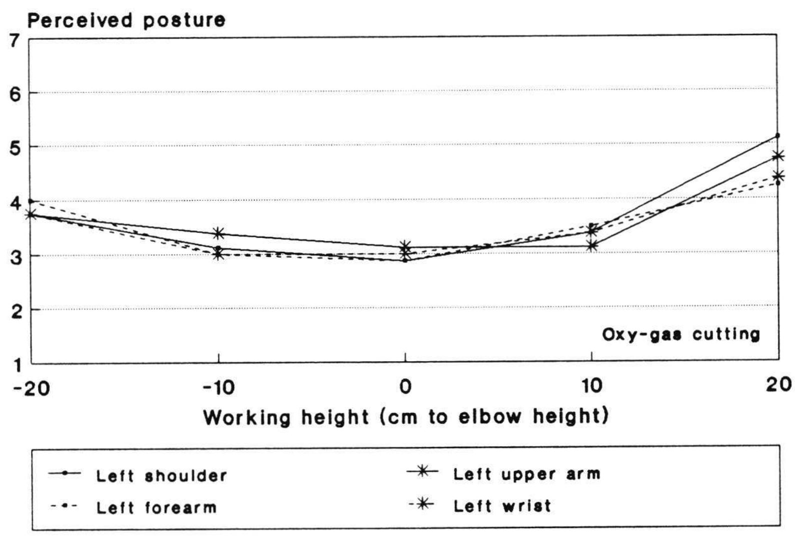
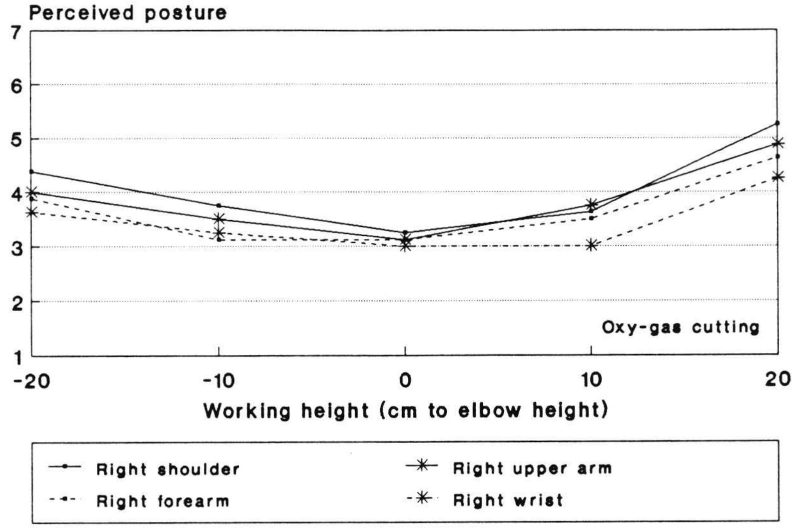


Figure 5.30 Oxy-gas cutting. Average group scores for perceived posture of the right shoulder, right upper arm, right forearm, and right wrist in relation to working height (relative to elbow height). 1 = very favourable, 3 = favourable, 5 = unfavourable, and 7 = very unfavourable



B. Local postural discomfort

Figures 5.31 and 5.32 show the effect of the working height on local postural discomfort of the whole body, neck, both shoulder/arms, upper back, low back, and both legs.

Postural discomfort of the whole body was lowest for working height 0 cm. For working heights below 0 cm the higher scores for postural discomfort of the whole body were determined mainly by the scores for the low back and to a lesser extent by the scores for the upper back and right leg. For working heights above 0 cm the higher scores for postural discomfort of the whole body were determined mainly by the scores for the left and right shoulder/arm, and to a lesser extent by the scores for neck, upper back, low back, and right leg.

Working height -20 cm.

The overall effect of working height on the postural discomfort of the low back was not significant (p=.09). The score for the low back on working height -20 cm was the highest seen. The score for postural discomfort of the whole body differed not significantly from the score on its optimum working height (0 cm) (p=.15).

Working height +20 cm.

The scores for postural discomfort of the <u>whole body</u> and of the <u>left shoulder/arm</u> differed significantly from the scores on their optimum working heights (0 and -10 cm, respectively).
The overall effect of working height for the right shoulder/arm was not significant (p=.06). The score for working height +20 cm was the highest seen.

Working heights -10, 0, and +10 cm.

The overall effect of working height on the postural discomfort of the low back was not significant (p=.09). The score for the low back on working height -10 cm was the second highest seen.
The scores for postural discomfort of the whole body on working heights -10 and + 10 cm differed not significantly from the score on the optimum working height (0 cm) (p= .23 and .12, respectively).

Figure 5.31 Oxy-gas cutting. Average group scores for local postural discomfort of the whole body, neck, left shoulder/arm, and right shoulder/arm in relation to working height (relative to elbow height). Positive and negative scores reflect the amount of increase and decrease in postural discomfort during the time of operation, respectively

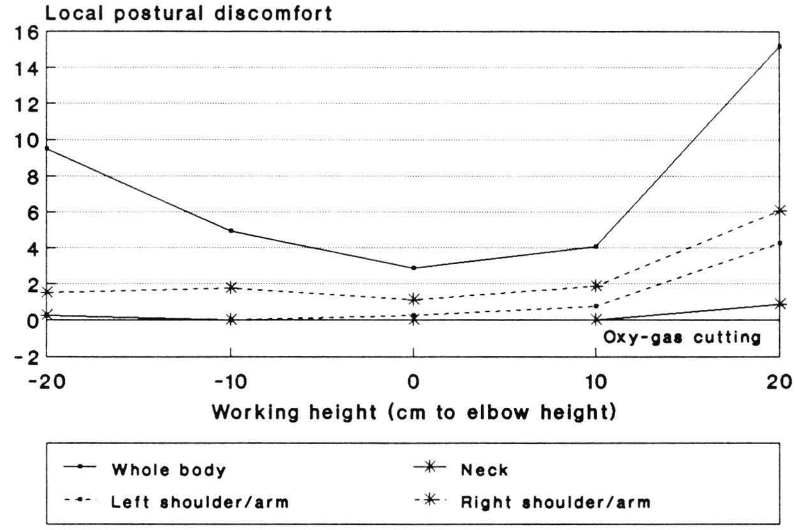
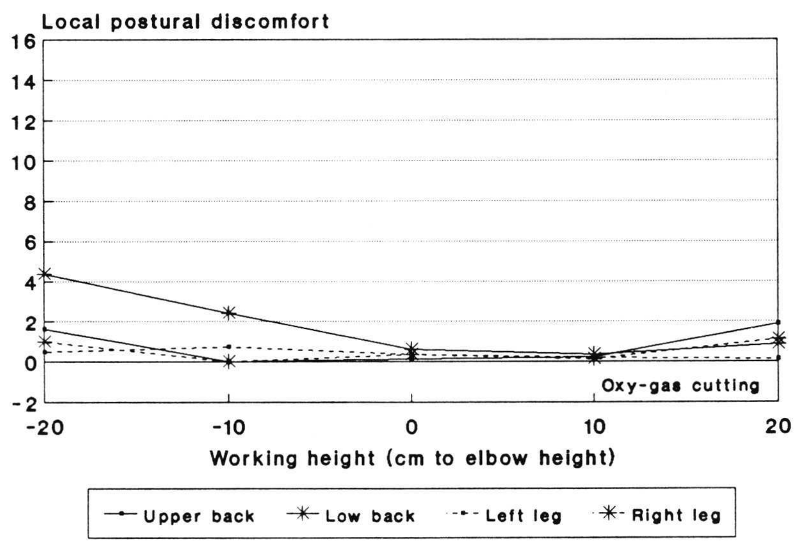


Figure 5.32 Oxy-gas cutting. Average group scores for local postural discomfort of the upper back, low back, left leg, and right leg in relation to working height (relative to elbow height). Positive and negative scores reflect the amount of increase and decrease in postural discomfort during the time of operation, respectively

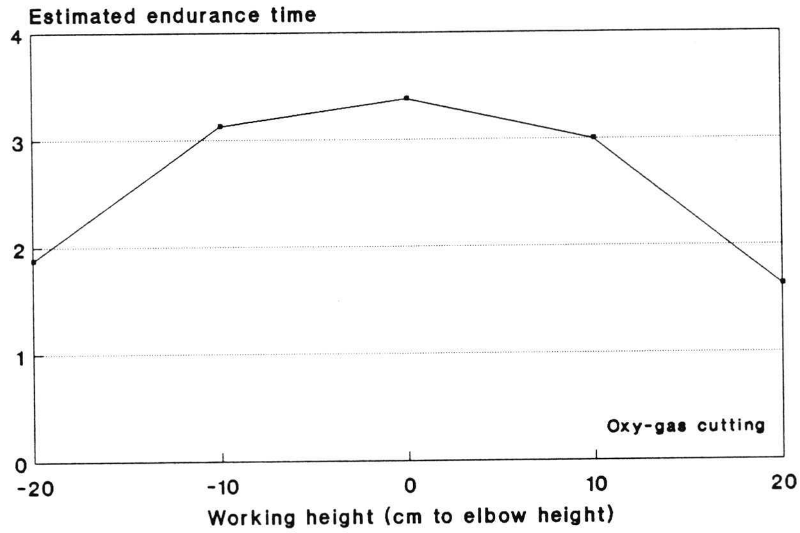


C. Estimated endurance time

Figure 5.33 shows the effect of the working height on estimated endurance time. The scores for working heights -10, 0, and 10 cm were highest, i.e. best. The estimated endurance time was longest for working height 0 cm.

The scores for working heights -20 and +20 cm differed significantly from the score on the optimum working height (0 cm).

Figure 5.33 Oxy-gas cutting. Average group scores for estimated endurance time in relation to working height (relative to elbow height). 0 = less than 5 minutes, 1 = 5 to 10 minutes, 2 = 10 to 20 minutes, 3 = 20 to 30 minutes, and 4 = 30 minutes to 1 hour

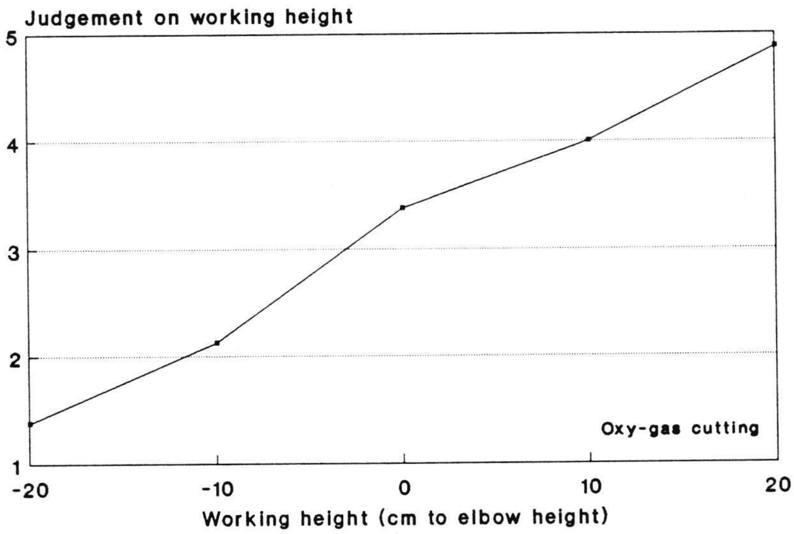


D. Judgement on working height

Figure 5.34 shows the effect of working height on judgement on working height. The score for working height 0 cm was closest to score 3 ('right'). The judgements on working heights -10 and +10 cm were approximately score 2 ('a little too low') and approximately score 4 ('a little too high').

The score on working height +20 cm differed significantly from the score on working height 0 cm. The score on working height -20 cm differed significantly from the score on working height -10 cm.
The score on working height +10 cm differed not significantly from the score on working height 0 cm (p=.07).

Figure 5.34 Oxy-gas cutting. Average group scores for judgement on working height in relation to working height (relative to elbow height). 1 = much too low, 2 = a little too low, 3 = right, 4 = a little too high, and 5 = much too high



Posture during oxy-gas cutting is characterised by left arm support on the work surface. Therefore trunk inclination depends heavily on working height. With decreasing working height the trunk gets more inclined. At the same time the head/trunk inclination is increased at a slower rate, resulting in a smaller neck angle, i.e. a reduced inclination of the head relative to the trunk. The elevation of the left upper arm is increased mainly at working heights above elbow height. The elevation of the right upper arm does not increase significantly with higher work surfaces. Most likely due to the trunk inclination mentioned above the right upper arm is in the position required for the operation. Probably the wrist posture (ulnar abduction) assists in realizing an adequate position of the oxy-gas cutter at certain high work surfaces, as was confirmed by observation from video-tapes. Furthermore it is seen that the elbow angle is constant for all working heights. The trunk - right upper arm angle shows a distinct optimum at working height -10 cm, which rapidly gets worse at higher or lower work surfaces.

The perceived posture and local postural discomfort with respect to almost all body parts studied are involved in the process of finding an optimum working height for oxy-gas cutting. The subjective experiences, related to the (relative) posture of specific body segments, depend on working height.
<u>Working height -20 cm</u> caused unfavourable posture for the back and the right upper arm, and to a lesser extent (close to significance) for both shoulders, the left forearm and wrist. Notwithstanding the left arm support on the work surface, most likely the unfavourable back posture is related to the large inclination of the trunk. The unfavourable posture of the right upper arm can be explained by the non-optimum trunk - right upper arm angle. The unfavourable posture of both shoulders may be explained by a relative elevation of the right shoulder with respect to the trunk, as was observed from video-tapes. The estimated endurance time for this working height (as well as for working height +20 cm) was longest. The judgement on this working height was close to the qualification 'much too low', which is worse than working height -10 cm that was also judged too low, but closer to the qualification 'right'.

Working height +20 cm caused unfavourable posture for the whole right and left shoulder/arm complex. This concerns most both shoulders and upper arms. For both shoulders this can be explained by their increased elevation relative to the trunk in comparison to lower work surfaces, as was observed from video-tapes. For the right upper arm an explanation can be found in the large trunk - right upper arm angle. For the left upper arm an explanation can be found in the large elevation, creating most probably also a large trunk - upper arm angle. The unfavourable posture of the right forearm and wrist may be explained by the fact that the wrist is increasingly abducted in the ulnar direction at higher work surfaces, as was observed from video-tapes. It seems that at working height +20 cm an extreme position is reached. The unfavourable posture of the left forearm and wrist may be explained by the fact that the left hand position required for support of the oxy-gas cutter creates an extreme supination of forearm at this high work surface.
The unfavourable posture of various body parts mentioned are substantiated by the highest postural discomfort for the whole body, the left shoulder/arm region, and to a lesser extent (close to significance) for the right shoulder/arm region.
The estimated endurance time for this working height (as well as for working height -20 cm) was longest. The judgement on this working height was close to the qualification 'much too high', which is worse than working height 0 cm that was also judged (slightly) too high, but closest to the qualification 'right'.

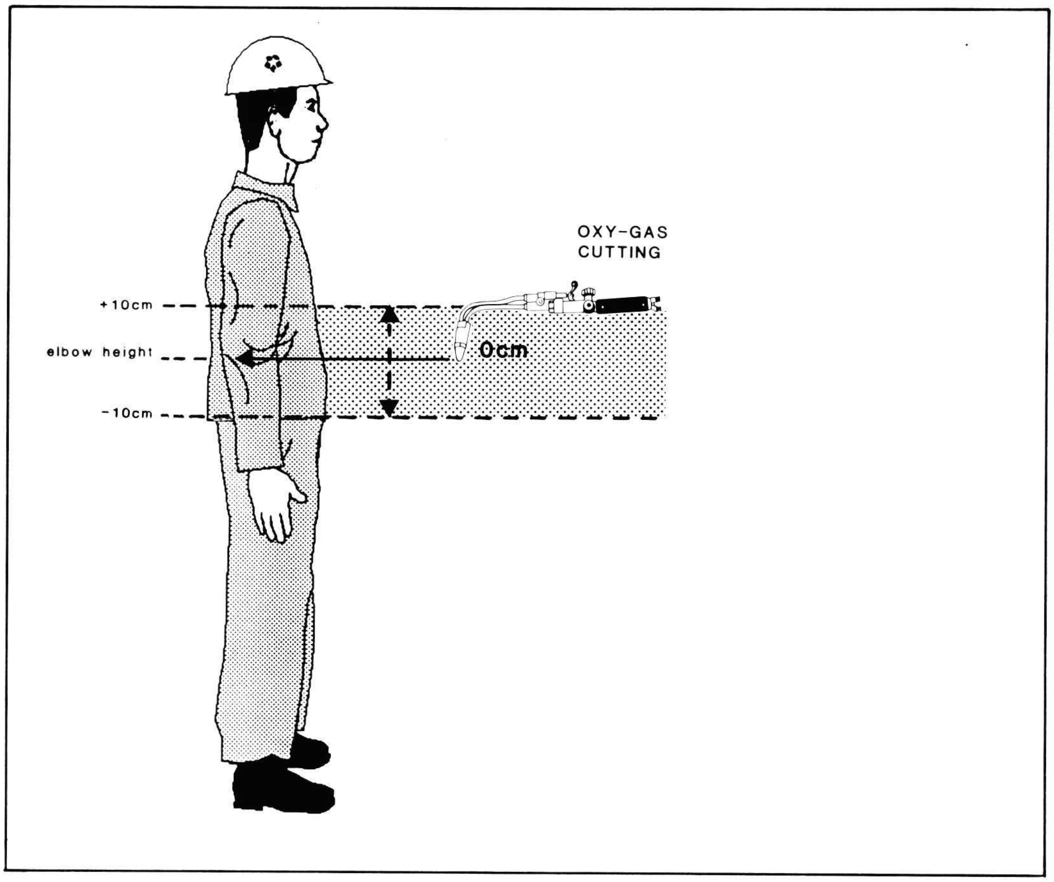
The results discussed above lead to the conclusion that working heights -20 and +20 cm should not be worked on. Therefore, a work height range from 10 below to 10 cm above elbow height is recommended.

From the remaining working heights -10, 0, and +10 cm no specific height can be recommended with certainty. The results for trunk inclination favour a working height towards +10 cm, and the results for trunk - right upper arm angle and right grip/wrist angle favour a working height towards -10 cm.
For the three heights solely working height -10 cm tended to unfavourable posture for the back. For working height +10 cm the perceived posture is lowest, i.e. best, for the back. All other body parts showed their lowest scores at working height 0 cm. For working height +10 cm the perceived posture of the right upper arm on this height was close to being significantly worse than for working height

0 cm. On basis of these results for perceived posture a working height 0 cm seems indicated.
Results on postural discomfort of the whole body show a preference for working height 0 cm. For working height -10 cm the increased postural discomfort of the whole body was determined mainly by the low back. The postural discomfort for this height was still somewhat higher than for working height 0 cm. For working height +10 cm the increased postural discomfort of the whole body was determined mainly by the scores for the left and right shoulder/arm. On basis of these results for local postural discomfort a working height 0 cm seems indicated.
Explanations for the results on perceived posture and postural discomfort for the both shoulders/arms and the back are the same as presented for working heights +20 and -20 cm respectively, as described before.
The judgement on working height 0 cm was closest to the qualification 'right'. The judgements on working heights -10 and +10 cm were given qualifications 'a little too low' and 'a little too high' respectively. The judgement on working height +10 cm was close to being significantly worse than for working height 0 cm.

The results discussed above lead to the conclusion that a strong preference exists for a working height on elbow height within the recommended working height range from 10 cm below to 10 cm above elbow height. Figure 5.35 visualizes this guideline.

Figure 5.35 Recommended working height range and preferred working height for oxy-gas cutting



5.4.3 Grinding

Posture

Summary

With increasing working height up to -35 cm the trunk gets less inclined at a moderate rate. Above working height -35 cm this is reduced. Furthermore, it was found that in particular the right upper arm is elevated increasingly. The left upper arm shows this elevation only in a minor way. In general, these large significant effects on the trunk and on the arms oppose each other with respect to the total load on the musculoskeletal system.

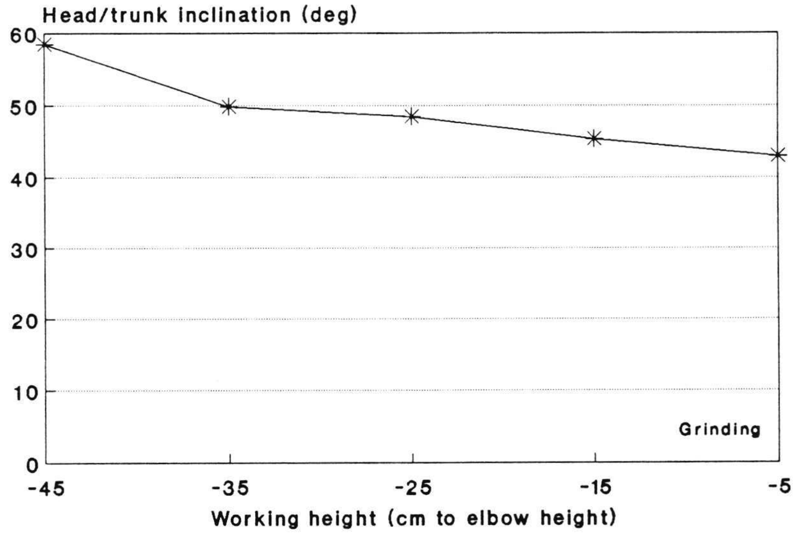
Both arms and the trunk are (partly) supported through the grinding-machine on the work surface directly and indirectly, respectively.

The right wrist gets into an extreme position (flexion) at working heights -25 cm and higher.

The reader who is not interested in details can go to page 103.

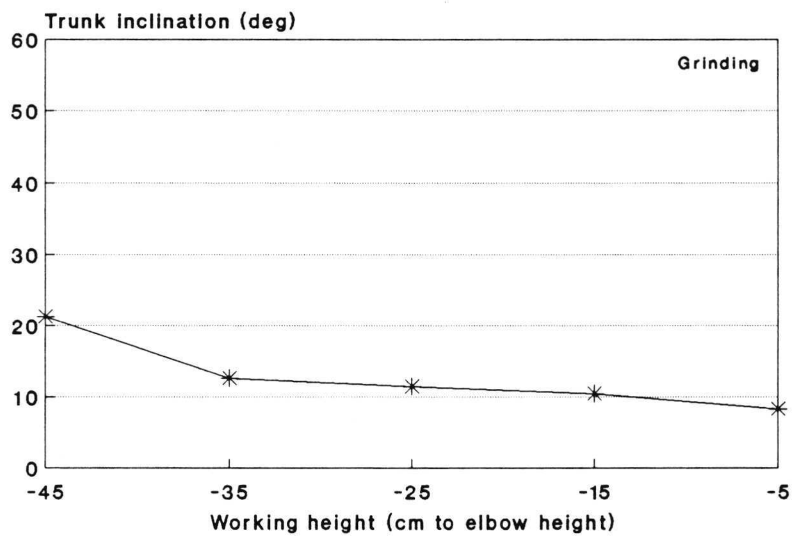
Head/trunk inclination
Figure 5.36 shows the effect of working height on head/trunk inclination. The scores for working heights -45 and -25 cm differed significantly from the score on its optimum working height (-5 cm). The score for working height -35 cm differed not significantly from the score on the optimum working height (p=.06). The score for working height -15 cm differed not significantly from the score on the optimum working height (p=.08).

Figure 5.36 Grinding. Average group scores for head/trunk inclination in relation to working height (relative to elbow height)



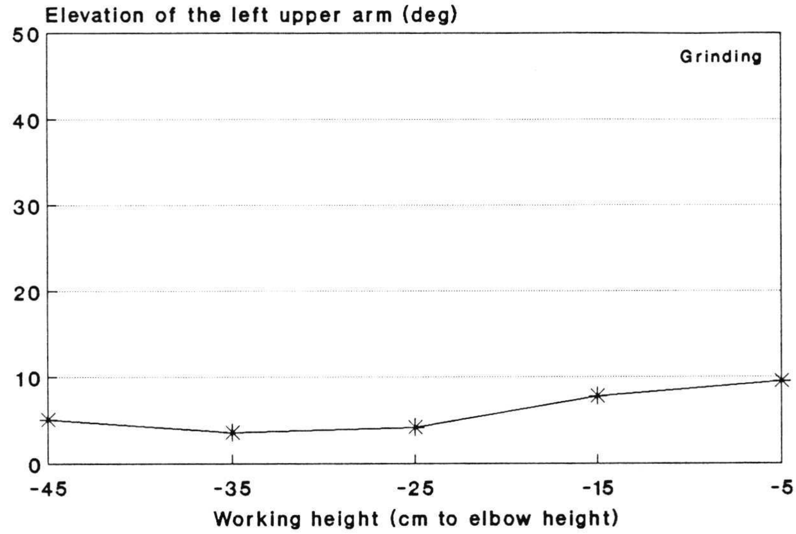
Trunk inclination
Figure 5.37 shows the effect of working height on trunk inclination. The scores for working heights -45, -35, -25, and -15 cm differed significantly from the score on its optimum working height (-5 cm).

Figure 5.37 Grinding. Average group scores for trunk inclination in relation to working height (relative to elbow height)



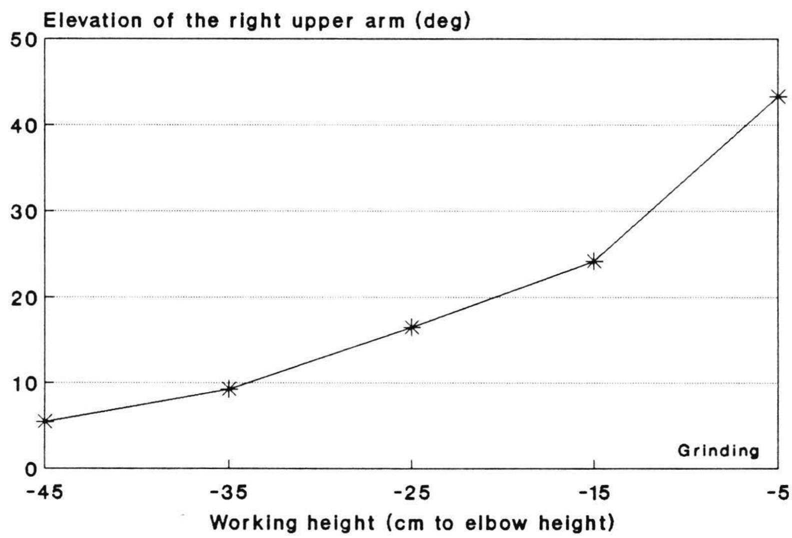
Elevation of the left upper arm
Figure 5.38 shows the effect of working height on the elevation of the left upper arm. The overall effect of working height on this dependent variable was not significant (p=.24).

Figure 5.38 Grinding. Average group scores for elevation of the left upper arm in relation to working height (relative to elbow height)



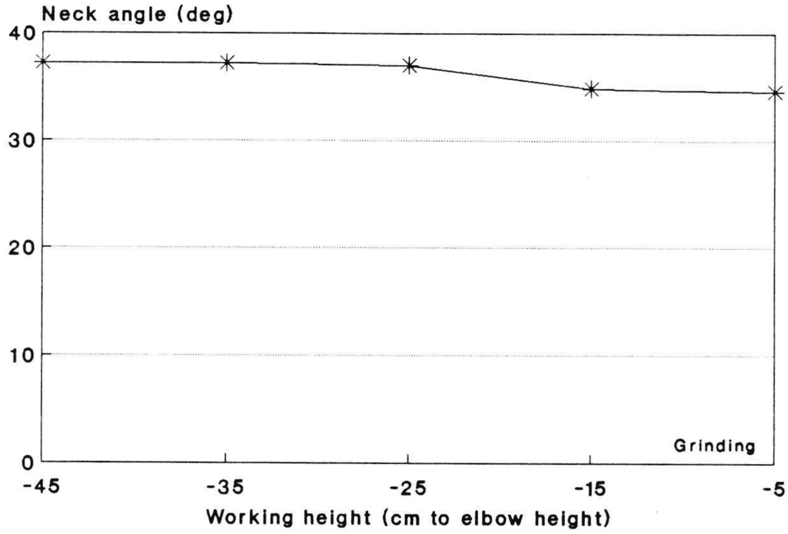
Elevation of the right upper arm
Figure 5.39 shows the effect of working height on the elevation of the right upper arm. The scores for working heights -25, -15, and -5 cm differed significantly from the score on its optimum working height (-45 cm). The score for working height -35 cm differed not significantly from the score for the optimum working height (p=.052).

Figure 5.39 Grinding. Average group scores for elevation of the right upper arm in relation to working height (relative to elbow height)



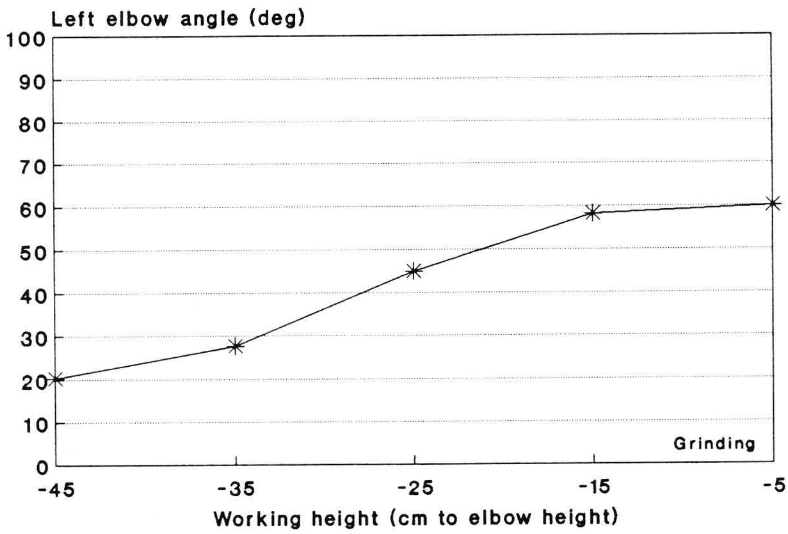
Neck angle
Figure 5.40 shows the effect of working height on the neck angle. The overall effect of working height on this dependent variable was not significant (p=.59).

Figure 5.40 Grinding. Average group scores for neck angle in relation to working height (relative to elbow height)



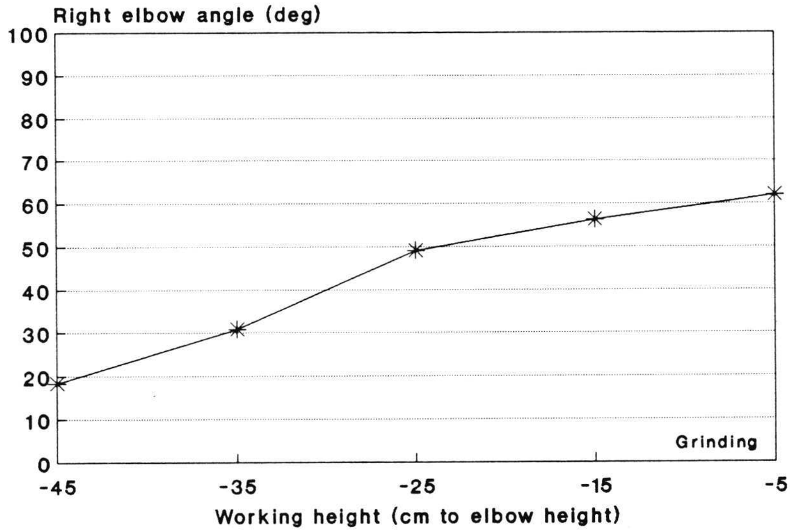
Left elbow angle
Figure 5.41 shows the effect of working height on the left elbow angle. The score for working height -45 cm differed not significantly from the score for working height -35 cm (p=.08). The score for working height -35 cm differed significantly from the score for working height -25 cm. The score for working height -25 cm differed significantly from the score for working height -15 cm.

Figure 5.41 Grinding. Average group scores for the left elbow angle in relation to working height (relative to elbow height)



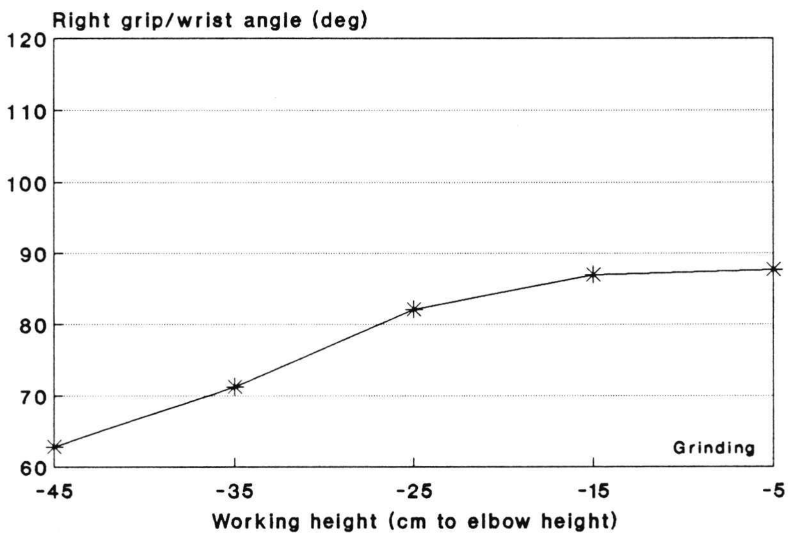
Right elbow angle
Figure 5.42 shows the effect of working height on the right elbow angle. The score for working height -45 cm differed significantly from the score for working height -35 cm. The score for working height -35 cm differed significantly from the score for working height -25 cm. The score for working height -25 cm differed significantly from the score for working height -15 cm.

Figure 5.42 Grinding. Average group scores for the right elbow angle in relation to working height (relative to elbow height)



Right grip/wrist angle
Figure 5.43 shows the effect of working height on the right grip/wrist angle. The score for working height -45 cm differed significantly from the score for working height -35 cm. The score for working height -35 cm differed significantly from the score for working height -25 cm. It seems that the right wrist gets into an extreme position at working heights -25 cm and higher. Observations from video-tapes show that the wrist is flexed at these heights.

Figure 5.43 Grinding. Average group scores for the right grip/wrist angle in relation to working height (relative to elbow height)



Subjective experiences

Summary

With increasing working height above -35 cm the right wrist posture gets more unfavourable, above working height -45 cm the local postural discomfort for the right shoulder/arm increases steeply.

Working height -5 cm is considered definitely unfavourable, leads to the highest score for local postural discomfort of the right shoulder/arm and for the whole body, and is judged too high.

Working height -45 cm is judged too low.

The reader who is not interested in details can go to page 111.

A. Perceived posture

Figures 5.44, 5.45, and 5.46 show the effect of working height on the perceived posture of 12 body parts. Results will be described separately for working height -45 cm, for working height -5 cm, and for working heights -35, -25, and -15 cm. For each of these three cases first a general distinction on the magnitude of the scores for a dependent variable will be made. Three types of qualification are used, i.e. below score 4 (at the favourable side of the favourable/unfavourable border-line), between score 4 and 5 (tending to unfavourable), and above score 5 (definitely unfavourable). Thereafter the results from statistical analyses are presented.

Working height -45 cm.

This working height caused scores higher than 4 (tending to unfavourable) on the perceived posture of the back and neck.

The overall effect of working height for the back was not significant (p=.12). The score for working height -45 cm was the highest seen.
The score for the right wrist differed nog significantly from the score on its optimum working height (-35 cm) (p=.14).
The overall effect of working height for the left wrist was not significant (p=.12). The score for working height -45 cm is slightly higher than the score for its optimum working (-35 cm).
The overall effect of working height for the right upper arm height was not significant (p=.10). The score for working height -45 cm is slightly higher than the score for its optimum working height (-35 cm).

Working height -5 cm.

This working height caused scores higher than 4 on the perceived posture of the left forearm, left wrist, right shoulder, and right upper arm. The scores of the <u>right forearm</u> and the <u>right wrist</u> were even higher than 5 (definitely unfavourable).

The score for the <u>right wrist</u> differed significantly from the score on its optimum working height (-35 cm).
The overall effect of working height for the right forearm was not significant (p=.06). The score for working height -5 cm was the highest seen. The overall effect of working height for the left wrist was not significant (p=.12). The score for working height -5 cm was the highest seen. The overall effect of working height for the right upper arm was not significant (p=.10). The score for working height -5 cm was the highest seen.

Working heights -35, -25, and -15 cm.

For working heights between -35 and -15 cm the scores on perceived posture of the neck, back, both upper legs, and the whole left shoulder/arm complex were nearly always between 3 and 4 (between favourable and favourable/unfavourable).

The overall effect of working height for the back was not significant (p=.12). The score for working height -35 cm was the second highest seen.
The overall effect of working height for the left wrist was not significant (p=.12). The scores for working heights -25 and -15 cm among the highest seen.

The perceived posture of all parts of the right shoulder/arm complex was nearly always between scores 3 and 5 (between favourable and unfavourable). Highest, i.e. worst, scores were for the right forearm and the right wrist. These parts of the right shoulder/arm complex were the most critical of all 12 body parts.

The scores for the <u>right wrist on working heights -25 and -15 cm</u> differed significantly from the score on their optimum working height (-35 cm).

The overall effect of working height for the right forearm was not significant (p=.06). The score for working height -25 cm was the third highest seen. The overall effect of working height for the right upper arm was not significant (p=.10). The score for working height -15 cm was the second highest seen.

The scores for the neck and back were lowest, i.e. best, at working height -25 cm or higher than -25 cm respectively. The scores for the right and left shoulder/arm complex were lowest at working height -35 cm. At working height -25 cm the left forearm and the left wrist showed scores close to 4 (favourable/ unfavourable) and the right forearm and the right wrist showed even scores close to 5 (unfavourable). On the opposite at working height -35 cm the neck and back showed scores close to 4.

Figure 5.44 Grinding. Average group scores for perceived posture of the neck, back, left upper leg, and right upper leg in relation to working height (relative to elbow height). 1 = very favourable, 3 = favourable, 5 = unfavourable, and 7 = very unfavourable

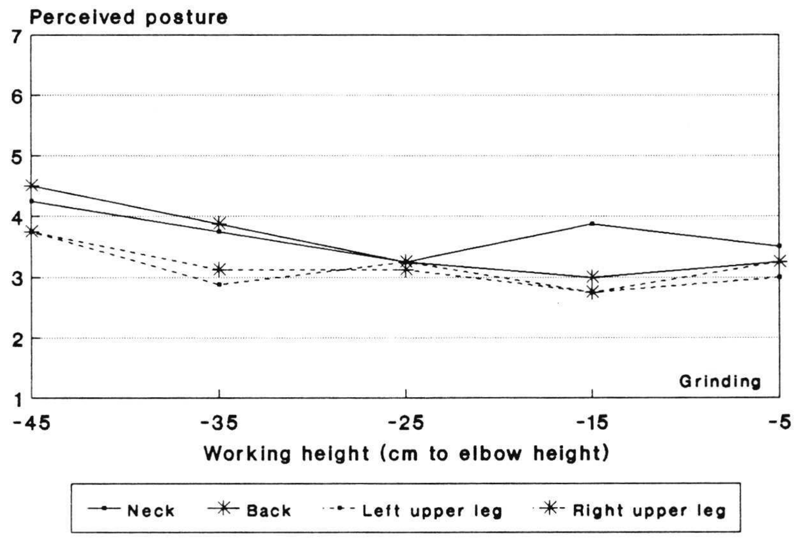


Figure 5.45 Grinding. Average group scores for perceived posture of the left shoulder, left upper arm, left forearm, and left wrist in relation to working height (relative to elbow height). 1 = very favourable, 3 = favourable, 5 = unfavourable, and 7 = very unfavourable

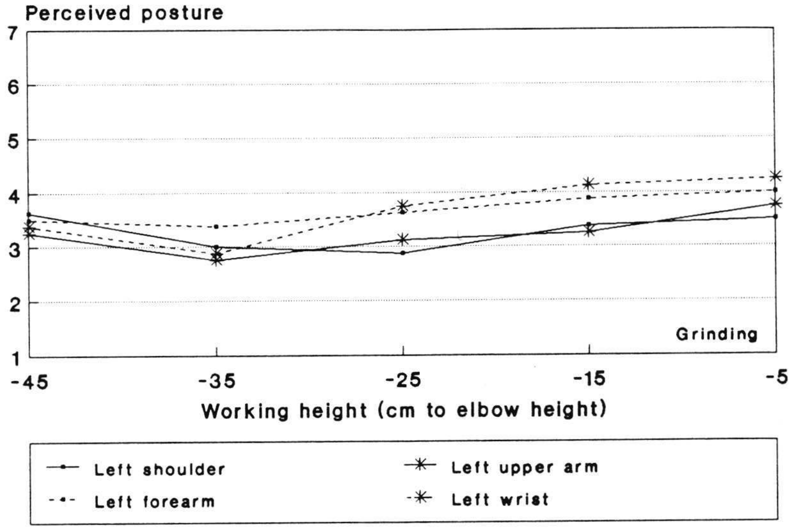
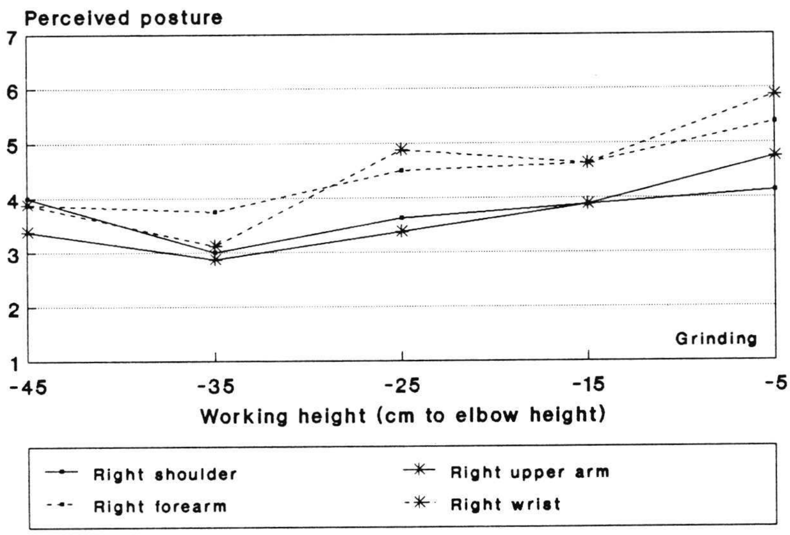


Figure 5.46 Grinding. Average group scores for perceived posture of the right shoulder, right upper arm, right forearm, and right wrist in relation to working height (relative to elbow height). 1 = very favourable, 3 = favourable, 5 = unfavourable, and 7 = very unfavourable



B. Local postural discomfort

Figures 5.47 and 5.48 show the effect of working height on local postural discomfort of the whole body, neck, both shoulder/arms, upper back, low back, and both legs.

Postural discomfort of the whole body was lowest, i.e. best, for working height -35 cm. For working height -45 cm the higher scores for postural discomfort of the whole body were determined mainly by the scores for the low back, and to a lesser extent by the scores for the neck and right leg. For working heights -25, -15, and -5 cm the higher scores for postural discomfort of the whole body were determined mainly by the scores for the left and right shoulder/arm. The scores for local postural discomfort of the low back, neck, and right leg were lowest at working height -25 cm or higher. The scores for both shoulder/arms were lowest at working height -35 cm or lower.

Working height -45 cm.

The score for postural discomfort of the right shoulder/arm on working height -45 cm differed significantly from the scores on all other working heights (see also the next two subsections).

Working height -5 cm.

The scores for postural discomfort of the whole body and the right shoulder/arm on working height -5 cm differed significantly from the score on their optimum working heights (-35 and -45 cm respectively).

Working heights -35, -25, and -15 cm.

The score for postural discomfort of the whole body on working height -15 cm differed not significantly from the score on its optimum working height (-35 cm) (p=.10).
The scores for postural discomfort of the right shoulder/arm on working heights -35, -25, and -15 cm differed significantly from the score on its optimum working height (-45 cm).
The score for postural discomfort of the left shoulder/arm on working height -15 cm differed significantly from the score on its optimum working height (-35 cm).

C. Estimated endurance time

Figure 5.49 shows the effect of the working height on estimated endurance time. The estimated endurance time was longest for working height -35 cm.
The overall effect of working height on the estimated endurance time was not significant (p=.24).

Figure 5.49 Grinding. Average group scores for estimated endurance time in relation to working height (relative to elbow height). 0 = less than 5 minutes, 1 = 5 to 10 minutes, 2 = 10 to 20 minutes, 3 = 20 to 30 minutes, and 4 = 30 minutes to 1 hour

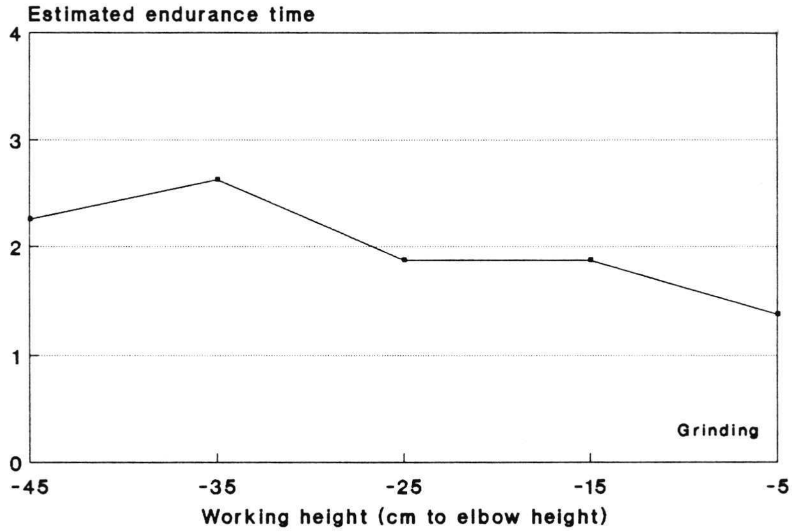


Figure 5.47 Grinding. Average group scores for local postural discomfort of the whole body, neck, left shoulder/arm, and right shoulder/arm in relation to working height (relative to elbow height). Positive and negative scores reflect the amount of increase and decrease in postural discomfort during the time of operation, respectively

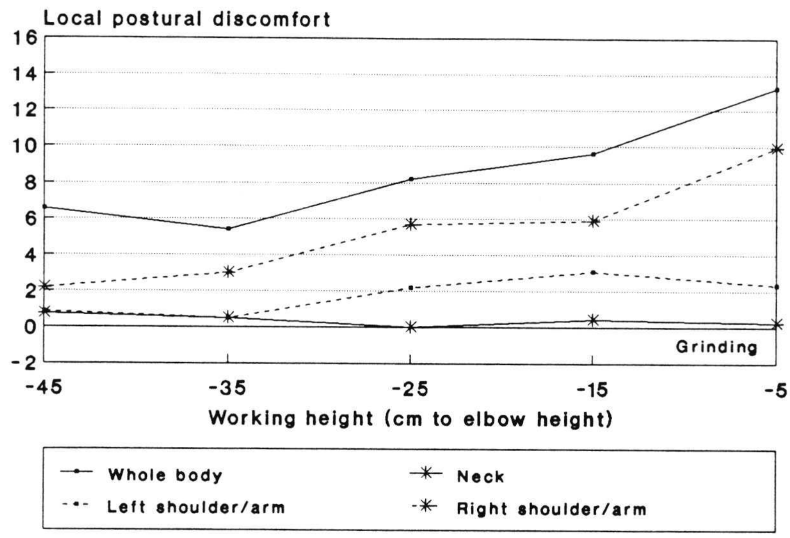
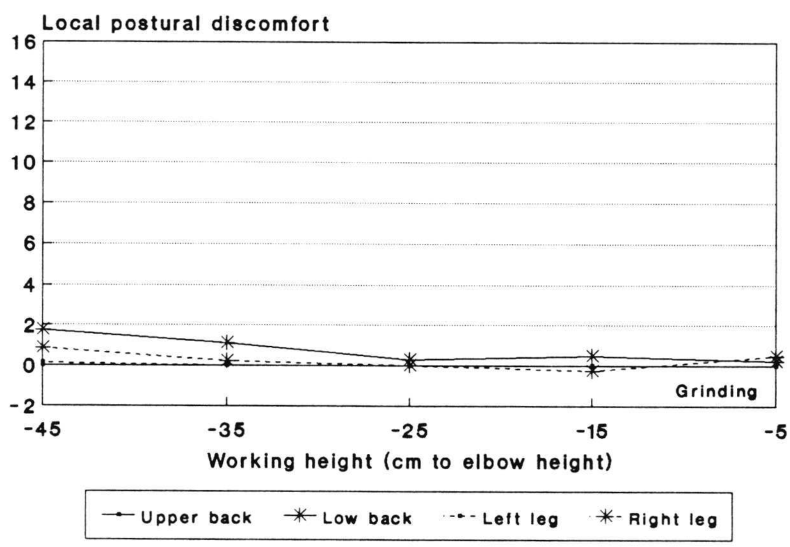


Figure 5.48 Grinding. Average group scores for local postural discomfort of the upper back, low back, left leg, and right leg in relation to working height (relative to elbow height). Positive and negative scores reflect the amount of increase and decrease in postural discomfort during the time of operation, respectively

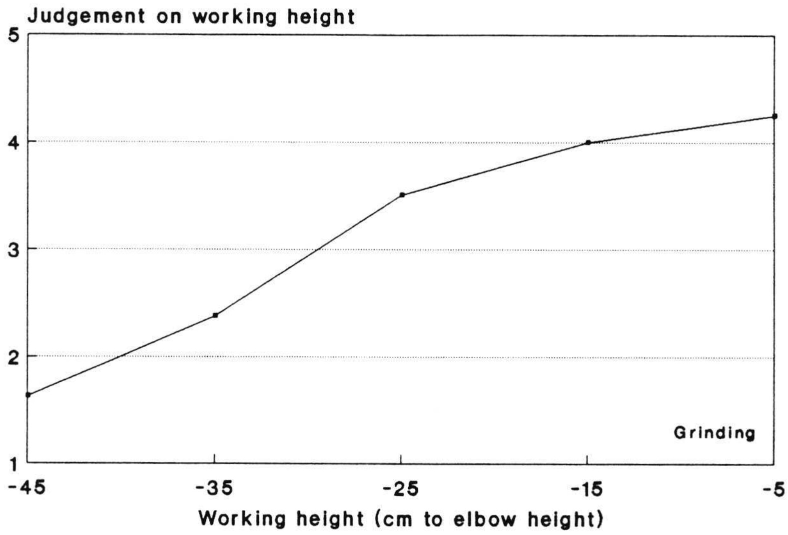


D. Judgement on working height

Figure 5.50 shows the effect of the working height on judgement on working height. The scores for working height -35 and -25 cm were closest to score 3 ('right'). The judgement of working height -35 cm tended to 'a little too low'. The judgement for working height -25 cm tended to 'a little too high'. Judgement 'right' fell between working heights -25 and -35 cm.

The score for <u>working height -45 cm</u> differed significantly from the score for working height -35 cm. The score for <u>working height -5 cm</u> differed significantly from the score for working height -25 cm.
The score for working height -15 cm differed not significantly from the score for working height -25 cm (p=.07).

<u>Figure 5.50</u> Grinding. Average group scores for judgement on working height in relation to working height (relative to elbow height). 1 = much too low, 2 = a little too low, 3 = right, 4 = a little too high, and 5 = much too high



Formulation of guideline

Results on posture reveal that during grinding the trunk gets more inclined with lower work surfaces at a slow rate till working height -35 cm is reached. For working heights below -35 cm inclination is increased at a higher rate. The inclination of the head/trunk related to working height shows the same pattern as for the trunk. This results into a nearly constant inclination of the head relative to the trunk for all experimental working heights. For higher work surfaces in particular the right upper arm is elevated increasingly. The left upper arm shows this elevation only in a minor way, while both elbows show increased flexion. Furthermore, it seems that the right wrist gets into an extreme position (flexion) at working heights -25 cm and higher.

The perceived posture and local postural discomfort with respect to almost all body parts studied are involved in the process of finding an optimum working height for oxy-gas cutting. The subjective experiences, related to the (relative) posture of specific body segments, depend on working height.
Working height -45 cm showed a judgement between qualifications 'a little too low' and 'much too low', which is worse than working height -35 cm that was also judged (slightly) too low, but closer to the qualification 'right'. The postural discomfort for the right shoulder/arm on this height was lower than for all other working heights. Therefore, it must be concluded that, though not statistically significant, the worse scores on perceived posture and local postural discomfort for the (low) back as compared to working height -35 cm have most influence on the judgement on working height. This conclusion is supported by the steeper increase in inclination of the trunk at working heights below -35 cm as compared to higher work surfaces.
Working height -5 cm caused unfavourable posture for the right wrist and forearm. This can be explained by the right grip/wrist angle that apparently reached a maximum. Observations from video-tapes show that the wrist is extremely flexed.
Postural discomfort from the whole body is higher for this working height as compared to its optimum working height. Postural discomfort at this highest experimental work surface is determined mainly by postural discomfort of the right shoulder/arm complex. The postural discomfort for the right shoulder/arm

for this height is higher than for its optimum working height. Apart from the right wrist posture, this can be explained by the steeper increase in right upper arm elevation for working heights above -15 cm as compared to lower work surfaces.
Working heights -25 and -15 cm caused unfavourable posture for the right wrist. As for working height -5 cm this can be explained by the fact that the right grip/wrist angle apparently is close to or in an extreme flexion position. Right grip/wrist angles are higher for working heights equal to and above -25 cm. These angles only get less below this height. Postural discomfort of the right shoulder/arm for both heights is higher than for their optimum height. Postural discomfort of the left shoulder/arm for working height -15 cm is higher than for its optimum height. Working height -25 cm showed a judgement close to qualification 'right', which is better than qualifications for working heights -15 (close to significance) and -5 cm. Both were judged as 'a little too high'.

Working height -35 cm caused the most favourable posture for the right and left shoulder/arm complex. It may seem a problem for work height recommendation that the posture for the neck and back is most favourable at working heights -25 cm or higher than -25 cm respectively, rather than at -35 cm. For the trunk this is even substantiated by the results on trunk inclination. However, a working height -25 cm (instead of -35 cm) would be more unfavourable for the right forearm and the right wrist, than a working height -35 cm (instead of -25 cm) would be for the neck and back. In concordance with this reasoning working height -35 cm showed lowest postural discomfort for the whole body. Furthermore, though not statistically significant, working height -35 showed longest estimated endurance time.

The results discussed above lead to the conclusion that a working height 35 cm below elbow height, i.e. approximately knuckle height for the average population*, is recommended. Figure 5.51 visualizes this guideline.

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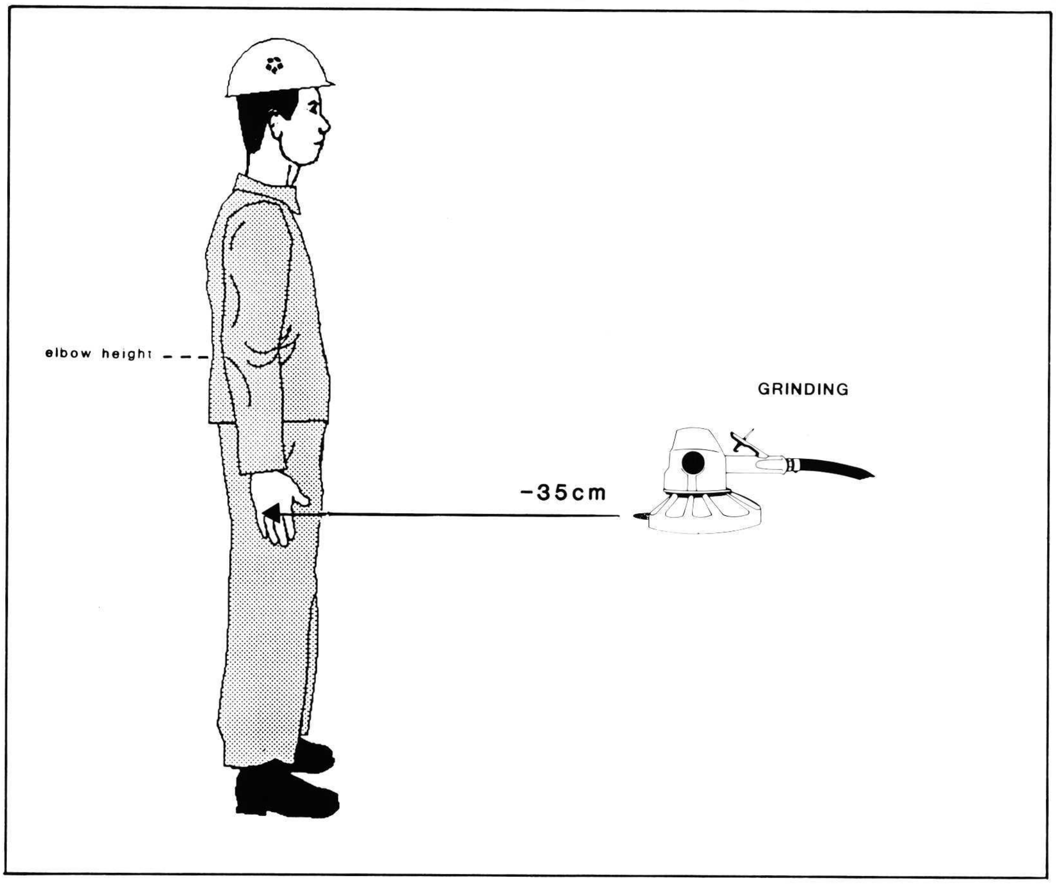
* Based on data for the Dutch population (Molenbroek, 1986).

Figure 5.51 Recommended working height for grinding



5.5 Discussion

The research approach chosen turned out to be valuable and successful. For all three operations studied supportive and non-conflicting information was obtained from posture and subjective experiences. For example, at oxy-gas cutting the posture of the right upper arm gets increasingly more unfavourable with increasing working height. However, the right upper arm is not elevated more against gravity. These results conflict and are not supportive. Detailed study of postural data revealed that the trunk - right upper arm angle increases with increasing working height. It is very likely that this increasing angle poses a burden on the shoulder structures, and causes an unfavourable right upper arm posture. Furthermore, at grinding a detailed posture study revealed that the unfavourable right wrist posture and accompanying postural discomfort most probably are caused by an extreme right grip/wrist angle.

In this study guidelines on optimum working height for operations pneumatic wrenching, oxy-gas cutting, and grinding were formulated. Three remarks related to the future use of these guidelines have to be made.

In general the three operations studied are executed standing at the same workbench. Optimum working heights for the operations, object heights, and workers' body height all show moderate to large variation. This means that an optimum working height during task execution can solely be created by height adjustable workbenches (or other height adjustable means). For the three operations studied working height should be adjustable to 35 cm below elbow height of the smallest employee*; this minimum height for adjustment should be reduced by the maximum height of the maintenance objects operated upon. Furthermore, the working height should adjustable to 10 cm above the elbow height of the largest employee**.
In case pneumatic wrenching, oxy-gas cutting, and grinding are executed at separate workbenches, these should be adjustable to -10, -10, and -35 cm***, respectively, relative to elbow height of the smallest employee; of course, this minimum height for adjustment should be reduced by the maximum height of the maintenance objects operated upon. For pneumatic wrenching, oxy-gas cutting, and grinding, the maximum adjustable working height should be +10, +10, and -35 cm, respectively, relative to elbow height of the largest employee****.

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* For the Dutch population equal to about 65 cm (5th percentile) (Molenbroek, 1986).

** For the Dutch population equal to about 130 cm (95th percentile) (Molenbroek, 1986).

*** For the Dutch population equal to about 90, 90, and 65 cm, respectively (5th percentile) (Molenbroek, 1986).

**** For the Dutch population equal to about 130, 130, and 85 cm, respectively (95th percentile) (Molenbroek, 1986).

The guidelines on optimum working heights apply for tools and operations such as present in the experiments. The experimental tools used are seen most often during maintenance work in the steel industry. Application of guidelines for tools that deviate from the experimental tools with respect to size and shape as well as for non-intended use of tools should be dealt with carefully.

The process of implementation of height adjustable workbenches (or other means) should be given special attention. Management and employees have to informed on the introduction and intended use. This holds for current as well as for new personnel. To guarantee actual use of height-adjustable workbenches, a systematic approach should be followed (Urlings et al., 1990).

Next to remarks above on the future use of these guidelines, it is recommended to start research on optimum tool characteristics (shape, weight) for various operations. The present study offers already insight into tool handling for pneumatic wrenching, oxy-gas cutting, and grinding. A similar research approach can be used for optimum tool (re-)design.

5.6 Conclusions

1. For pneumatic wrenching a working height between 10 cm below and 10 cm above elbow height is recommended, while a working height of 5 to 10 cm below elbow height is to be preferred.

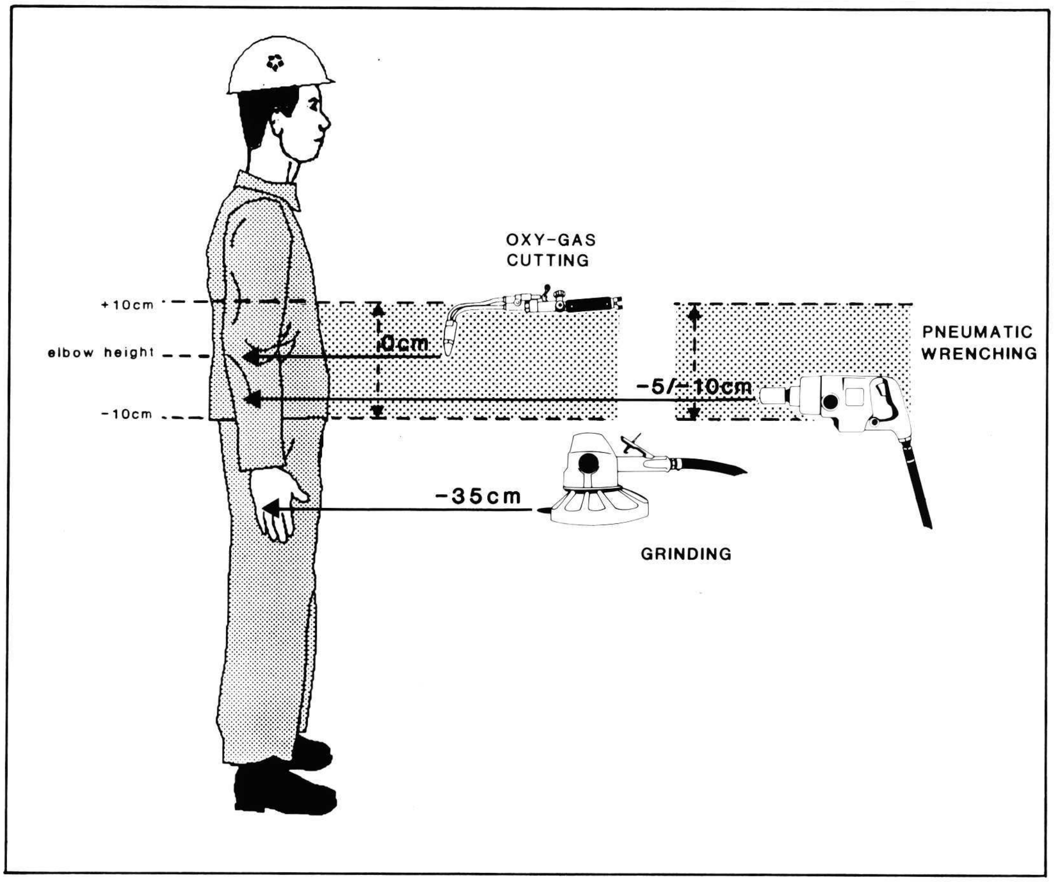
2. For oxy-gas cutting a strong preference exists for a working height on elbow height, while a working height range between 10 cm below and 10 cm above elbow height is recommended.

3. For grinding a working height 35 cm below elbow height, i.e. approximately knuckle height for average males, is recommended.

4. Height adjustable means to create an optimum working height fast and easy during execution of maintenance tasks at workbenches are essential and indispensable.

Figures 5.52 visualizes the conclusions 1, 2, and 3.

Figure 5.52 Recommended working height ranged and preferred working heights for pneumatic wrenching and for oxy-gas cutting. Recommended working height for grinding



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6. CONCLUSIONS AND RECOMMENDATIONS*

The research approach with four phases as presented in this report turned out to be feasible and useful. In the health survey (phase 1, chapter 2), maintenance tasks which were 'high risk' for the musculoskeletal system could de identified using a questionnaire filled in by the workers. For the work load survey (phase 2, chapter 3), existing observation data from Hoogovens could be used to get insight in the 'heaviness' of tasks. In phase 3 (chapter 4), relevant work variables within high risk and heavy tasks were selected by observations at the workplace and interviews with workers and management. In the last phase (chapter 5), for three specific maintenance task operations ergonomic guidelines could be developed by using both 'objective' and 'subjective' measurements of musculoskeletal load (posture and subjective experiences).

The basis for the successful execution of this research approach was a good co-operation, during all phases of the research, between the TNO researchers, the workers and management of the maintenance departments involved, and the research project leader at Hoogovens.

It is important that the tasks for which ergonomic guidelines will be developed are selected on the basis of **both** a health survey **and** a work load survey. In a health survey high risk tasks can be missed, due to the "healthy worker effect". On the other hand, high risks could be missed by the work load survey because the risks cannot be observed.

From the health survey it turned out that in all maintenance departments workers had a very heterogeneous set of tasks. Only 20 out of 76 tasks which were performed by more than 15 workers could therefore be analyzed in more detail.

It should be emphasized that the ergonomic guidelines for the selected high risk, heavy maintenance operations were formulated on basis of short term work load effects (posture and subjective experiences). Although it is generally accepted that these short term effects are related to long term effects such as health complaints, sick leave and disability, this relationship has not yet been shown.

In future research for the development of ergonomic guidelines, it might be considered to extent the research activities of phase 3. A new phase 3 could con-

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sist of a specific study for all 'high risk' or 'heavy' tasks as identified in the health survey and the work load survey. In such study the tasks are observed, and workers and management are interviewed. This should result not only in a selection of 'heavy' task operations (possibly responsible for the observed musculoskeletal problems from the health survey and/or the 'heaviness' of the tasks as identified in the work load survey) but also in possible (ergonomic) improvements. These improvements could be classified into three categories:

1. a valid solution is available and ready for implementation,
2. a solution is in principle available but further tests on the validity are needed (see phase 4 in the present approach), and
3. solution has to be developed.

If valid ergonomic guidelines are available, the next step is to implement the solutions in the industry. It is generally known that such implementation in many cases is not successful. Recently a new (research) method has been developed for changing the attitudes and behaviour of management and employees to stimulate the implementation of ergonomic improvements (Urlings et al., 1990). It should be realized that, apart from (often large) research investments in the development of ergonomics improvements, research investments are also needed in implementation research.

Based on the results of the present study, the following further research activities can be formulated:

- implementation research to stimulate the application of (a selection of) the ergonomic recommendations for maintenance work, which were presented in Chapter 4 (working height during pneumatic wrenching, oxy-gas cutting, and grinding),
- development of ergonomic recommendations for other heavy aspects of maintenance work reported in Chapter 4 (in particular tool redesign)
- application of the research approach to occupational groups in the coal and steel industry, other than maintenance workers.

The scope of musculoskeletal problems, and its impact on the workers in the European coal and steel industry justify more research in these areas.

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APPENDICES

page

Appendix I

Questionnaire on health and work at the Technical Department of Hoogovens (in Dutch) 125

Appendix II

Medical Task Analysis (MAT) of maintenance tasks at Hoogovens 157

Appendix III

Additional work site and task observation 163

Appendix IV

Questionnaire on subjective experiences (in Dutch) 167

APPENDIX I

Questionnaire on health and work
at the Technical Department of Hoogovens
(in Dutch)

afdelingscode: W11000		
TNOcode:		k010711
<u>funktienummer:</u>		k011216

VRAGENLIJST OVER

GEZONDHEID EN WERK

bij de Technische Dienst van Hoogovens

Nederlands Instituut voor Praeventieve Gezondheidszorg TNO
Onderzoeksgroep Bewegingsapparaat
Leiden 1989

DE VERTROUWELIJKHEID VAN DE DOOR U VERSTREKTE GEGEVENS

Uw antwoorden worden strikt vertrouwelijk behandeld. Alleen het onderzoeksinstituut TNO krijgt inzage daarin; geen enkele funktionaris van Hoogovens krijgt toegang tot deze gegevens zonder uw toestemming. In het TNO-rapport over dit onderzoek zijn uw gegevens niet herkenbaar.

Na afloop van het onderzoek wordt deze vragenlijst door TNO vernietigd. Als u er echter prijs op stelt dat uw vragenlijst wordt toegevoegd aan uw persoonlijk medisch dossier, dan kunt u dat hieronder opgeven.

Om ook het ziekteverzuim te kunnen analyseren in samenhang met de gegevens die met deze vragenlijst worden verzameld, vragen wij u hieronder uw personeelsnummer op te geven. De reden om ook ziekteverzuim te analyseren is dat ook deze gegevens aanwijzingen kunnen opleveren over ongunstige arbeidssituaties die verbeterd moeten worden. Ook hierbij zullen uw individuele gegevens vertrouwelijk blijven en in het rapport niet herkenbaar zijn.

Als u anoniem wilt blijven, vult u uw personeelsnummer niet in.

Wat is uw personeelsnummer ?	....	k011722

Alleen als u onderstaande vraag met 'ja' beantwoordt wordt de lijst na verwerking naar uw bedrijfsarts gestuurd (dit kan overigens alleen als u ook uw personeelsnummer hebt ingevuld!); in alle andere gevallen wordt uw vragenlijst op het onderzoeksinstituut na verwerking vernietigd.

Stelt u het op prijs dat deze vragenlijst na verwerking bij TNO wordt toegevoegd aan uw BGD-dossier? *Zo nee, dan wordt de vragenlijst na verwerking door TNO vernietigd.*	ja ( )1 nee ( )2	k0123

LEES DIT EERST:

Dit onderzoek gaat over úw werk en úw gezondheid.
Naast een aantal algemene vragen, bevat deze lijst dan ook een groot aantal vragen over deze twee onderwerpen: uw werk en uw gezondheid.
Waarom we over deze onderwerpen veel willen weten, is uitgelegd in de brief die u al eerder is uitgereikt.

Wij willen u vragen deze vragenlijst zo goed mogelijk in te vullen.
Als u de vragen op uw gemak beantwoordt, zult u ongeveer drie kwartier nodig hebben.
De meeste antwoorden kunt u eenvoudig met ja of nee beantwoorden. Het is niet de bedoeling dat u lang over elke vraag gaat nadenken.
Kruis steeds het best passende antwoord aan. Probeer zo goed mogelijk alle vragen te beantwoorden.

VOORBEELD HOE IN TE VULLEN:	
Heeft u nogal eens last van hoofdpijn?	*ja (X)1 nee ( )2*
Zo ja: Hoe vaak per week?	*0-5 keer ( )1*
	6-10 keer ( )2
	meer dan 10 keer ( )3

Als u nogal eens last heeft van hoofdpijn, zet dan een kruisje zoals in dit voorbeeld aangegeven en beantwoordt dan ook de vervolg-vraag. Als u niet nogal eens hoofdpijn heeft, kruist u 'nee' aan en kunt u de vervolg-vraag overslaan. Twijfelt u, probeer dan toch te kiezen voor die mogelijkheid die het dichtst bij de werkelijkheid komt. Kruis nooit zowel 'ja' als 'nee' aan of iets ertussen in; dan kan uw antwoord niet meer verwerkt worden!

Alvast hartelijk dank voor uw medewerking!

Er volgen nu een aantal algemene vragen; daarna vragen over uw werk en tenslotte vragen over uw gezondheid.
Lees eerst de toelichting op de vorige pagina voor u gaat invullen!

ALGEMENE VRAGEN

1. Wat is uw geboortedatum ?	.. .. 19.. dag maand jaar	k012429
2. Bent u man of vrouw?	man ( )1 vrouw ( )2	k0130
3. Uit hoeveel personen bestaat uw gezin/huishouden?	.. personen	k013132
4. Welke nationaliteit heeft U ?	Nederlandse ( )1 Spaanse ( )2 Turkse ( )3 andere, ( )4 namelijk:	k0133
5. Welk onderwijs heeft u <u>afgemaakt</u> ? *(u mag meerdere mogelijkheden aankruisen)*		
- lagere school	( )1	k0134
- lager beroepsonderwijs, lagere technische school	( )1	k0135
- MAVO,(M)ULO, 3-jarige HBS	( )1	k0136
- Hoogovens Bedrijfsschool	( )1	k0137
- middelbaar beroepsonderwijs, middelbare technische school	( )1	k0138
- HAVO, HBS, Atheneum, gymnasium	( )1	k0139
- hoger beroepsonderwijs, hogere technische school	( )1	k0140
- ander, namelijk:	( )1	k0141
6. Wat is uw lichaamslengte?	(ongeveer) ... cm	k014244
7. Wat is uw lichaamsgewicht?	(ongeveer) ... kg	k014547
8. Bent u rechts- of linkshandig?	rechtshandig ( )1 linkshandig ( )2	k0148

VRAGEN OVER UW WERK (1)

1. Hoeveel jaar doet u uw huidige werk al? .. jaar k014950

2. Heeft u vroeger ander werk gedaan in dit bedrijf ? ja ( )1 nee ( )2 k0151

Zo ja - wat voor werk ?

.... k0152

- hoelang? .. jaar k015354

3. Heeft u vroeger ander werk gedaan in een ander bedrijf ? ja ( )1 nee ( )2 k0155

Zo ja - wat voor werk ?

.... k0156

- hoelang? .. jaar k015758

4. Welk dienstrooster heeft u normaal ?

- dagdienst ( )1
- 2-ploegendienst ( )2
- 3-ploegendienst ( )3 k0159
- 4-ploegendienst ( )4
- 5-ploegendienst ( )5
- anders, namelijk .... ( )6

5. Hoeveel minuten bent u gemiddeld onderweg van uw woning naar uw werk (enkele reis)? ... minuten k016062

6. Krijgt u een uitkering wegens arbeidsongeschiktheid? ja ( )1 nee ( )2 k0163

Zo ja - voor welk percentage?

- minder dan 25% ( )1 k0164
- 25%-50% ( )2
- meer dan 50% ( )3

VRAGEN OVER UW WERK (2)

1. Hieronder ziet u een lijst van taken die op uw afdeling voorkomen. Wilt u al de taken aankruisen die u af en toe, vrij veel of overwegend uitvoert ?

	af en toe	vrij veel	overwegend	
1. Werkzaamheden OBD CWO:				
- slopen	( )1	( )2	( )3	k0250
- metselen	( )1	( )2	( )3	k0251
- spuiten	( )1	( )2	( )3	k0252
- storten	( )1	( )2	( )3	k0253
2. Werkzaamheden OBD centraal:				
- slopen	( )1	( )2	( )3	k0254
- metselen	( )1	( )2	( )3	k0255
- spuiten	( )1	( )2	( )3	k0256
- storten	( )1	( )2	( )3	k0257
- tegelen	( )1	( )2	( )3	k0258
3. Pannenonderhoud OX1:				
- slopen	( )1	( )2	( )3	k0259
- metselen	( )1	( )2	( )3	k0260
- spuiten	( )1	( )2	( )3	k0261
- storten	( )1	( )2	( )3	k0262
4. Pannenonderhoud OX2:				
- slopen	( )1	( )2	( )3	k0263
- metselen	( )1	( )2	( )3	k0264
- spuiten	( )1	( )2	( )3	k0265
- storten	( )1	( )2	( )3	k0266
5. Verdeelbakreparatie OX1/2:				
- slopen	( )1	( )2	( )3	k0267
- spuiten	( )1	( )2	( )3	k0268
6. Werkzaamheden Convecter OX1:				
- slopen	( )1	( )2	( )3	k0269
- metselen	( )1	( )2	( )3	k0270
- spuiten	( )1	( )2	( )3	k0271
7. Werkzaamheden Convecter OX2:				
- slopen	( )1	( )2	( )3	k0272
- metselen	( )1	( )2	( )3	k0273
- spuiten	( )1	( )2	( )3	k0274

+5x

2. Zijn de omstandigheden waaronder u deze taken moet uitvoeren steeds gelijk of wisselend?

steeds gelijk ( )1
enigzins wisselend ( )2 k0477
sterk wisselend ( )3

3. Als uw taken <u>niet</u> in bovenstaande lijst genoemd zijn, wat voor soort werk doet u dan gewoonlijk?

- kantoorwerk ( )1 k0478
- toezicht houden in fabriek, werkplaats etc ( )1 k0479
- anders, namelijk .... ( )1 k0480

4. Hieronder ziet u opnieuw de lijst van taken die op uw afdeling voorkomen. Wilt u nu bij iedere taak die u wel eens doet het getal in de rij omcirkelen dat het beste weergeeft hoe zwaar u die taak voor uzelf vindt (licht, normaal, zwaar of erg zwaar) ?

de taak is voor mij:

	licht	.	nor-maal	.	zwaar	.	erg zwaar	
	1	2	3	4	5	6	7	
1. Werkzaamheden OBD CWO:								
- slopen	1	2	3	4	5	6	7	k0550
- metselen	1	2	3	4	5	6	7	k0551
- spuiten	1	2	3	4	5	6	7	k0552
- storten	1	2	3	4	5	6	7	k0553
2. Werkzaamheden OBD centraal:								
- slopen	1	2	3	4	5	6	7	k0554
- metselen	1	2	3	4	5	6	7	k0555
- spuiten	1	2	3	4	5	6	7	k0556
- storten	1	2	3	4	5	6	7	k0557
- tegelen	1	2	3	4	5	6	7	k0558
3. Pannenonderhoud OX1:								
- slopen	1	2	3	4	5	6	7	k0559
- metselen	1	2	3	4	5	6	7	k0560
- spuiten	1	2	3	4	5	6	7	k0561
- storten	1	2	3	4	5	6	7	k0562
4. Pannenonderhoud OX2:								
- slopen	1	2	3	4	5	6	7	k0563
- metselen	1	2	3	4	5	6	7	k0564
- spuiten	1	2	3	4	5	6	7	k0565
- storten	1	2	3	4	5	6	7	k0566
5. Verdeelbakreparatie OX1/2:								
- slopen	1	2	3	4	5	6	7	k0567
- spuiten	1	2	3	4	5	6	7	k0568
6. Werkzaamheden Convecter OX1:								
- slopen	1	2	3	4	5	6	7	k0569
- metselen	1	2	3	4	5	6	7	k0570
- spuiten	1	2	3	4	5	6	7	k0571
7. Werkzaamheden Convecter OX2:								
- slopen	1	2	3	4	5	6	7	k0572
- metselen	1	2	3	4	5	6	7	k0573
- spuiten	1	2	3	4	5	6	7	k0574

+5x

5. Ieder werk kent 'zware' klussen. Wilt u hieronder opschrijven
- welke zware klussen er in úw werk zijn
- bij welke taak die horen en
- welke suggesties u heeft om ze te verbeteren ?

taaknr:	soort klus:	hoe te verbeteren:	
......	....	....	k0780
......	....	....	
......	....	....	

VRAGEN OVER UW WERK (3)
Hieronder volgt een aantal vragen over allerlei houdingen en bewegingen die van invloed kunnen zijn op uw gezondheid; het gaat erom hoe vaak die houdingen en bewegingen in úw werksituatie voorkomen. Kruis steeds het meest passende antwoord aan!

1a. Doet u werk waarbij u vaak (dat wil zeggen meer dan 15 keer per uur) moet **bukken**?		
af en toe of nooit	( )1	k0812
niet dagelijks, maar wel regelmatig	( )2	
iedere dag, minder dan de helft van de dag	( )3	
iedere dag, meer dan de helft van de dag	( )4	
1b. Heeft u moeite met **bukken**?	ja ( )1 nee ( )2	k0813
2a. Doet u werk waarbij u vaak (dat wil zeggen meer dan 15 keer per uur) moet **draaien met de rug**?		
af en toe of nooit	( )1	k0814
niet dagelijks, maar wel regelmatig	( )2	
iedere dag, minder dan de helft van de dag	( )3	
iedere dag, meer dan de helft van de dag	( )4	
2b. Heeft u moeite met **draaien** van de rug?	ja ( )1 nee ( )2	k0815
3a. Doet u werk waarbij u vaak (dat wil zeggen meer dan 15 keer per uur) moet **bukken met gedraaide rug**?		
af en toe of nooit	( )1	k0816
niet dagelijks, maar wel regelmatig	( )2	
iedere dag, minder dan de helft van de dag	( )3	
iedere dag, meer dan de helft van de dag	( )4	
3b. Heeft u moeite met **bukken met gedraaide rug**?	ja ( )1 nee ( )2	k0817
4a. Doet u werk waarbij u de **rug** minuten lang **voorovergebogen** moet houden?		
af en toe of nooit	( )1	k0818
niet dagelijks, maar wel regelmatig	( )2	
iedere dag, minder dan de helft van de dag	( )3	
iedere dag, meer dan de helft van de dag	( )4	
4b. Heeft u moeite met een **voorovergebogen houding van de rug**?	ja ( )1 nee ( )2	k0819

5a. Doet u **werk waarbij** u de **rug** minuten lang **gedraaid** moet houden?

af en toe of nooit	( )1	k0820
niet dagelijks, maar wel regelmatig	( )2	
iedere dag, minder dan de helft van de dag	( )3	
iedere dag, meer dan de helft van de dag	( )4	

5b. Heeft u moeite met het **gedraaid houden van de rug**? ja ( )1 nee ( )2 k0821

6a. Doet u werk waarbij u vaak (dat wil zeggen meer dan 15 keer per uur) moet **tillen of sjouwen**?

af en toe of nooit	( )1	k0822
niet dagelijks, maar wel regelmatig	( )2	
iedere dag, minder dan de helft van de dag	( )3	
iedere dag, meer dan de helft van de dag	( )4	

6b. Heeft u moeite met **tillen of sjouwen**? ja ( )1 nee ( )2 k0823

6c. Heeft u **werk** waarbij u zeer zware lasten (meer dan **40 kg**) moet tillen of sjouwen?

zelden of nooit	( )1	
soms	( )2	k0824
vaak	( )3	

6d. *De rest van deze vraag hoeft u alleen in te vullen als u dagelijks moet tillen of sjouwen:*

- hoeveel keer per dag tilt u lasten lichter dan **10 kg**?

minder dan 10 keer	( )1	k0825
tussen 10 en 25 keer	( )2	
tussen 25 en 50 keer	( )3	
meer dan 50 keer	( )4	

- **hoeveel keer per dag tilt u lasten tussen de 10-25 kg?**

minder dan 10 keer	( )1	k0826
tussen 10 en 25 keer	( )2	
tussen 25 en 50 keer	( )3	
meer dan 50 keer	( )4	

- **hoeveel keer per dag tilt u lasten zwaarder dan 25 kg?**

minder dan 10 keer	( )1	k0827
tussen 10 en 25 keer	( )2	
tussen 25 en 50 keer	( )3	
meer dan 50 keer	( )4	

De volgende vragen bestaan vaak uit meerdere onderdelen;
LET OP DAT U GEEN VRAGEN OVERSLAAT!

7. Moet u tijdens uw werk vaak lang achtereen:			
- staan?	ja ( )1	nee ( )2	k0828
- zitten?	ja ( )1	nee ( )2	k0829
- lopen?	ja ( )1	nee ( )2	k0830
8. Moet u tijdens uw werk vaak lang achtereen:			
- gebukt werken?	ja ( )1	nee ( )2	k0831
- geknield of gehurkt werken?	ja ( )1	nee ( )2	k0832
- draaiende bewegingen maken met uw handen of armen?	ja ( )1	nee ( )2	k0833
9. Moet u tijdens uw werk vaak lang achtereen uw armen:			
- tot <u>onder</u> de schouders geheven houden?	ja ( )1	nee ( )2	k0834
- tot <u>boven</u> de schouders geheven houden?	ja ( )1	nee ( )2	k0835
10. Moet u in het werk vaak:			
- de nek <u>buigen</u>?	ja ( )1	nee ( )2	k0836
- de nek naar opzij of naar achteren <u>draaien</u>?	ja ( )1	nee ( )2	k0837
- de nek lang achtereen <u>voorovergebogen</u> houden?	ja ( )1	nee ( )2	k0838
- de nek lang achtereen naar opzij of naar achteren <u>gedraaid</u> houden?	ja ( )1	nee ( )2	k0839
11. Moet u in het werk vaak:			
- de pols <u>buigen</u>?	ja ( )1	nee ( )2	k0840
- de pols <u>draaien</u>?	ja ( )1	nee ( )2	k0841
- de pols lang achtereen <u>gebogen</u> houden?	ja ( )1	nee ( )2	k0842
- de pols lang achtereen <u>gedraaid</u> houden?	ja ( )1	nee ( )2	k0843
12. Moet u tijdens uw werk vaak ver reiken met uw handen of armen?	ja ( )1	nee ( )2	k0844
13. Moet u tijdens uw werk vaak zware lasten duwen of trekken?	ja ( )1	nee ( )2	k0845
14. Moet u vaak grote kracht uitoefenen op gereedschappen ?	ja ( )1	nee ( )2	k0846
15. Heeft u in het werk te maken met duidelijk voelbare mechanische trillingen of schokken?	ja ( )1	nee ( )2	k0847

16. - Moet u vaak plotselinge, onverwachte bewegingen maken?	ja ( )1	nee ( )2	k0848
- Komt het voor dat u tijdens uw werk uitglijdt of valt?	ja ( )1	nee ( )2	k0849
- Moet u vaak korte, maar maximale krachtsinspanningen leveren?	ja ( )1	nee ( )2	k0850
17. Heeft u in uw werk te maken met:			
- tocht, wind	ja ( )1	nee ( )2	k0851
- kou	ja ( )1	nee ( )2	k0852
- warmte	ja ( )1	nee ( )2	k0853
- temperatuurswisselingen	ja ( )1	nee ( )2	k0854
- vochtige lucht	ja ( )1	nee ( )2	k0855
18. - Moet u vaak in ongemakkelijke houdingen werken?	ja ( )1	nee ( )2	k0856
- Moet u zich vaak in allerlei bochten wringen om uw werk te kunnen doen ?	ja ( )1	nee ( )2	k0857
- Heeft u in het algemeen voldoende ruimte om u heen om uw werk goed te kunnen doen?	ja ( )1	nee ( )2	k0858
- Heeft u in het algemeen goed zicht met uw ogen op uw werk ?	ja ( )1	nee ( )2	k0859
19. - Heeft u vaak te weinig beenruimte om uw werk goed te kunnen doen?	ja ( )1	nee ( )2	k0860
- Kunt u vaak niet goed kracht zetten omdat u in een ongunstige houding moet werken?	ja ( )1	nee ( )2	k0861
- Kunt u vaak weinig steun vinden tijdens het uitvoeren van werkzaamheden?	ja ( )1	nee ( )2	k0862
- Heeft u vaak moeite uw evenwicht te bewaren tijdens het uitvoeren van werkzaamheden?	ja ( )1	nee ( )2	k0863
20. - Kunt u met uw gereedschap in het algemeen overal goed bij?	ja ( )1	nee ( )2	k0864
21. - Is uw gereedschap soms niet goed geschikt om uw werk naar behoren uit te voeren?	ja ( )1	nee ( )2	k0865

Zo ja

- welk gereedschap is niet geschikt?
- heeft u suggesties hoe dit te verbeteren?

soort gereedschap:	**hoe te verbeteren:**	
....	....	k0866
....	....	
....	....	

VRAGEN OVER UW WERK (4)

Tot slot van de vragen over uw werk nog een aantal meer algemene vragen over werkomstandigheden die van invloed kunnen zijn op uw gezondheid. Kruis steeds het meest passende antwoord aan.
LET ER WEER OP DAT U GEEN VRAGEN OVERSLAAT!

1. Is uw werk lichamelijk erg inspannend?	ja ( )1	nee ( )2	k0912
2. Is uw werk geestelijk erg inspannend?	ja ( )1	nee ( )2	k0913
3. - Ligt het tempo of de drukte van het werk geregeld behoorlijk hoog?	ja ( )1	nee ( )2	k0914
- Werkt u geregeld onder tijdsdruk?	ja ( )1	nee ( )2	k0915
- Moet u geregeld jagen om op tijd klaar te zijn?	ja ( )1	nee ( )2	k0916
4. - Heeft u geregeld problemen met het tempo of de drukte van het werk?	ja ( )1	nee ( )2	k0917
- Zou u het in het werk eigenlijk kalmer aan moeten doen?	ja ( )1	nee ( )2	k0918
- Is het werk voor u vaak te vermoeiend?	ja ( )1	nee ( )2	k0919
- Heeft u voldoende aan de gewone rustpauzes?	ja ( )1	nee ( )2	k0920
5. Moet u in het werk vaak:			
- ingespannen kijken?	ja ( )1	nee ( )2	k0921
- scherp luisteren?	ja ( )1	nee ( )2	k0922
- veel onthouden?	ja ( )1	nee ( )2	k0923
- erg gekoncentreerd bezig zijn?	ja ( )1	nee ( )2	k0924
- erg nauwkeurig werk doen?	ja ( )1	nee ( )2	k0925
6. Heeft u in het werk veel hinder van:			
- lawaai?	ja ( )1	nee ( )2	k0926
- gebrek aan frisse lucht?	ja ( )1	nee ( )2	k0927
- droge lucht?	ja ( )1	nee ( )2	k0928
- wisseling van temperatuur?	ja ( )1	nee ( )2	k0929
- stank?	ja ( )1	nee ( )2	k0930
- hitte?	ja ( )1	nee ( )2	k0931
7. - Is uw werk meestal boeiend?	ja ( )1	nee ( )2	k0932
- Heeft u in uw werk voldoende afwisseling?	ja ( )1	nee ( )2	k0933
- Vindt u het werk te eenvoudig?	ja ( )1	nee ( )2	k0934
- Heeft u voor dit werk genoeg scholing?	ja ( )1	nee ( )2	k0935
- Heeft u meestal plezier in uw werk?	ja ( )1	nee ( )2	k0936

8. - Heeft u in uw werk voldoende zelfstandigheid?	ja ( )1	nee ( )2	k0937
- Kunt u uw werk zelf indelen?	ja ( )1	nee ( )2	k0938
- Kunt u uw werktempo zelf beïnvloeden?	ja ( )1	nee ( )2	k0939
- Kunt u op ieder moment als u dat nodig vindt even het werk onderbreken?	ja ( )1	nee ( )2	k0940
- Heeft u tijdens het werk voldoende kontakten met anderen?	ja ( )1	nee ( )2	k0941
9. - Wordt uw werk vaak belemmerd door onverwachte situaties?	ja ( )1	nee ( )2	k0942
- Is uw werk doorgaans goed georganiseerd?	ja ( )1	nee ( )2	k0943
- Kunt u voldoende overleggen over uw werk?	ja ( )1	nee ( )2	k0944
- Wordt uw werk vaak bemoeilijkt door afwezigheid van anderen?	ja ( )1	nee ( )2	k0945
- Wordt u in het werk geregeld gehinderd door gebreken in het werk van anderen?	ja ( )1	nee ( )2	k0946
10. - Werkt u onder goede dagelijkse leiding?	ja ( )1	nee ( )2	k0947
- Ergert u zich vaak aan anderen op het werk?	ja ( )1	nee ( )2	k0948
- Houdt de dagelijkse leiding voldoende rekening met wat u zegt?	ja ( )1	nee ( )2	k0949
- Vindt u de onderlinge sfeer op het werk goed?	ja ( )1	nee ( )2	k0950
- Heeft de dagelijkse leiding een juist beeld van u in uw werk?	ja ( )1	nee ( )2	k0951
11. - Zijn er omstandigheden in het werk die een ongunstige invloed hebben op uw privé-leven?	ja ( )1	nee ( )2	k0952
- Vindt u dat het in orde is met de veiligheid in uw werk?	ja ( )1	nee ( )2	k0953
- Zijn uw vooruitzichten bij deze werkgever goed?	ja ( )1	nee ( )2	k0954
- Voelt u zich in dit bedrijf voldoende gewaardeerd?	ja ( )1	nee ( )2	k0955
- Vindt u uw beloning in overeenstemming met het werk dat u doet?	ja ( )1	nee ( )2	k0956
12. Al met al, vindt u nu zelf dat u goed, redelijk, matig of niet goed zit met uw werk?	goed ( )1 redelijk ( )2 matig ( )3 niet goed ( )4		k0957

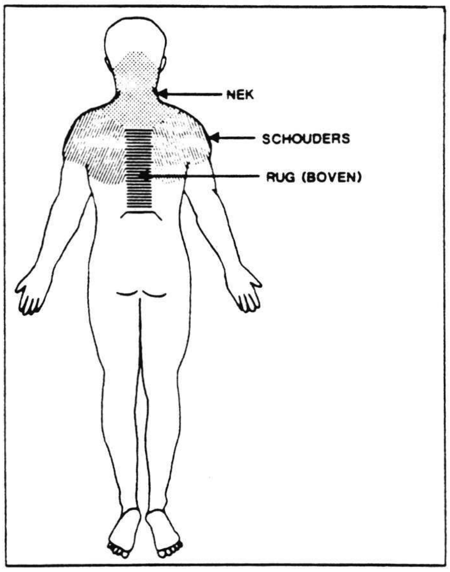
VRAGEN OVER UW GEZONDHEID

Op de volgende pagina's staan vragen over uw gezondheid. Deze zijn verdeeld in een aantal algemene vragen en een aantal vragen over eventuele klachten van rug en ledematen.
LET ER WEER OP DAT U GEEN VRAGEN OVERSLAAT!

1. Hebt u de laatste tijd gezondheidsklachten?	ja ( )1	nee ( )2	kl012
2. Bent u de afgelopen zes maanden naar de dokter geweest? (geen sportkontrole)	ja ( )1	nee ( )2	kl013
3. Bent u nu onder behandeling van een arts?	ja ( )1	nee ( )2	kl014
4. Bent u de afgelopen zes maanden wel eens van uw werk thuisgebleven wegens ziekte of ongeval?	ja ( )1	nee ( )2	kl015
5. Gebruikt u geregeld medicijnen?	ja ( )1	nee ( )2	kl016
6. Rookt u?	ja ( )1	nee ( )2	kl017
7. Hoe is naar uw mening op dit moment uw lichamelijke konditie?	goed ( )1 redelijk ( )2 matig ( )3 slecht ( )4		kl018
8. - Heeft u geregeld hoofdpijn?	ja ( )1	nee ( )2	kl019
- Heeft u regelmatig klachten in de maagstreek?	ja ( )1	nee ( )2	kl020
- Heeft u regelmatig buikpijn?	ja ( )1	nee ( )2	kl021
- Heeft u nogal eens last van benauwdheid of kortademigheid?	ja ( )1	nee ( )2	kl022
9. - Voelt u zich vaak gespannen?	ja ( )1	nee ( )2	kl023
- Bent u vaak nerveus?	ja ( )1	nee ( )2	kl024
- Voelt u zich vaak gejaagd?	ja ( )1	nee ( )2	kl025
- Bent u na het werk vaak erg moe?	ja ( )1	nee ( )2	kl026
- Bent u vaak moedeloos?	ja ( )1	nee ( )2	kl027
- Staat u geregeld moe op?	ja ( )1	nee ( )2	kl028

10.- Hebt u last van slapeloosheid of slaapt u onrustig?	ja ( )1	nee ( )2	k1029
- Wordt u geplaagd door zenuwachtigheid, gejaagdheid of gespannenheid?	ja ( )1	nee ( )2	k1030
- Hebt u 's-morgens moeite met opstaan?	ja ( )1	nee ( )2	k1031
- Hebt u last van zwetende handen zodat ze klam en vochtig aanvoelen?	ja ( )1	nee ( )2	k1032
- Bent u wel eens kortademig zonder dat u zich inspant of hard werkt?	ja ( )1	nee ( )2	k1033
- Hebt u last van hartkloppingen?	ja ( )1	nee ( )2	k1034
- Voelt u zich in het algemeen gezond genoeg om de dingen te doen die u graag zou doen?	ja ( )1	nee ( )2	k1035
- Heeft u het gevoel last te hebben van allerlei pijntjes en kwaaltjes op verschillende plaatsen in uw lichaam?	ja ( )1	nee ( )2	k1036
11. Heeft u regelmatig pijn of stijfheid in de **bovenste ledematen**?	ja ( )1	nee ( )2	k1037
Zo ja: - schouder?	ja ( )1	nee ( )2	k1038
- bovenarm?	ja ( )1	nee ( )2	k1039
- elleboog?	ja ( )1	nee ( )2	k1040
- onderarm?	ja ( )1	nee ( )2	k1041
- pols?	ja ( )1	nee ( )2	k1042
- hand of vingers?	ja ( )1	nee ( )2	k1043
12. Heeft u regelmatig pijn of stijfheid in de **onderste ledematen**?	ja ( )1	nee ( )2	k1044
Zo ja: - heup?	ja ( )1	nee ( )2	k1045
- bovenbeen?	ja ( )1	nee ( )2	k1046
- knie?	ja ( )1	nee ( )2	k1047
- onderbeen?	ja ( )1	nee ( )2	k1048
- enkel?	ja ( )1	nee ( )2	k1049
- voet of tenen?	ja ( )1	nee ( )2	k1050
13. **Heeft u nogal eens last van rugpijn?**	ja ( )1	nee ( )2	k1051
Zo ja - boven in de rug?	ja ( )1	nee ( )2	k1052
- onder in de rug?	ja ( )1	nee ( )2	k1053

Aangezien klachten van nek, rug en ledematen zoveel voorkomen, gaan we op de volgende pagina's wat dieper in op eventuele klachten die u daarover heeft. Op het figuurtje is steeds de plaats van die lichaamsdelen aangegeven.



1. **Heeft u <u>ooit</u> last (pijn, ongemak) gehad van uw <u>nek</u>?** ja ( )1 nee ( )2 kl112

   Zo ja

   Heeft u de afgelopen <u>12 maanden</u> last gehad? ja ( )1 nee ( )2 kl113

   Heeft u de afgelopen <u>7 dagen</u> last gehad? ja ( )1 nee ( )2 kl114

   Heeft u vooral last bij bepaald werk? ja ( )1 nee ( )2 kl115

   <u>Zo ja</u>, - bij welk werk?

   .... kl116

   - heeft u een idee hoe dat werk is te verbeteren ?

   .... kl117

2. **Heeft u ooit last (pijn, ongemak) gehad <u>boven in uw rug</u>?** ja ( )1 nee ( )2 kl118

   Zo ja

   Heeft u de afgelopen <u>12 maanden</u> last gehad? ja ( )1 nee ( )2 kl119

   Heeft u de afgelopen <u>7 dagen</u> last gehad? ja ( )1 nee ( )2 kl120

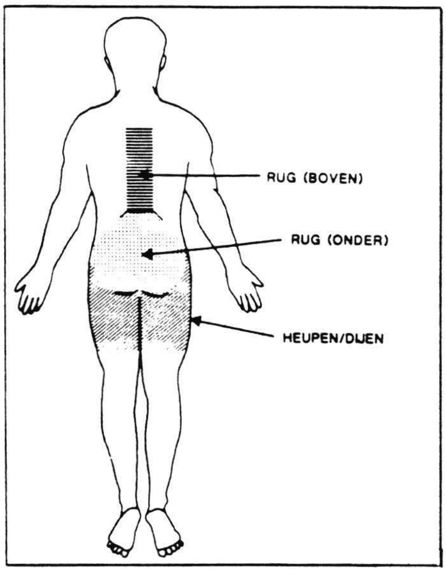
   Heeft u vooral last bij bepaald werk? ja ( )1 nee ( )2 kl121

   <u>Zo ja</u>, - bij welk werk?

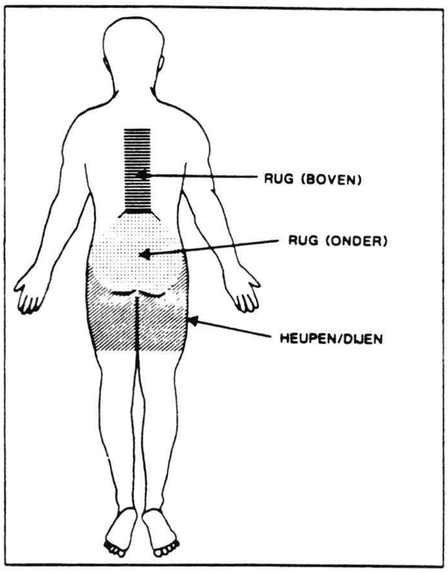
   .... kl122

   - heeft u een idee hoe dat werk is te verbeteren ?

   .... kl123



3. Heeft u ooit last (pijn, ongemak) gehad <u>onder in uw rug</u>?	ja ( )1	nee ( )2	kl124
Zo ja Heeft u de afgelopen <u>12 maanden</u> last gehad?	ja ( )1	nee ( )2	kl125
Heeft u de afgelopen <u>7 dagen</u> last gehad?	ja ( )1	nee ( )2	kl126
Heeft u <u>op dit moment</u> last?	ja ( )1	nee ( )2	kl127
Heeft u vanwege deze klachten uw aktiviteiten moeten beperken in de afgelopen 12 maanden:			
- <u>in uw werk</u>?	ja ( )1	nee ( )2	kl128
- <u>in uw vrije tijd</u>?	ja ( )1	nee ( )2	kl129
Heeft u vooral last bij bepaald werk?	ja ( )1	nee ( )2	kl130
<u>Zo ja</u>, - bij welk werk?			
....			kl131
- Heeft u een idee hoe dat werk is te verbeteren ?			
....			kl132



4. **Heeft u ooit last (pijn, ongemak) gehad van uw linkerheup of linkerdij?** ja ( )1 nee ( )2 kl133

Zo ja

Heeft u de afgelopen 12 maanden last gehad? ja ( )1 nee ( )2 kl134
Heeft u de afgelopen 7 dagen last gehad? ja ( )1 nee ( )2 kl135

Heeft u vooral last bij bepaald werk? ja ( )1 nee ( )2 kl136
Zo ja, - bij welk werk?

.... kl137

- heeft u een idee hoe dat werk is te verbeteren ?

.... kl138

5. **Heeft u ooit last (pijn, ongemak) gehad van uw rechterheup of rechterdij?** ja ( )1 nee ( )2 kl139

Zo ja

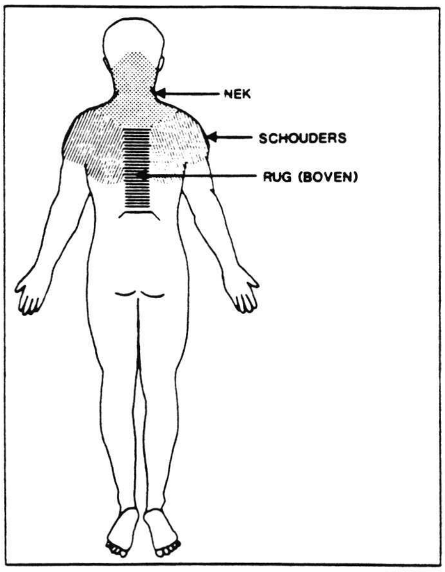
Heeft u de afgelopen 12 maanden last gehad? ja ( )1 nee ( )2 kl140
Heeft u de afgelopen 7 dagen last gehad? ja ( )1 nee ( )2 kl141

Heeft u vooral last bij bepaald werk? ja ( )1 nee ( )2 kl142
Zo ja, - bij welk werk?

.... kl143

- heeft u een idee hoe dat werk is te verbeteren ?

.... kl144



6. Heeft u ooit last (pijn, ongemak) gehad van uw linkerschouder? ja ( )1 nee ( )2 k1145

Zo ja

Heeft u de afgelopen 12 maanden last gehad? ja ( )1 nee ( )2 k1146
Heeft u de afgelopen 7 dagen last gehad? ja ( )1 nee ( )2 k1147

Heeft u vooral last bij bepaald werk? ja ( )1 nee ( )2 k1148
Zo ja, - bij welk werk?

.... k1149

- heeft u een idee hoe dat werk is te verbeteren ?

.... k1150

7. Heeft u ooit last (pijn, ongemak) gehad van uw rechterschouder? ja ( )1 nee ( )2 k1151

Zo ja

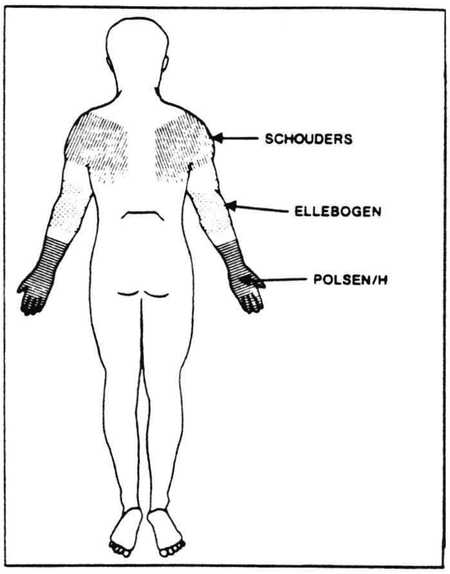
Heeft u de afgelopen 12 maanden last gehad? ja ( )1 nee ( )2 k1152
Heeft u de afgelopen 7 dagen last gehad? ja ( )1 nee ( )2 k1153

Heeft u vooral last bij bepaald werk? ja ( )1 nee ( )2 k1154
Zo ja, - bij welk werk?

.... k1155

- heeft u een idee hoe dat werk is te verbeteren ?

.... k1156

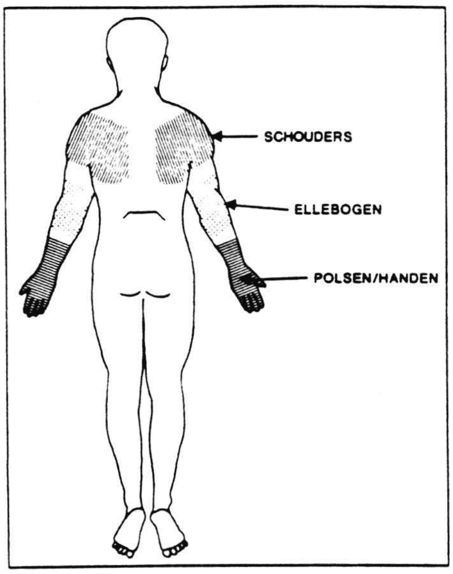


8. Heeft u ooit last (pijn, ongemak) gehad van uw linkerelleboog? **ja ( )1 nee ( )2** kl157

Zo ja	Heeft u de afgelopen 12 maanden last gehad?	ja ( )1	nee ( )2	kl158
	Heeft u de afgelopen 7 dagen last gehad?	ja ( )1	nee ( )2	kl159
	Heeft u vooral last bij bepaald werk?	ja ( )1	nee ( )2	kl160
	Zo ja, - bij welk werk?			
	....			kl161
	- heeft u een idee hoe dat werk is te verbeteren ?			
	....			kl162

9. Heeft u ooit last (pijn, ongemak) gehad van uw rechterelleboog? **ja ( )1 nee ( )2** kl163

Zo ja	**Heeft u de afgelopen 12 maanden last gehad?**	**ja ( )1**	**nee ( )2**	kl164
	Heeft u de afgelopen 7 dagen last gehad?	**ja ( )1**	**nee ( )2**	kl165
	Heeft u vooral last bij bepaald werk?	**ja ( )1**	**nee ( )2**	kl166
	Zo ja, - bij welk werk?			
	....			kl167
	- heeft u een idee hoe dat werk is te verbeteren ?			
	....			kl168



10. Heeft u ooit last (pijn, ongemak) gehad van uw <u>linkerpols of linkerhand</u>? ja ( )1 nee ( )2 kl169

Zo ja

Heeft u de afgelopen <u>12 maanden</u> last gehad? ja ( )1 nee ( )2 kl170
Heeft u de afgelopen <u>7 dagen</u> last gehad? ja ( )1 nee ( )2 kl171

Heeft u vooral last bij bepaald werk? ja ( )1 nee ( )2 kl172
<u>Zo ja</u>, - bij welk werk?

.... kl173

- heeft u een idee hoe dat werk is te verbeteren ?

.... kl174

11. Heeft u ooit last (pijn, ongemak) gehad van uw <u>rechterpols of rechterhand?</u> ja ( )1 nee ( )2 kl175

Zo ja

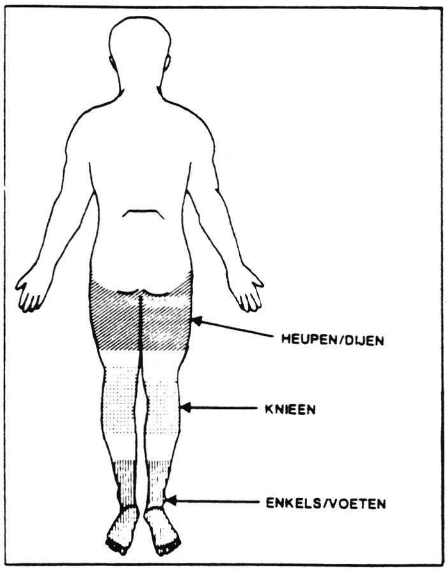
Heeft u de afgelopen <u>12 maanden</u> last gehad? ja ( )1 nee ( )2 kl176
Heeft u de afgelopen <u>7 dagen</u> last gehad? ja ( )1 nee ( )2 kl177

Heeft u vooral last bij bepaald werk? ja ( )1 nee ( )2 kl178
<u>Zo ja</u>, - bij welk werk?

.... kl179

- heeft u een idee hoe dat werk is te verbeteren ?

.... kl180



12. Heeft u ooit last (pijn, ongemak) gehad van uw linkerknie? ja ( )1 nee ( )2 kl212

Zo ja

Heeft u de afgelopen 12 maanden last gehad? ja ( )1 nee ( )2 kl213
Heeft u de afgelopen 7 dagen last gehad? ja ( )1 nee ( )2 kl214

Heeft u vooral last bij bepaald werk? ja ( )1 nee ( )2 kl215
Zo ja, - bij welk werk?

.... kl216

- heeft u een idee hoe dat werk is te verbeteren ?

.... kl217

13. Heeft u ooit last (pijn, ongemak) gehad van uw rechterknie? ja ( )1 nee ( )2 kl218

Zo ja

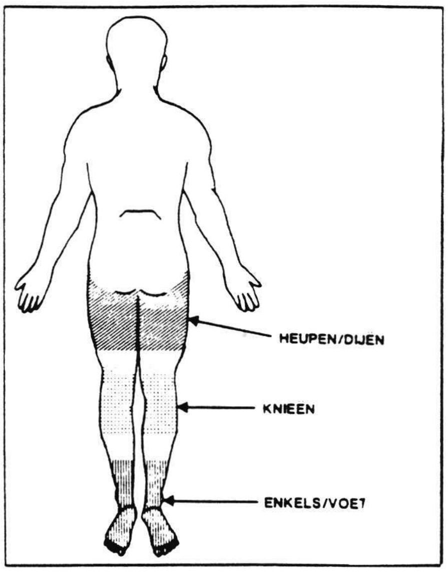
Heeft u de afgelopen 12 maanden last gehad? ja ( )1 nee ( )2 kl219
Heeft u de afgelopen 7 dagen last gehad? ja ( )1 nee ( )2 kl220

Heeft u vooral last bij bepaald werk? ja ( )1 nee ( )2 kl221
Zo ja, - bij welk werk?

.... kl222

- heeft u een idee hoe dat werk is te verbeteren ?

.... kl223



14. **Heeft u ooit last (pijn, ongemak) gehad van uw linker enkel of voet?** ja ( )1 nee ( )2 kl224

Zo ja				
	Heeft u de afgelopen 12 maanden last gehad?	ja ( )1	nee ( )2	kl225
	Heeft u de afgelopen 7 dagen last gehad?	ja ( )1	nee ( )2	kl226
	Heeft u vooral last bij bepaald werk?	ja ( )1	nee ( )2	kl227

Zo ja, - bij welk werk?

.... kl228

- heeft u een idee hoe dat werk is te verbeteren ?

.... kl229

15. **Heeft u ooit last (pijn, ongemak) gehad van uw rechter enkel of voet?** ja ( )1 nee ( )2 kl230

Zo ja				
	Heeft u de afgelopen 12 maanden last gehad?	ja ( )1	nee ( )2	kl231
	Heeft u de afgelopen 7 dagen last gehad?	ja ( )1	nee ( )2	kl232
	Heeft u vooral last bij bepaald werk?	ja ( )1	nee ( )2	kl233

Zo ja, - bij welk werk?

.... kl234

- heeft u een idee hoe dat werk is te verbeteren ?

.... kl235

15. Bent of wordt u **behandeld** wegens:

- spit, hernia of andere rugaandoeningen?	ja ( )1	nee ( )2	kl236
- nekaandoeningen?	ja ( )1	nee ( )2	kl237
- schouderaandoeningen?	ja ( )1	nee ( )2	kl238
- elleboogaandoeningen?	ja ( )1	nee ( )2	kl239
- aandoeningen van pols of hand?	ja ( )1	nee ( )2	kl240
- knie-aandoeningen?	ja ( )1	nee ( )2	kl241
- aandoeningen van enkel of voet?	ja ( )1	nee ( )2	kl242
- andere spier- of gewrichtsaandoeningen?	ja ( )1	nee ( )2	kl243

16. **Heeft u gezondheidsklachten waarvan u denkt dat ze door het werk komen?** ja ( )1 nee ( )2 kl244

Zo ja **Welke gezondheidsklachten en met welke handelingen hebben deze te maken?**

gezondheidsprobleem: **te maken met:**

1) ....

2) kl245

3) ....

17. Beoefent u **lichamelijk inspannende sport(en)?** ja ( )1 nee ( )2 kl246

Zo ja - hoeveel uur gemiddeld per **week?** .. uur per week kl124748

- welke sport(en)? kl249

....

18. Heeft u andere **lichamelijk inspannende aktiviteiten in uw vrije tijd?** ja ( )1 nee ( )2 kl250

Zo ja - hoeveel uur gemiddeld per week? .. uur per **week** kl125152

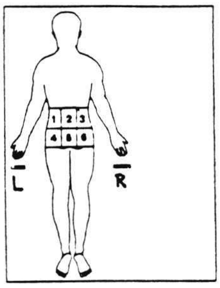
- **welke aktiviteiten?** kl253

....

Op de nu volgende pagina's volgen nog enige extra vragen over <u>klachten onder in de rug</u>. Als u <u>nooit</u> klachten onder in de rug hebt gehad, kunt u deze pagina's overslaan.

De vragen op deze pagina zijn alleen bestemd voor personen die ooit klachten onder in de rug hebben gehad.

1. Wilt u het gebied aankruisen waar op de onderstaande tekening uw klachten precies zitten/zaten? *(Kruis het getal aan van het gebied waar uw klachten zitten/zaten; zo nodig meerdere gebieden).*



1	( )1	kl312
2	( )1	kl313
3	( )1	kl314
4	( )1	kl315
5	( )1	kl316
6	( )1	kl317

2. Welke klachten heeft/had u van uw rug? *(U mag meerdere klachten aankruisen)*

erg moe gevoel	( )1	kl318
stijf gevoel	( )2	kl319
zeurend, knagend gevoel	( )3	kl320
'doof' of 'dood' gevoel en/of tintelingen	( )4	kl321
krachtsverlies	( )5	kl322
krampen	( )6	kl323
lichte pijn	( )7	kl324
behoorlijke pijn	( )8	kl325
erge pijn	( )9	kl326

3. Is de aard van uw klachten in de loop der tijd veranderd of gelijk gebleven?

aard van mijn klachten is veranderd	( )1	kl327
aard van mijn klachten is gelijk gebleven	( )2	

4. Wisselt/wisselde de ernst van uw klachten sterk? ja ( )1 nee ( )2 kl328

5. Heeft u last (gehad) van uitstralende pijn naar de benen? ja ( )1 nee ( )2 kl329

Zo ja Tot waar straalt/straalde die pijn uit? *(u mag hier meerdere kruisjes zetten)*

tot de rechterknie	( )1	kl330
tot de rechterenkel of -voet	( )1	kl331
tot de linkerknie	( )1	kl332
tot de linkerenkel of -voet	( )1	kl333

6. Hebt u ooit bedrust moeten houden vanwege uw klachten? ja ( )1 nee ( )2 kl334

7. Blijven uw klachten in de vakanties bestaan ? ja ( )1 nee ( )2 kl335

8. Kunt u één of meer oorzaken voor uw klachten noemen?

.... kl336

De vragen op deze pagina zijn alleen bestemd voor personen die ooit klachten onder in de rug hebben gehad.

9. Begonnen uw klachten plotseling of geleidelijk?	plotseling ( )1 geleidelijk ( )2	kl337
10. Had u al last van uw rug voordat u uw huidige werkzaamheden begon?	ja ( )1 nee ( )2	kl338
11. Hoe lang achtereen duren/duurden de klachten?	enkele uren ( )1 enkele dagen ( )2 enkele weken ( )3 enkele maanden ( )4 klachten zijn (vrijwel) altijd aanwezig ( )5 duur wisselt sterk per keer ( )6	kl339
12. Hoe vaak heeft u in de afgelopen 6 maanden klachten gehad?	geen enkele keer ( )1 één keer ( )2 2-5 keer ( )3 5-10 keer ( )4 meer dan 10 keer ( )5 klachten zijn (vrijwel) altijd aanwezig ( )6	kl340
13. Wat is het totaal **aantal dagen** dat u rugklachten heeft gehad gedurende in de afgelopen 6 maanden?	geen ( )1 1-2 dagen ( )2 3-7 dagen ( )3 8-14 dagen ( )4 meer dan 14 dagen ( )5	kl341
14. Wat is het totaal **aantal dagen** in de afgelopen 6 maanden dat u door rugklachten uw gewone werk niet heeft kunnen doen, maar wel op uw werk aanwezig was?	geen ( )1 1-2 dagen ( )2 3-7 dagen ( )3 8-14 dagen ( )4 meer dan 14 dagen ( )5	kl342
15. Wat is het totaal **aantal dagen** dat u door rugklachten van uw werk heeft verzuimd in de afgelopen 6 maanden?	geen ( )1 1-2 dagen ( )2 3-7 dagen ( )3 8-14 dagen ( )4 meer dan 14 dagen ( )5	kl343
16. Hoe oud was u toen u voor het eerst last kreeg?	.. jaar	kl34445

De vragen op deze pagina zijn alleen bestemd voor personen die <u>ooit</u> klachten <u>onder in de rug</u> hebben gehad.

17. Wanneer heeft/had u vooral last?	's-ochtends ( )1	kl346
(u mag hier meerdere mogelijkheden aankruisen)	's-middags ( )1	kl347
	's-avonds ( )1	kl348
	's-nachts ( )1	kl349
18. Staat u s'ochtends meestal met een stijf gevoel op?	ja ( )1 nee ( )2	kl350
19. In welke seizoenen heeft/had u vooral last van uw rug?	voorjaar ( )1	kl351
(u mag hier meerdere seizoenen aankruisen)	zomer ( )1	kl352
	najaar ( )1	kl353
	winter ( )1	kl354
20. Zijn uw rugklachten het gevolg van:		
- uw werk?	ja ( )1 nee ( )2	kl355
- een ongeval (in of buiten uw werk)?	ja ( )1 nee ( )2	kl356
- sportbeoefening?	ja ( )1 nee ( )2	kl357
- andere bezigheden in uw vrije-tijd?	ja ( )1 nee ( )2	kl358
21. Worden uw rugklachten erger door:		
- voorover buigen	ja ( )1 nee ( )2	kl359
- achterover buigen	ja ( )1 nee ( )2	kl360
- zitten	ja ( )1 nee ( )2	kl361
- langdurig staan	ja ( )1 nee ( )2	kl362
- opstaan na lang liggen, zitten	ja ( )1 nee ( )2	kl363
- weersinvloeden (kou, vocht)	ja ( )1 nee ( )2	kl364
- gespannenheid, emoties	ja ( )1 nee ( )2	kl365
- hoesten, niezen, persen	ja ( )1 nee ( )2	kl366
- andere zaken, namelijk:	ja ( )1 nee ( )2	kl367
1.		
2.		

De vragen op deze pagina zijn alleen bestemd voor personen die ooit klachten onder in de rug hebben gehad.

22. Hieronder ziet u opnieuw de lijst van taken die op uw afdeling voorkomen. Wilt u nu bij iedere taak het getal omcirkelen dat het beste weergeeft hoe zwaar u die taak voor uw rug vindt.

	licht	.	nor-maal	.	zwaar	.	erg zwaar	
	1	2	3	4	5	6	7	
1. Werkzaamheden OBD CWO:								
- slopen	1	2	3	4	5	6	7	kl450
- metselen	1	2	3	4	5	6	7	kl451
- spuiten	1	2	3	4	5	6	7	kl452
- storten	1	2	3	4	5	6	7	kl453
2. Werkzaamheden OBD centraal:								
- slopen	1	2	3	4	5	6	7	kl454
- metselen	1	2	3	4	5	6	7	kl455
- spuiten	1	2	3	4	5	6	7	kl456
- storten	1	2	3	4	5	6	7	kl457
- tegelen	1	2	3	4	5	6	7	kl458
3. Pannenonderhoud OX1:								
- slopen	1	2	3	4	5	6	7	kl459
- metselen	1	2	3	4	5	6	7	kl460
- spuiten	1	2	3	4	5	6	7	kl461
- storten	1	2	3	4	5	6	7	kl462
4. Pannenonderhoud OX2:								
- slopen	1	2	3	4	5	6	7	kl463
- metselen	1	2	3	4	5	6	7	kl464
- spuiten	1	2	3	4	5	6	7	kl465
- storten	1	2	3	4	5	6	7	kl466
5. Verdeelbakreparatie OX1/2:								
- slopen	1	2	3	4	5	6	7	kl467
- spuiten	1	2	3	4	5	6	7	kl468
6. Werkzaamheden Convecter OX1:								
- slopen	1	2	3	4	5	6	7	kl469
- metselen	1	2	3	4	5	6	7	kl470
- spuiten	1	2	3	4	5	6	7	kl471
7. Werkzaamheden Convecter OX2:								
- slopen	1	2	3	4	5	6	7	kl472
- metselen	1	2	3	4	5	6	7	kl473
- spuiten	1	2	3	4	5	6	7	kl474

+5x

U bent nu klaar met het invullen van de vragenlijst.

Wilt u controleren of u geen vragen of pagina's heeft overgeslagen?

U kunt de vragenlijst daarna in bijgeleverde enveloppe doen en de enveloppe dichtplakken.

Hartelijk dank voor uw medewerking.

APPENDIX II

Medical Task Analysis (MAT) of maintenance tasks at Hoogovens

Table II.1-II.5 show MTT classes for all CARSHOB-systems of all maintenance tasks for CW (table II.1), MOB (table II.2), WO (table II.3), OB (table II.4) and EWS (table II.5).

Table II.1 Numbers and names of the tasks at the CW-department, and their MTT classes for the CARSHOB-systems

task number	task name	MTT classes C A R S H O B
1325	machine bankwerken	3 3 5 6 6 7 4
1326	reparatie hydrauliek en pneumatiek	1 0 3 4 6 5 3
1327	testen hydrauliek en pneumatiek	1 0 3 2 6 8 3
1328	pompen reparatie	1 1 3 4 6 2 3
1332	werkzaamheden schoonmaakmachine	1 1 3 2 7 8 3
1338	kraandrijven A kranen	0 2 3 0 2 7 0
1339	kraandrijven B kranen	0 2 3 0 2 7 0
1340	kraandrijven C kranen	0 1 3 0 2 7 0
1364	controle versporing/machine bankwerken	0 0 2 1 3 4 2
1365	controle constructie werkplaats	2 3 2 2 3 7 3
1372	zagen	1 0 3 2 6 8 2
1374	branden automatisch	1 1 2 2 3 8 2
1376	aftekenen	0 0 3 2 3 8 2
1377	knippen	0 0 3 2 3 8 2
1378	zetten	0 0 3 2 3 8 2
1379	walsen	1 0 2 2 3 8 2
1380	richten	1 1 3 2 3 8 2
1381	constructie bankwerken algemeen	2 1 4 5 6 8 4
1382	constructie bankwerken zwaar	2 3 5 6 6 8 5
1383	constructie bankwerken wagons	3 3 5 7 3 8 5
1384	lassen lasbox	2 1 4 5 3 8 4
1385	lassen machinaal	2 1 3 5 3 8 2
1386	lassen werkplaatsen	3 3 5 6 3 8 5
1387	gereedschapbeheer	0 0 1 2 3 2 1

Table II.2 Numbers and names of the tasks at the MOB-department, and their MTT classes for the CARSHOB-systems

task number	task name	MTT classes C A R S H O B
1410	onderhoud bankwerken RZD	5 6 5 8 6 5 6
1411	onderhoud bankwerken RCN	3 3 5 5 6 8 5
1412	branden werkplaats RZD	1 0 2 2 3 2 2
1413	werkzaamheden werkplaats RZD	1 0 3 4 3 5 3
1414	kwaliteitslassen RZD	3 3 4 4 3 5 4
1416	transport Bandinspectie/algemene werkzaamheden RZD	1 3 1 2 3 5 3
1417	vulcaniseren	4 5 6 7 3 5 6
2334	best. unimog. vulcaniseerd. RZD	1 2 3 3 3 4 1
2595	onderhoud pompen/motoren	2 2 5 5 6 8 5
2596	draaien RZD	0 - 3 2 6 4 2
1420	onderhoud bankwerken RND	4 5 5 6 6 8 6
1421	onderhoud smeersysteem RND	2 2 4 4 7 8 5
1422	onderhoud pompen/ventilator RND	4 4 5 8 7 8 6
1423	werkzaamheden werkplaats RND	1 0 4 5 3 5 3
1424	kwalilteit lassen RND	3 4 4 4 3 8 4
2600	werkzaamheden buispost/sprinklers RND	2 2 1 2 3 8 2
1425	kwaliteit lassen RCV	3 3 4 5 3 5 4
1426	pijpbewerken algemeen	4 5 6 7 6 5 6
1427	pijpbewerken/P.O.ketels	5 4 5 7 6 8 5
1429	werkzaamheden werkplaats RCV	1 0 4 5 3 5 3
1433	algemene werkzaamheden smeerdienst	2 3 3 3 7 5 3

Table II.3 Numbers and names of the tasks at the WO-department, and their MTT classes for the CARSHOB-systems

task number	task name	MTT classes C A R S H O B
1470	bankwerken storingsdienst	0 0 2 2 6 4 2
1471	lassen	1 1 3 2 3 7 3
1472	steunwals ombouw	2 1 5 7 3 7 4
1473	werkwalsombouw	1 0 3 4 3 4 3
1474	walsentransport	1 1 1 2 3 4 1
1475	walsen slijpen	0 0 1 3 5 4 1
1476	walsen draaien	0 0 1 3 2 7 1
1477	onderhoud bankwerken	1 0 3 4 7 8 3
1478	walsen ruwen	1 2 2 3 3 4 2
1482	kraandrijven	0 1 3 0 2 4 0
1483	rubberrollen slijpen	0 1 1 2 3 4 1
1484	rond en vlakslijpen	1 0 1 2 6 2 2
1485	centerdraaien	0 0 1 2 3 4 1
1486	werkzaamheden werkplaats controle	0 0 0 1 2 2 1

Table II.4 Numbers and names of the tasks at the OB-department, and their MTT classes for the CARSHOB-systems

task number	task name	MTT classes C A R S H O B
2348	onderhoud werkzaamheden materiaalwerkplaats	0 0 2 2 5 5 2
2349	werkzaamheden betonwerkplaats	1 1 4 5 5 5 3
2350	werkzaamheden CWO	1 3 3 4 7 5 3
2351	werkzaamheden algemeen	4 5 4 6 7 5 4
2362	menger spuiten CWO	2 2 4 5 3 8 3
2364	pannenonderhoud OX1/OX2	2 2 4 4 6 7 4
2369	verdeelbak.spuiten OX1/OX2	1 1 3 3 6 5 1

Table II.5 Numbers and names of the tasks at the EWS-department, and their MTT classes for the CARSHOB-systems

task number	task name	MTT classes C A R S H O B
1980	demontage- en montagewerkzaamheden	1 0 4 4 7 5 3
1981	wikkelen	1 0 3 2 5 4 3
1982	schoonmaak motoren	3 3 5 5 7 8 5
1983	verfspuitwerkzaamheden	1 2 4 5 7 5 5
1984	balanceren/zagen	1 1 4 5 2 4 3
1985	werkzaamheden proefveld	0 0 2 1 3 5 1
1986	werkzaamheden buitenploeg	4 4 6 6 8 5 6
1987	transportwerkzaamheden	2 2 2 4 3 2 2
1988	werkzaamheden koppelingenveld	2 1 4 4 6 8 3
1989	draaien	1 0 3 2 6 4 2

APPENDIX III

Additional work site and task observation

'Onderhoud Bankwerken RZD'

The employees execute 90 to 95 percent of their task on blast-furnaces, locations for iron-ore preparation, and cokes-plants. Every location poses different demands and asks for different approach and solutions. Operations done concern dismounting, mounting, cleaning, welding, oxy-gas cutting, and grinding. Furthermore, lifting, stair climbing, and awkward postures as well as manipulation of parts of various sizes, shapes, and weights are involved. Confined work spaces and bad visual conditions are observed.
In general, tool characteristics (shape, weight) may be improved to create a better adaptation to the required operation. Management should consider the installation of permanent maintenance facilities like scaffoldings and platforms, and creation of detachable parts of such size that they can be put on a workbench.

'Onderhoud Bankwerken RND'

In general the operations involved and possible solutions to improve working conditions in this task are identical to those seen at task 'Onderhouds Bankwerken RZD'. However, the locations for this task are rolling-mills and steel production plants.

'Werkplaatsen'

Less then 10 percent of the task can be executed at a central workplace by taking objects out of large installations as blast-furnaces, rolling-mills, etcetera. The operations required are done there on workbenches.

'Pijpbewerken Algemeen'

The task consists of prefabrication of pipe-constructions of all kinds of sizes and shapes. Operations involved are done on workbenches or on trestles.

APPENDIX IV

Questionnaire on subjective experiences (in Dutch)

VRAGENLIJST

Toelichting

- In deze vragenlijst worden vragen gesteld over het lichamelijk ongemak en soms ook over de werkhoogte.

- Tijdens de proeven wordt u een aantal keren gevraagd dit formulier in te vullen. Hierop staat het lichaam afgebeeld verdeeld in gebieden.

- Op het moment dat u het formulier krijgt wordt gevraagd aan te geven in welke gebieden van het lichaam u last (bijvoorbeeld: ongemak, pijn, etc.) heeft.

- Hoe u dat aan moet geven wordt op het formulier beschreven.

- Soms wordt u, op een tweede formulier, ook een oordeel gevraagd over de werkhoogte.

- Zoals altijd worden de gegevens door het NIPG-TNO vertrouwelijk behandeld.

- Met vragen of opmerkingen kunt u terecht bij de proefleider.

Leiden, november 1989
M.P. van der Grinten/N.J. Delleman
BEWAP
NIPG-TNO

HIER	datum	dag	taak	tijd	pnr	werkhoogte
NIET	mnd. 12	ma/di/wo	snijbr.	vo	1 2 3 4	1 2 3 4 5
INVUL-	dag. ..	do/vr	slijpen	mi	5 6 7 8	
LEN			(de-)mont.	na	9 10 11 12	

AANWIJZINGEN LINKS RECHTS

- Kijk naar de afbeelding van het lichaam dat in verschillende gebieden is verdeeld.

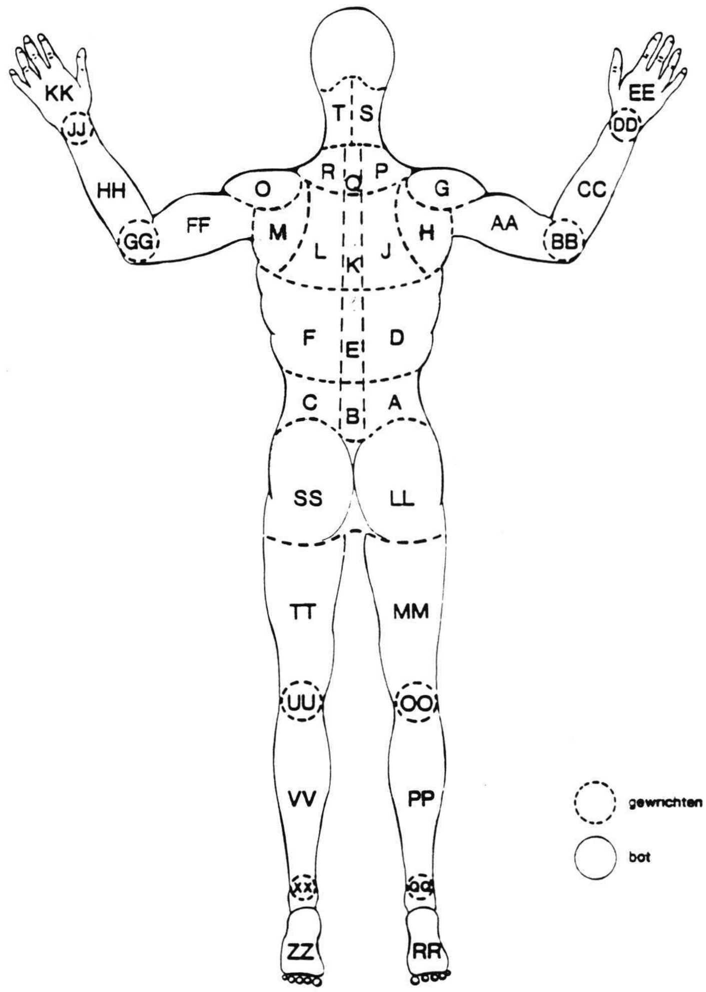
- Indien u op dit moment in één of meer van deze gebieden last (ongemak, pijn, etc.) heeft, zet dan in elk van de betreffende gebieden een getal: ½, 1, 2, 3, 4, 5, 6, 7, 8, 9 of 10 uit onderstaande schaal.

  Schaal voor de mate van last die u op dit moment ervaart:

□	= geen enkele last
½	= uitermate weinig last (net waarneembaar)
1	= zeer weinig last
2	= enige last
3	= nogal wat last
4	=
5	= veel last
6	=
7	= zeer veel last
8	=
9	=
10	= uitermate veel last (bijna maximaal)
.	= maximaal

  met dit getal geeft u aan hoeveel last u in dat gebied heeft.

- Indien u op dit moment geen enkele last heeft in een der weergegeven gebieden zet dan een kruisje in het □



	datum	dag	taak	tijd	pnr	werkhoogte
HIER NIET INVUL-LEN	mnd. 12 dag. ..	ma/di/wo do/vr	snijbr. slijpen (de-)mont.	vo mi na	1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5

AANWIJZINGEN

- Kijk naar de afbeelding van het lichaam dat in verschillende gebieden is verdeeld.

- Indien u op dit moment in één of meer van deze gebieden last (ongemak, pijn, etc.) heeft, zet dan in elk van de betreffende gebieden een getal: ½, 1, 2, 3, 4, 5, 6, 7, 8, 9 of 10 uit onderstaande schaal.

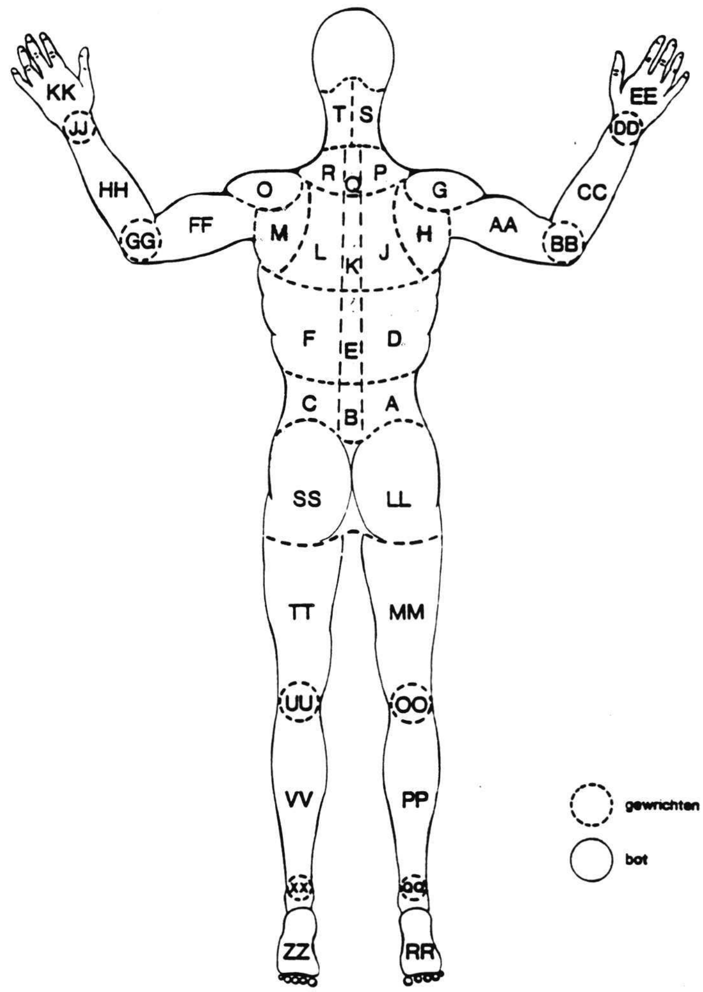
  Schaal voor de mate van last die u op dit moment ervaart:

□	= geen enkele last
½	= uitermate weinig last (net waarneembaar)
1	= zeer weinig last
2	= enige last
3	= nogal wat last
4	=
5	= veel last
6	=
7	= zeer veel last
8	=
9	=
10	= uitermate veel last (bijna maximaal)
.	= maximaal

  met dit getal geeft u aan hoeveel last u in dat gebied heeft.

- Indien u op dit moment geen enkele last heeft in een der weergegeven gebieden zet dan een kruisje in het □

LINKS RECHTS



HIER	datum	dag	taak	tijd	pnr	werkhoogte
NIET	mnd. 12	ma/di/wo	snijbr.	vo	1 2 3 4	1 2 3 4 5
INVUL-	dag. ..	do/vr	slijpen	mi	5 6 7 8	
LEN			(de-)mont.	na	9 10 11 12	

AANWIJZINGEN

- Kijk naar de afbeelding van het lichaam dat in verschillende gebieden is verdeeld.

- Indien u op dit moment in één of meer van deze gebieden last (ongemak, pijn, etc.) heeft, zet dan in elk van de betreffende gebieden een getal: ½, 1, 2, 3, 4, 5, 6, 7, 8, 9 of 10 uit onderstaande schaal.

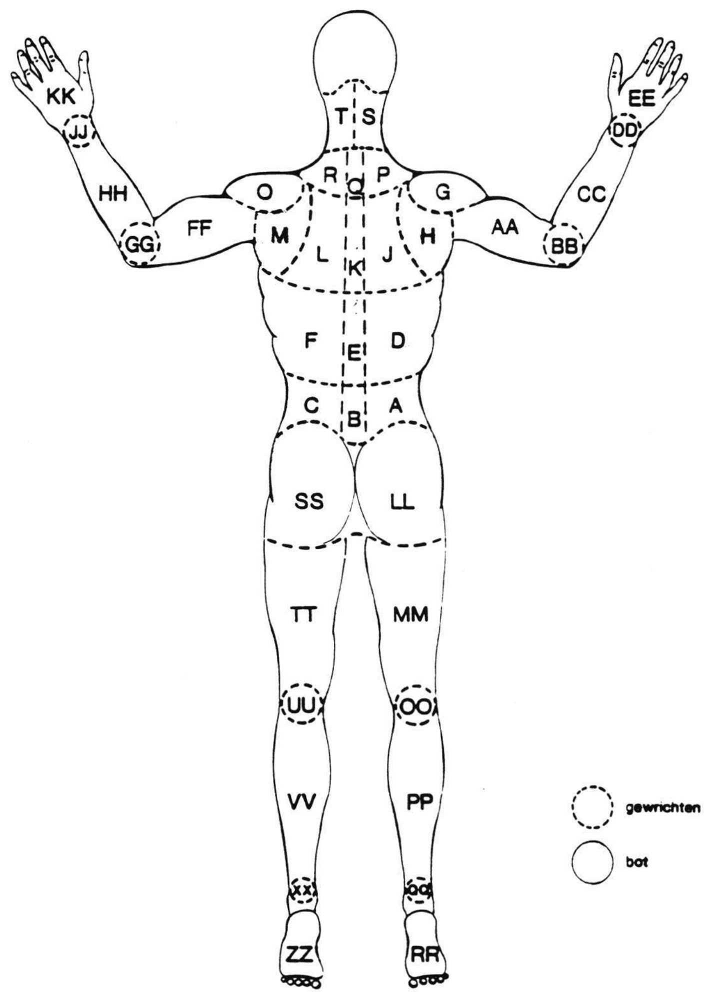
  Schaal voor de mate van last die u op dit moment ervaart:

□	= geen enkele last
½	= uitermate weinig last (net waarneembaar)
1	= zeer weinig last
2	= enige last
3	= nogal wat last
4	=
5	= veel last
6	=
7	= zeer veel last
8	=
9	=
10	= uitermate veel last (bijna maximaal)
.	= maximaal

  met dit getal geeft u aan hoeveel last u in dat gebied heeft.

- Indien u op dit moment geen enkele last heeft in een der weergegeven gebieden zet dan een kruisje in het □

LINKS RECHTS



HIER	datum	dag	taak	pnr	werkhoogte
NIET	mnd. 12	ma/di/wo	snijbr.	1 2 3 4	1 2 3 4 5
INVULLEN	dag. ..	do/vr	slijpen	5 6 7 8	
			(de-)mont.	9 10 11 12	

AANWIJZINGEN

- Op de volgende bladzijden staan enkele vragen over hoe u de werkhouding vindt bij deze werkhoogte; wilt u per lichaamsdeel één kruisje zetten achter het best passende antwoord?

* Hoe gunstig voor uzelf vindt u bij <u>deze werkhoogte</u> de stand van uw:

NEK

zeer gunstig	1	[ ]
	2	[ ]
gunstig	3	[ ]
	4	[ ]
ongunstig	5	[ ]
	6	[ ]
zeer ongunstig	7	[ ]

* Hoe gunstig voor uzelf vindt u bij deze werkhoogte de stand van uw:

RECHTERSCHOUDER	zeer gunstig	1	[ ]
		2	[ ]
	gunstig	3	[ ]
		4	[ ]
	ongunstig	5	[ ]
		6	[ ]
	zeer ongunstig	7	[ ]

* Hoe gunstig voor uzelf vindt u bij deze werkhoogte de stand van uw:

RECHTERBOVENARM	zeer gunstig	1	[ ]
		2	[ ]
	gunstig	3	[ ]
		4	[ ]
	ongunstig	5	[ ]
		6	[ ]
	zeer ongunstig	7	[ ]

* Hoe gunstig voor uzelf vindt u bij deze werkhoogte de stand van uw:

RECHTERPOLS	zeer gunstig	1	[ ]
		2	[ ]
	gunstig	3	[ ]
		4	[ ]
	ongunstig	5	[ ]
		6	[ ]
	zeer ongunstig	7	[ ]

* Hoe gunstig voor uzelf vindt u bij deze werkhoogte de stand van uw:

LINKERSCHOUDER

zeer gunstig	1	[ ]
	2	[ ]
gunstig	3	[ ]
	4	[ ]
ongunstig	5	[ ]
	6	[ ]
zeer ongunstig	7	[ ]

* Hoe gunstig voor uzelf vindt u bij deze werkhoogte de stand van uw:

LINKERBOVENARM	zeer gunstig	1	[ ]
		2	[ ]
	gunstig	3	[ ]
		4	[ ]
	ongunstig	5	[ ]
		6	[ ]
	zeer ongunstig	7	[ ]

* Hoe gunstig voor uzelf vindt u bij <u>deze werkhoogte</u> de stand van uw:

LINKERPOLS	zeer gunstig	1	[ ]
		2	[ ]
	gunstig	3	[ ]
		4	[ ]
	ongunstig	5	[ ]
		6	[ ]
	zeer ongunstig	7	[ ]

* Hoe gunstig voor uzelf vindt u bij deze werkhoogte de stand van uw:

LINKERONDERARM	zeer gunstig	1	[ ]
		2	[ ]
	gunstig	3	[ ]
		4	[ ]
	ongunstig	5	[ ]
		6	[ ]
	zeer ongunstig	7	[ ]

* Hoe gunstig voor uzelf vindt u bij deze werkhoogte de stand van uw:

RECHTERONDERARM	zeer gunstig	1	[ ]
		2	[ ]
	gunstig	3	[ ]
		4	[ ]
	ongunstig	5	[ ]
		6	[ ]
	zeer ongunstig	7	[ ]

* Hoe gunstig voor uzelf vindt u bij deze werkhoogte de stand van uw:

RUG

zeer gunstig	1	[ ]
	2	[ ]
gunstig	3	[ ]
	4	[ ]
ongunstig	5	[ ]
	6	[ ]
zeer ongunstig	7	[ ]

* Hoe gunstig voor uzelf vindt u bij deze werkhoogte de stand van uw:

RECHTERBOVENBEEN	zeer gunstig	1	[ ]
		2	[ ]
	gunstig	3	[ ]
		4	[ ]
	ongunstig	5	[ ]
		6	[ ]
	zeer ongunstig	7	[ ]

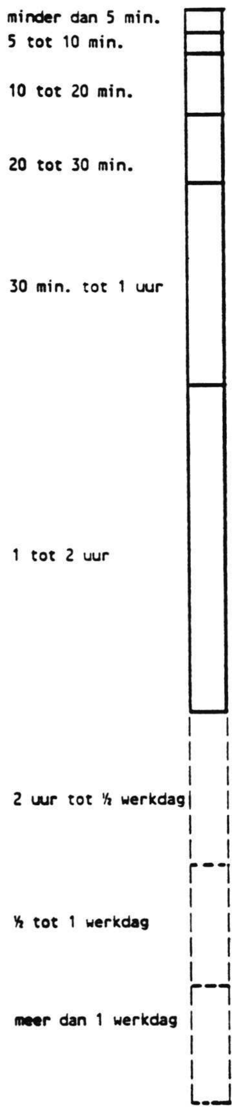
* Hoe gunstig voor uzelf vindt u bij deze werkhoogte de stand van uw:

LINKERBOVENBEEN	zeer gunstig	1	[ ]
		2	[ ]
	gunstig	3	[ ]
		4	[ ]
	ongunstig	5	[ ]
		6	[ ]
	zeer ongunstig	7	[ ]

* U heeft de taak nu gedurende .. minuten uitgevoerd.

Hoelang verwacht u uw werkhouding bij deze werkhoogte zonder moeite nog te kunnen volhouden?

Ik verwacht deze werkhouding zonder moeite nog vol te kunnen houden, gedurende:



S.v.p. één hok(je) aankruisen.

HIER	datum	dag	taak	pnr				werkhoogte				
NIET	mnd. 12	ma/di/wo	snijbr.	1	2	3	4	1	2	3	4	5
INVUL-	dag	do/vr	slijpen	5	6	7	8					
LEN			(de-mont.)	9	10	11	12					

AANWIJZINGEN

- Graag bij de volgende vraag over de werkhoogte **één antwoord aankruisen** en eventueel een toelichting geven:

  · Wat vindt U van deze werkhoogte:

  Deze werkhoogte is voor mij:

  veel te laag [ ]
  iets te laag [ ]
  goed [ ]
  iets te hoog [ ]
  veel te hoog [ ]

  Indien 'te laag' of 'te hoog', hieronder graag toelichten waarom:

  ____
  ____
  ____