Effectiveness of interventions to reduce workload in refuse collectors
Kuijer, P.P.F.M.

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Chapter 7

Epilogue
7.1 Work demands and workload in intervention studies

What can be learned from this thesis on the effect of ergonomic interventions in refuse collecting? As stated in the introduction, the ultimate aim of the ergonomic interventions studied in this thesis is to reduce musculoskeletal and fatigue complaints among refuse collectors. However, in only one study of this thesis musculoskeletal complaints were assessed as a dependent variable (chapter 6). No study assessed fatigue complaints. The latency in the development of complaints was the predominant reason for this choice. Instead, in chapters 3, 4 and 5 the efficacy was determined in terms of work demands and physical workload. The work demands in this study were mainly assessed by the time spent on activities performed. The physical workload was assessed by mechanical workload variables such as net moment at the shoulder, and energetic workload variables such as heart rate. The assumption was that dependent variables regarding work demands and physical workload are related to musculoskeletal and fatigue complaints. Consequently, the selected dependent variables for work demands and physical workload in an ergonomic intervention study aimed at reducing musculoskeletal and fatigue complaints merits some discussion. Three considerations are of primary importance.

First, if epidemiological evidence exists for a relationship between the dependent variable and the associated health complaint, an improvement in the dependent variable can be interpreted as predictive of a reduction in the associated health complaint. Unfortunately, most epidemiological studies on musculoskeletal complaints assess exposure only in terms of job title, job description or tasks performed and do not provide supplementary, quantitative information on work demands or workload. In that case, exposure to a risk factor is present or not. This information is in most cases not useful in intervention studies, because it has become impossible to evaluate when exposure (work demands or workload in terms of level, frequency, and duration) results in a positive or negative health effect. Only in the last decade, more occupational epidemiological studies have included quantitative exposure variables such as posture or compression force on the low back in relation to musculoskeletal health effects, for instance. Therefore, we should be careful when using work demands and physical workload to predict possible health effects. A reduction in work demands and physical workload does not always imply a reduction in risk. In this thesis, the interventions were mainly aimed at preventing low back, shoulder and fatigue complaints. Oxygen uptake and heart rate, related to an individual's maximum, are generally accepted as predictors of fatigue. Perceived exertion is seen as related to heart rate and muscle force, rather than loading of joints. However, to the author's knowledge there is no epidemiological evidence as to the relations between these variables and physical fatigue complaints. Some epidemiological evidence exists for trunk posture and mechanical load of the low back as predictors for risk of low back pain. For shoulder complaints,
no studies were found on the relationship between mechanical shoulder load and shoulder complaints. Although no exact postures were given, Hales and Bernard stated in their review that working at or above shoulder height can be seen as an important risk factor for shoulder disorders. On the basis of a systematic review of 29 studies, Van der Windt et al. concluded that the associations between existing occupational risk factors and shoulder pain were not strong. Although not consistent over studies, awkward postures were seen as potential risk factors. Finally, in a criteria document for evaluating the work-relatedness of upper-extremity musculoskeletal disorders, specific postures are described as one of the three physical factors that define whether a shoulder disorder might be work-related. In conclusion, there is some evidence for a relationship between on the one hand work demands and workload, and on the other hand musculoskeletal complaints of, for instance, the low back and shoulder.

Second, when epidemiological evidence is lacking or incomplete, dependent variables used should be generally accepted in scientific studies. In chapter 3, the main focus was on the effect of the number of two-wheeled containers at a gathering point on the energetic workload. Therefore, oxygen uptake and heart rate were assessed. Besides, subjective ratings of perceived exertion were used. These variables are widely used in ergonomic research. In chapter 4 on the redesign of a two-wheeled containers we applied state of the art biomechanical models of the low back and shoulder. These biomechanical models have been used previously to quantify the load on these body regions. In § 5.1 the effect of job rotation between collecting polythene bags, sweeping streets and driving a sweeping machine on back and shoulder loading was assessed by observation of trunk flexion and arm elevation. In general, observational posture data can be regarded as accurate in moderate dynamic work. There are even international standards on working postures, for instance, ISO/CD 11226. Finally, in § 5.2 the effect of job rotation between collecting two-wheeled containers and driving a refuse truck was evaluated using the excretion rate of catecholamines and cortisol. Sluiter et al. showed in their review a number of studies that used these variables. Besides dependent variables for work demands and workload, (need for) recovery was also assessed. Insufficient recovery is seen as an important intermediate variable in the onset of complaints. In a study on coach drivers, need for recovery appeared to be a powerful predictor of experienced health complaints. In § 5.2 recovery was assessed using the excretion rate of catecholamines after work. The excretion rate of these hormones after work are generally accepted as indicators of the recovery process. In chapter 6 the need for recovery was assessed using a validated scale of Van Veldhoven and Meijman.

Third, the studies described in chapter 3 and 4 were performed in a mock up. The efficacy studies presented in chapter 5 were performed in the working situation. This was done for different reasons. For the study in chapter 3 this choice was made to control for possible
confounders and for the study in chapter 4 to secure reliable data collection. In general, to 
increase the external validity of an efficacy study one should strive for measurements in the 
working situation (chapter 5). But even then, a study on efficacy, in contrast to a study on 
effectiveness, provides no information on important aspects such as compliance or unforeseen 
effects. Two examples may illustrate this. A number of refuse collecting organisations hires 
temporary personnel to collect the refuse. This temporary personnel is often unfamiliar with 
the routes or do not have a truck driver’s licence. In that case, a truck driver/refuse collector is 
not able to rotate and to comply to a rotation schema. The second example is a fictitious one. 
The ease of use of the redesigned two-wheeled container might be so great, that employees 
push and pull two two-wheeled containers instead of one. Thereby, the physical workload 
might even increase compared to the original situation with the standard two-wheeled 
container.

7.2 Intervention with the highest efficacy?
In this thesis, the efficacy of four ergonomic interventions on work demands and workload 
was studied. Of course, the question should be answered which of these interventions would 
have the highest efficacy. Despite the use of different dependent variables in the four studies, 
an educated guess can be made with the help of two of the three principle dimensions: level 
and duration. The third dimension, frequency, was not included for two reasons. First, little is 
known about the relationship between frequency of work demands or workload and health 
effects, outside the context of cyclic work. Second, frequency of work demands and workload 
were not assessed in this thesis. To clarify the differences in efficacy of the four ergonomic 
interventions, this is done for an 8-hour working day (table 1). During collecting, the increase 
in the number of two-wheeled containers at a gathering point did not result in a reduction of 
the mean level of oxygen uptake, heart rate and rated perceived exertion. As expected, the 
increase in the number of two-wheeled containers at a gathering point resulted in a decrease 
of the duration of collecting. Assuming that the remainder of the time activities are performed 
at a lower energetic workload, a positive effect of this intervention is expected on the 
dependent variables during an 8-hour working day.

The redesign of the two-wheeled container resulted in a reduction of the level of nearly all 
dependent variables during collecting, except for (peak and mean) compression force on the 
low back. It is expected that the redesigned container had no effect on duration, because the 
use of the redesigned two-wheeled container seemed not to result in a faster working 
technique. Assuming that the remainder of the time activities are performed involving a lower 
mechanical workload, a positive effect of this intervention is expected on the same dependent 
variables during an 8-hour working day.
For both types of job rotation, the dependent variables during an 8-hour working day were actually assessed. Especially job rotation between collecting bags, sweeping streets and driving a sweeping machine resulted in a positive effect on a number of dependent variables. Job rotation seemed to have no effect on the level of the dependent variables during collecting. It is expected that the positive results are due to a reduction in the duration in the time collecting.

Table 1.  (Estimated) effect of the four interventions on the dependent variables\(^1\) for work demands and physical workload of a refuse collector during an 8-hour working day (0 = no effect, + = positive effect). The complaints (musculoskeletal or fatigue) that these dependent variables are considered to be predictors of are also given.

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Study Design</th>
<th>Outcome</th>
<th>(Estimated) Effect</th>
<th>Aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of containers</td>
<td>Experimental, Mock-up</td>
<td>(\text{VO}_2)</td>
<td>+</td>
<td>Fatigue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HR</td>
<td>+</td>
<td>Fatigue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RPE</td>
<td>+</td>
<td>Fatigue</td>
</tr>
<tr>
<td>Redesign container</td>
<td>Experimental, Mock-up</td>
<td>F exerted</td>
<td>+</td>
<td>Musculoskeletal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M back</td>
<td>+</td>
<td>Musculoskeletal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M shldr</td>
<td>+</td>
<td>Musculoskeletal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fc back</td>
<td>0</td>
<td>Musculoskeletal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fc shldr</td>
<td>+</td>
<td>Musculoskeletal</td>
</tr>
<tr>
<td>Job rotation Bags</td>
<td>Experimental, Work-site</td>
<td>%HRR</td>
<td>+</td>
<td>Fatigue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Back&gt;45(^\circ)</td>
<td>+</td>
<td>Musculoskeletal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arm&gt;60(^\circ)</td>
<td>0</td>
<td>Musculoskeletal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RPE</td>
<td>+</td>
<td>Fatigue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RPF</td>
<td>+</td>
<td>Fatigue</td>
</tr>
<tr>
<td>Job rotation Containers</td>
<td>Experimental, Work-site</td>
<td>HR</td>
<td>0</td>
<td>Fatigue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% (\text{VO}<em>2)(</em>\text{max})</td>
<td>+</td>
<td>Fatigue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA</td>
<td>0</td>
<td>Fatigue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RPE</td>
<td>+</td>
<td>Fatigue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RPF</td>
<td>0</td>
<td>Fatigue</td>
</tr>
</tbody>
</table>

\(\text{VO}_2 = \) oxygen uptake, \(\text{HR} = \) heart rate, \(\text{RPE} = \) rated perceived exertion, \(\text{F exerted} = \) exerted force with the hands, \(\text{M back} = \) moment round L5/S1, \(\text{M shldr} = \) moment round glenohumeral joint, \(\text{Fc back} = \) compression force at L5/S1, \(\text{Fc shldr} = \) contact force on glenohumeral joint, \(\%\text{HRR} = \) percentage of the heart rate reserve, \(\text{back}>45\(^\circ\) = \) time flexion of the trunk is more than 45\(^\circ\), \(\text{arm}>60\(^\circ\) = \) time elevation of arm(s) is more than 60\(^\circ\), \(\text{RPF} = \) rated perceived fatigue, \(\%\text{VO}_2\text{max} = \) percentage of the maximum oxygen uptake, \(\text{NA} = \) noradrenaline excretion rate during workday

Hence, all four interventions had a positive effect on several dependent variables for work demands and physical workload during an 8-hour working day. The ultimate aim of the
ergonomic interventions studied in this thesis was to reduce the risk of musculoskeletal and fatigue complaints. Job rotation appears to have a more substantial effect on both mechanical and energetic workload variables than the other two interventions. As shown in § 5.1 and § 5.2, the time collecting decreased by about 50% and 30% in both studies on job rotation, respectively. Therefore, it is expected that job rotation is the intervention with the highest efficacy. To evaluate the effectiveness of job rotation, the study in chapter 6 was performed. Unfortunately, the results of this study remained inconclusive as to whether job rotation between collecting two-wheeled containers and truck driving is an (in)effective intervention. As mentioned in chapter 6, an explanation might be that peak and cumulative back load are independent risk factors for low back pain. In a simulation study on the effect of rotation between two tasks on the estimated risk of low back pain, Frazer et al. concluded that the effects of job rotation are not always intuitively predictable, because of the subtle effects when combining peak and cumulative load. When peak load emerges to be a more important predictor for back and shoulder complaints than cumulative load, job rotation might even be less effective than the redesign of a two-wheeled container. Therefore, a combined intervention in refuse collecting is probably most effective. When implementing a redesigned container and a job rotation scheme, the risk for musculoskeletal complaints might be reduced more than when implementing a single intervention.

7.3 Recommendations for practice

7.3.1 Refuse collecting methods studied

Most refuse collecting organisations already have implemented job rotation between collecting refuse and driving a truck. The Dutch refuse collecting guideline stimulates the implementation of job rotation by allowing a team of three rotating employees to collect more refuse during a working day than a non-rotating team. Before the introduction of the Dutch refuse collecting guideline, this intervention seemed quite unthinkable due the normal career development from collector to driver. No information is available on the implementation of job rotation between collecting bags, sweeping streets and driving a sweeping machine in other refuse collecting organisations.

Job rotation has another advantage over the other two ergonomic interventions studied, because it is probably applicable in other jobs with a high physical workload and a low socio-economic status. Moreover, in the case that job rotation involves supplementary education as seen for the truck driver’s licence, it has a direct effect on the socio-economic status of the employee, which from the perspective of workers and the labour unions representing them might be beneficial.

A redesign of two-wheeled containers is probably harder to implement. In the 1980’s it was expected that a two-wheeled container would last for about 10 years. However, the durability
of the two-wheeled containers appeared to be much longer. Therefore, it seems unlikely that a redesigned container will be introduced on the market in the near future. Besides, due to the change in size of the two-wheeled container, probably also the pick-up system of the refuse truck has to be changed. Both developments require large investments from manufacturers and refuse collecting organisations. Because the redesigned container probably does not result in an increase in the amount of refuse collected according to the Dutch refuse collecting guideline, the most likely way to implement the results of the study is to inform industrial designers working for the manufacturers. In this way, the suggested design improvements can hopefully be taken into account in future designs of two-wheeled containers.

The decrease in the duration of the time collecting due to the increase in the number of two-wheeled containers at a gathering point, will probably be used to increase the number of two-wheeled containers that can be collected during an 8-hour working day. In this way, no reduction of the physical workload is expected. Thus, the productivity will be improved without further gains for the refuse collectors.

### 7.3.2 New collecting methods

In the past years, probably also due to the introduction of the Dutch refuse collecting guideline, a lot of different collection methods have been developed and implemented. For instance, side collection has been introduced in some places. In this production system, a mechanical arm on the refuse truck picks up a two-wheeled container, empties it and puts it back on the street. In some cases, a refuse collector walks beside the refuse truck to position the two-wheeled container in the right way. It is expected that in 2003 about 25% of all domestic refuse will be collected in this way. Another example is the introduction of a metro system. Citizens carry their own refuse to a sort of dustbin on the street with a large depot underground. The large depots are emptied with the use of a crane on a refuse truck. In general, these new production systems can be considered huge improvements. However, these new ways of collecting also bring new health risks. Frequent joy-stick use to position the mechanical arm and the crane may increase the risk of work-related upper extremity disorders. A solitary function as a driver/operator may lead to complaints due to an increased psychosocial workload. In Swedish forestry a similar change has taken place from a multi-person heavy manual labour task to a one person sitting operating task. Several studies have been carried out evaluating the effects of improvements of the production systems in forestry on the physical and psychosocial workload of these operators. Refuse collecting organisations should play an active role to secure that issues related to health are taken into account, when these new production systems are developed and implemented. Training and education of the employees become even more important. Moreover, an active role of the branch organisations NVRD (Dutch Association for Waste and Cleansing Management) and
VNA (Association of Dutch Waste Management Companies) and labour unions can initiate and support this kind of activities. A national platform on the topic of health and safety in refuse collecting already exists. Two times a year, both branch organisations discuss work-related health and safety topics with representatives of labour unions, Labour Inspection Service, refuse collecting organisations and research institutes. This platform should keep its important function.

The existing policy of the Labour Inspection Service, based on the Dutch refuse collecting guideline, should be maintained. Refuse collecting organisations are free to collect more refuse than allowed according to the Dutch refuse collecting guideline, as long as employers can prove that they offer their employees the same level of health protection. A recently performed study on rotation between two instead of three employees is a nice example in which this requisite was proven in a specific refuse collecting organisation

Despite these initiatives to further improve the working conditions, it is unlikely that all health risks can be eliminated. Probably, specific work demands maintain present. The branch organisations NVRD and VNA, and BGZ Wegvervoer (the Dutch organisation for occupational health care in the road transport industry) were aware of this need and have financed the development of guidelines for periodic health surveillance of refuse collectors. These guidelines should be implemented to provide standardised and good quality periodic health surveillance for each refuse collector.

Finally, it is recommended that Dutch Ministry of Social Affairs and Employment initiates a study on the effectiveness of the Dutch refuse collecting guideline in terms of health risks as well as financial costs and benefits.

7.4 Recommendations for research

Does an intervention really work in the workplace? That is the question we should dare to address more often. In a review on the effect of ergonomic interventions in the workplace, Westgaard and Winkel found 52 studies published in the period between 1964-1996. Of these 52 studies, only 28 studies evaluated the effect of the intervention in terms of health effects. Volinn performed a review study on the effect of workplace interventions to prevent low back disorders. In the period between 1982-1995, he found 6 studies. Van der Beek et al. performed a review study on the effect of interventions on return to work after musculoskeletal complaints. In the period between 1989 and 1999, they found 10 studies that met their inclusion criteria. On the basis of a recent systematic review, Linton and Van Tulder concluded that no good quality studies could be identified evaluating the effectiveness of ergonomics in preventing back and neck pain problems. Therefore, more good quality studies should be performed in which the effectiveness of ergonomic interventions is at stake. A shift should take place from studies on risk factors of musculoskeletal complaints towards studies
on the effectiveness of interventions in the reduction of musculoskeletal complaints. Moreover, if these studies provide information on work demands and workload in terms of level, duration and frequency, this information can be used to define evidence based guidelines.

Besides efficacy and effectiveness of an intervention, the implementation strategy is of utmost importance, in terms of flexibility and sustainability. The fact that an ergonomic intervention works is not enough to get an intervention implemented. To the author's knowledge, no studies exist that evaluate the effectiveness of strategies to implement technical or organisational interventions. Despite the attention given to, for instance, participatory ergonomics, no studies have been published that have proven this approach to be (more) effective. In other areas, such as in work stress and in health promotion in the workplace, this type of studies have been published. Therefore, a start has to be made with the evaluation of different implementation strategies for proven effective ergonomic interventions.