Effectiveness of interventions to reduce workload in refuse collectors
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Chapter 2

Work situation and physical workload

of refuse collectors in three different time periods

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Chapter 2

Abstract
City officials from Haarlem, a Dutch city in which one of the first scientific studies on the workload of refuse collectors was performed, wanted to compare the work situation and physical workload in 1997 with the results of a study performed in Haarlem in 1985 and with the results of a national study conducted in 1993. Depending on the results, they wanted to implement effective preventive measures. The present study consisted of a field study, a simulation experiment in the laboratory, and a questionnaire concerning work characteristics and health effects among eighteen refuse collectors.

The work situation and the energetic workload were not more favourable in Haarlem in 1997 when compared to Haarlem of 1985 or the national study conducted in 1993. On several important parameters, such as the time carrying plastic bags or pushing containers, amount of refuse collected and percentage VO_2max during a working day, the results in the present study did not differ from those in earlier studies. However, the working postures and the perceived exertion of the refuse collectors in Haarlem in 1997 were more favourable when compared to the refuse collectors in the national study. The results have convinced the management to plan an intervention study of potentially effective measures to improve the work situation and to reduce the physical workload. Planned measures are the introduction of job rotation, an effective work-rest schedule and the redesign of two-wheeled containers.
2.1 Introduction
Working as a Dutch refuse collector is associated with high prevalence rates of musculoskeletal complaints and high sickness rates in comparison with the general Dutch working population. In Denmark, Poulsen et al. found that in the period between 1984 and 1992 the reported health complaints due to musculoskeletal disorders were about twice as high in the group of refuse collectors as compared to the total work force. Similar results might be expected in other countries of Western Europe and North America.

Haarlem is a Dutch city in which one of the first scientific studies on the workload of refuse collectors was performed. Kemper et al. concluded that the physical workload of refuse collectors was too high. Since that study, several measures to reduce the physical workload were introduced in a non-systematic way, such as the introduction of smaller districts, a back training program, a (periodic) medical examination by the occupational health physician, and the possibility of individual task adjustment. Before implementing more work improvements, Haarlem city officials wanted to know whether these changes resulted in a reduction in the physical workload and an improvement of the work situation. Because the measures had already been implemented, no pre-measurements could be performed. Therefore, the effect of the (separate) measures could not be evaluated. However, comparing current data of the work situation and workload of Haarlem with those collected in 1985 by Kemper et al. provides an indication of the extent of change in the work situation and workload. Furthermore, a comparison of these current data with results of the national study performed in 1993 by Frings-Dresen et al. gives insight into whether the work situation and workload are more or less favourable in Haarlem than in other parts of the Netherlands. A comparison is also made on the number of reported health complaints between these two populations. As a result of the national study, a Dutch guideline concerning the acceptable workload of refuse collectors was implemented in 1996. The current results obtained in Haarlem will be compared with this guideline.

Summarised, the aim of this study is to compare the current work situation and physical workload in Haarlem (study III) with an earlier study performed in Haarlem (study I) and the national study (study II). Finally, a comparison is made between the results of the study III and the Dutch guidelines for refuse collecting concerning the acceptable workload.
Chapter 2

2.2 Methods

The study consisted of a field study, a simulation experiment in the laboratory, and a questionnaire concerning work characteristics and health effects. The methods used in this study (study III) were the same as those used in study II by Frings-Dresen et al. and partly the same as those used in study I by Kemper et al. Table 1 provides a schematic representation of the methods used in the three studies. The methods are described in further detail in the rest of this section.

A comparison is made between study III and study II on refuse collection with both plastic bags and two-wheeled containers (content: 240 l). Only a comparison could be made with the refuse collecting of plastic bags between study III and study I, because all refuse was collected by means of plastic bags during study I.

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Plastic bags</th>
<th>Plastic bags</th>
<th>Two-wheeled containers</th>
<th>Plastic bags</th>
<th>Two-wheeled containers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study I Haarlem</td>
<td>1985</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Study II Netherlands</td>
<td>1993</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Study III Haarlem</td>
<td>1997</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

*In 1985 all refuse was collected by means of plastic bags in Haarlem*

The measurements of study III were carried out between November 1996 and February 1997 in Haarlem. Because of the increase in refuse in the days around Christmas and New Year, no
measurements were performed in the last two weeks of December and the first week of January.

2.2.1 Subjects
The selection criteria of the male refuse collectors were:
- they had to collect domestic refuse
- they had to collect at least four days a week with one refuse-collecting method
- they had to have at least one year of experience with this method

All nineteen refuse collectors in Haarlem fulfilled these criteria. Six of them collected refuse by means of plastic bags. Thirteen employees collected refuse by means of two-wheeled containers. One employee who used two-wheeled containers refused to participate in this study. All other refuse collectors participated voluntarily. In the laboratory, body height, body weight, percentage body fat and maximum oxygen uptake ($V_{O_2}max$) of these eighteen refuse collectors were measured.

The refuse collectors were compared regarding these variables (and age) with their colleagues from study II (51 refuse collectors using plastic bags and 47 refuse collectors using two-wheeled containers) and with their colleagues in study I (23 refuse collectors using plastic bags). Four of the refuse collectors who used plastic bags in study I were involved in study III.

2.2.2 Work situation
The work situation is described by the work demand and the actual working method. The work demand is defined as the total weight of refuse collected during the day. The truck was weighed before and after the refuse was dumped. This information was used to calculate the weight of the total amount of refuse.

The actual working method of each refuse collector was assessed by observing the tasks, the activities performed during these tasks, the postures during the task ‘loading’ and the (number of) objects being handled, all by means of the TRAC-system (Task Recording and Analysis on Computer) during a full working day. The following variables and categories within variables were observed on a real time basis: task (e.g. loading, driving, dumping, refuelling and pausing [defined as the time during which an employee takes a break from his work]), activity (e.g. walking, pushing, pulling, throwing or sitting), load handled (e.g. plastic bag, [empty or full] two-wheeled containers) and number of objects handled (e.g. three plastic bags or two two-wheeled containers). The working posture during loading was recorded on the basis of time sampling (‘multi-moment’). Every 15 seconds at an audible cue, the position of the trunk, upper arms and legs were observed. In order to get a representative sample of the
working postures during the task loading, the total observation time was at least 4 periods of 10 minutes per refuse collector.  

2.2.3 Physical workload

The physical workload was defined as the percentage of the $\dot{V}O_{2\text{max}}$ during loading and during the whole working day, and as the ratings of perceived exertion. To estimate the $\dot{V}O_2$ during loading, the heart rate (HR) of each refuse collector was continuously recorded with a sample rate of 15 seconds by means of the sporttester PE 4000 (Polar Electro, Finland) during the course of the whole working day. To assess the energetic workload of the refuse collectors during loading, the individual relationship between HR and $\dot{V}O_2$, and the $\dot{V}O_{2\text{max}}$ of each refuse collector was determined in the laboratory by simulating the work activities. For both tasks, i.e. collecting of plastic bags and two-wheeled containers, a specific sub-maximal (treadmill) test was developed.  

Corresponding to every group's specific situation at the workplace, the protocols of these tests provided for intervals of walking, alternated with intervals of additional activities like carrying or pushing. Following the sub-maximal test, the $\dot{V}O_{2\text{max}}$ was determined by running on a treadmill against an increasing slope. On the basis of the recorded HR during loading at the workplace and the individual relationship between HR and $\dot{V}O_2$ from data of the sub-maximal treadmill test, the $\dot{V}O_2$ during this task was estimated. The percentage of the $\dot{V}O_{2\text{max}}$ was calculated in order to determine the energetic workload during loading. To estimate the $\% \dot{V}O_{2\text{max}}$ during the working day, the $\dot{V}O_2$ during tasks other than loading was based on the study of Frings-Dresen et al. The duration of the different tasks was derived from real-time observations. Each time before going to the dump, the perceived exertion of the last loading period was rated by the refuse collector on a visual analog scale. The scale ranges from 0 ('not at all effortful') to about 120 ('tremendously effortful').

2.2.4 Health effects

The questionnaire consisted of scales concerning musculoskeletal complaints during the last 12 months, difficulty experienced with back bending and twisting activities, perceived health complaints, sleep disturbances, and the need for work recovery. The same questionnaire was used in study II. The scales were derived from existing validated questionnaires such as the questionnaire on locomotor system, the questionnaire on perceived health, the Groninger Sleep Quality Scale, and the questionnaire concerning work recovery. In order to overcome possible language and reading problems, the researchers assisted the refuse collectors while filling in the questionnaire. The results are presented as the mean number of
items per scale on which an employee reported a complaint. For each scale applies that the
lower the score, the lesser the number of complaints.

2.2.5 Guidelines
The workload in terms of collecting time, amount of refuse collected, and number of objects
collected in this study were compared with the Dutch guidelines of the Ministry of Social
Affairs and Employment. The energetic workload of the individual refuse collectors was also
compared with the guideline of 30% $\text{VO}_{2\text{max}}$ during an eight hour working day$^{69}$.

2.2.6 Data analysis and statistics
The results of the work analysis and the questionnaire of the group of refuse collectors of
plastic bags and two-wheeled containers in this study were mutually compared with the
results of study II and with the results of study I. Differences were tested with a two-tailed
unpaired Student's t-test. Statistically significant differences were accepted at $p < 0.05$. 

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2.3 Results

2.3.1 Subjects
The mean and standard deviation of age, body height, body weight, percentage body fat and \( \text{VO}_2\text{max} \) of the subjects in the three studies, categorised by method of collection, are presented in figure 1. The refuse collectors of plastic bags in study III were on average older than those in study II. They also had a higher percentage of body fat and a lower \( \text{VO}_2\text{max} \) than their counterparts in study I. The \( \text{VO}_2\text{max} \) of the refuse collectors of two-wheeled containers in study III was higher than the \( \text{VO}_2\text{max} \) of the refuse collectors in study II. The refuse collectors did not differ on the other characteristics.

![Figure 1](image)

**Figure 1.** Mean and standard deviation of age, body height, body weight, percentage body fat and \( \text{VO}_2\text{max} \) for the group of refuse collectors of plastic bags in the studies I, II and III and for the group of refuse collectors of two-wheeled containers in the studies II and III (\# significant difference between study I and III, * significant difference between study II and III).

2.3.2 Work demand & actual working method
Figure 2 presents the duration (in minutes) of the most important tasks and of the total working day. The duration of the tasks - loading, driving and dumping - did not differ between study III and study II. The duration of pausing and the total working day of the refuse collectors of plastic bags were significant longer in study III than that of the refuse collectors in study II. Although the standard deviation is unknown, it seems that the duration of loading and of the total working day did not differ between study III and I. The duration of the different tasks and the total working day of the refuse collectors of two-wheeled containers in study III and in study II did not differ.
Work situation and physical workload of refuse collectors in three different time periods

The duration of the most important activities is shown in figure 3. The duration of the activities performed by the refuse collectors of plastic bags in study III and in study II did not differ except for the variable walking. The refuse collectors in study III walked for a longer period of time than their colleagues in study II. The combined time spent on the activities ‘picking up, walking with and throwing of bags’ and ‘throwing of bags while standing’, classified as handling bags, was shorter in study III than in study I. The refuse collectors of two-wheeled containers in study III and in study II differed for the variables standing, walking, handling of bags, and pulling of empty two-wheeled containers. In study III, the refuse collectors were occupied longer with these activities.

The number of handled objects and the daily collected amount of refuse for the different refuse-collecting methods are shown in figure 4. The amount of refuse collected (number of objects, number of objects per minute, and amount per day) did not differ between the refuse collectors of plastic bags in study III compared with study II and I. In study III, more two-wheeled containers were handled during the day and emptied (per minute) and a larger amount of refuse was collected than in study II.

Figure 2. Mean and standard deviation of the duration of the most important tasks and the working day for the group of refuse collectors of plastic bags in the studies I, II and III and for the group of refuse collectors of two-wheeled containers in the studies II and III (* significant difference between study II and III).
Figure 3. Mean and standard deviation of the duration of the most important activities for the group of refuse collectors of plastic bags in the studies I, II and III and for the group of refuse collectors of two-wheeled containers in the studies II and III (# significant difference between study I and III, * significant difference between study II and III).

Figure 4. Mean and standard deviation of the number of objects handled during a day, the number of objects handled per minute during loading, and the amount of refuse collected during a working day by a refuse collector of plastic bags in the studies I, II and III and a refuse collector of two-wheeled containers in the studies II and III (* significant difference between study II and III).
The refuse collectors of plastic bags in study III flexed their trunk, elevated their arms and bent their knees less often than the refuse collectors in study II. The refuse collectors of two-wheeled containers in study III flexed their trunk and elevated their arms less often than the refuse collectors in study II. The results are presented in figure 5.

![Plastic bags](image1)

![Two-wheeled containers](image2)

**Figure 5.** Mean and standard deviation of the time flexion of the trunk is more than 15°, elevation of the upper arm(s) is more than 60°, and bending of the knees is more than 15° for the group of refuse collectors of plastic bags in the studies II and III and for the group of refuse collectors of two-wheeled containers in the studies II and III (* significant difference between study II and III).

### 2.3.3 Physical workload

The mean and standard deviation of the energetic workload as a percentage of the VO₂max during the task loading and during a working day are presented in figure 6. These variables did not differ for any of the refuse collectors in study III and in study II. Nor did they differ for the energetic workload of refuse collectors of plastic bags during the working day for study III and study I. The refuse collectors in study III rated their exertion lower than those in study II (figure 6).
2.3.4 Health effects

The results of the questionnaire concerning work and health are presented in figure 7. The refuse collectors in study III did not differ from the refuse collectors in study II regarding the number of reported musculoskeletal complaints during the last 12 months, the difficulty experienced with back bending and twisting activities, the perceived health complaints, the sleep disturbances and the need for work recovery.

2.3.5 Guidelines

Table 2 shows the maximal acceptable workload in terms of collecting time, amount of refuse collected, and number of objects collected during an eight-hour working day according to the Dutch guideline and the corresponding values in the present study. The guideline was exceeded for all three aspects. Furthermore, 50% (or more) of the employees exceeded the physiological criterion regardless the method of collecting.
Work situation and physical workload of refuse collectors in three different time periods

Plastic bags

![Bar chart showing mean and standard deviation of scale scores for various questionnaire scales among refuse collectors with plastic bags.](chart1.png)

Two-wheeled containers

![Bar chart showing mean and standard deviation of scale scores for various questionnaire scales among refuse collectors with two-wheeled containers.](chart2.png)

Figure 7. Mean and standard deviation of the scale score on the questionnaire concerning the number of musculoskeletal complaints in the last 12 months, perceived difficulty with activities concerning back bending and twisting, perceived health complaints, sleep difficulties, and need for work recovery for the refuse collectors of plastic bags and two-wheeled containers in study II and III. The results are presented as the mean number of items per scale on which an employee reported a complaint.

Table 2. Maximal acceptable workload according to the Dutch guideline and the corresponding values in study III. The percentage of refuse collectors that exceeds the physiological criterion of 30% \( \text{VO}_{2\text{max}} \) is also given.

<table>
<thead>
<tr>
<th></th>
<th>Plastic bags</th>
<th>Two-wheeled containers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work demand criterion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guideline</td>
<td>2.8</td>
<td>3.5</td>
</tr>
<tr>
<td>Time (hours)</td>
<td>6.4</td>
<td>10.0</td>
</tr>
<tr>
<td>Amount (1000 kg)</td>
<td>914</td>
<td>1424</td>
</tr>
<tr>
<td>Number of objects</td>
<td>377</td>
<td>584</td>
</tr>
<tr>
<td>Physiological criterion</td>
<td>50</td>
<td>51</td>
</tr>
<tr>
<td>%&gt;30% ( \text{VO}_{2\text{max}} ) working day</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.4 Discussion

2.4.1 Work situation and physical workload

In this study, the energetic workload, working postures and perceived exertion of Haarlem refuse collectors were assessed and compared with two earlier studies performed in the Netherlands. It can be concluded that the energetic workload of these refuse collectors has not reduced compared to the situation twelve years ago nor was it more favourable when compared to the national situation of 1993. Several other researchers have also investigated refuse collecting. In their study on workload in different age groups, Schibye & Christensen reported that a group of refuse collectors of bags, containers and waste bins had a mean heart rate reserve (HRR) of 47% during loading. Unfortunately, no comparisons can be made with the workload in the present study because the workload during lifting of bags and bins is probably higher than that during pushing and pulling of containers, and because no information is available concerning the number of employees in each (age) group. Klimmer et al. reported in their study on garbage collectors of two-wheeled containers with a content from 110 l to 240 l, a mean workload of 50% \( \text{VO}_{2\max} \) during loading. This is about the same as in our study. In their review, Poulsen et al. mentioned a study by Hanssons and Klussell, in which the workload varied between 58 and 63% \( \text{VO}_{2\max} \) during loading of bags. Kuijer et al. found a mean workload of 61% \( \text{VO}_{2\max} \) during the collecting of bags. In the present study, the %\( \text{VO}_{2\max} \) for refuse collectors of bags seemed to be lower. Poulsen et al. did not report other findings concerning, for instance, the work situation or the actual working method. Therefore, no explanation can be given for the differences found. An explanation for the lower workload in the present study compared to the study of Kuijer et al. might be that the number of bags collected per minute was about 20% less.

The observed working postures seemed to be more favourable in the study III when compared to the study II. The more favourable working postures can not be explained by a difference in the number of bags or two-wheeled containers collected, differences in pick up height of the bags or handle height of the containers or a difference in body height between the refuse collectors of plastic bags and two-wheeled containers in the two studies. Might the preventive back training program mentioned in the introduction have contributed to this result? Some studies have shown that training in work technique can result in better working postures. Another explanation might be the inter-observer reliability. Although an observer had to pass a reliability test in both studies, inter-individual differences might still be large. This might especially be the case while observing rapid lifting movements. In the present study only one person performed the observations and in the former study four persons performed them.

The perceived exertion was also lower in the present study. This is remarkable in the light of similarities in work demand and the energetic workload. An explanation might be that the
refuse collectors in this study are better informed and more involved in decisions concerning their work. Laitinen et al. have shown that focusing on technical and physical solutions can have a positive effect on the psychosocial work environment experienced. Furthermore, the commitment of management to improve work conditions and to invest in an objective evaluation of interventions might have contributed to this finding.

Finally, one remark has to be made. During study II and I, green ('organic fraction') and grey ('non organic fraction') refuse was not collected separately, regardless of the collecting method. In the present study, the measurements for refuse collected by means of two-wheeled containers were only performed in the weeks during which grey refuse was collected. The weeks during which green refuse was collected were not taken into account. This means that the daily workload of refuse collectors of two-wheeled containers on an annual basis is not yet known.

In summary, although there are some differences between the present study and the two earlier studies, the workload of refuse collecting can still be classified as heavy physical work.

2.4.2 Preventive measures

Because this study did not evaluate the interventions, remarks on the effectiveness of preventive measures to reduce the physical workload of refuse collectors are made only on basis of former studies.

It is still unclear whether improving lifting technique results in a lowering of the physical workload. On the basis of a review of the literature, Van Dieën et al. stated that it is not the lifting technique but the lifting tactics, such as the speed of lifting, that are of primary importance. Therefore, trying to improve the working posture might not be an effective means of reducing the physical workload.

Reducing the number of bags and two-wheeled containers handled per day might be an effective measure. This can be done by reducing the size of the districts as mentioned in the study by Kemper et al. or by the introduction of job rotation. Kuijer et al. evaluated the effect of job rotation between sweeping, driving and refuse collecting. They concluded that job rotation between these three tasks resulted in an overall reduction of the physical workload in a refuse collecting department.

In a work physiology field study on transportation capacity for refuse collection of 1.1 m³ containers Luttmann et al. recommended at least a 10-minute rest break per hour to secure an equilibrium between fatigue and recovery. Besides these organisational changes, technical solutions might contribute to a reduction in the physical workload. For instance, for bags lowering the in-throw height of the hopper barge of the dustcart might decrease the physical workload. In addition, for two-wheeled containers optimising handle height and point of
application of the centre of gravity, and creating smooth and horizontal surfaces might be appropriate measures.²⁸,⁶⁷,¹²³,¹³⁷
2.5 Conclusion
The work situation and the energetic workload of refuse collectors were not more favourable in Haarlem in 1997 when compared to Haarlem of 1985 or to a national study of refuse collectors in 1993. On several important parameters - such as the time carrying plastic bags or pushing containers, amount of refuse collected and percentage $\text{VO}_2^{\text{max}}$ during a working day - the results in the present study did not differ from those in earlier studies. However, the working postures and the perceived exertion of the refuse collectors in Haarlem in 1997 were more favourable when compared to the refuse collectors in the national study.

The results have convinced the management of the municipality of Haarlem to plan an evaluation study of potentially effective measures to reduce the physical workload. Planned measures are the introduction of job rotation between driving and pushing and pulling of wheeled containers, more effective work-rest schedules, and the redesign of two-wheeled containers.

Acknowledgements
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