Effectiveness of interventions to reduce workload in refuse collectors
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Citation for published version (APA):
Kuijer, P. P. F. M. (2002). Effectiveness of interventions to reduce workload in refuse collectors

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Chapter 5.2

Effect of job rotation on workload and recovery of refuse truck drivers and collectors

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Submitted for publication

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Abstract
Job rotation is often advocated to reduce the workload, but its efficacy has seldom been investigated. Therefore, the aim of this study is to compare physical workload, mental workload and recovery between 1) truck driving, collecting refuse and rotating between these two jobs, and between 2) rotating between days and rotating during the day. Three teams of three workers participated in this study. Each team member worked at least one week as truck driver, one week as refuse collector, one week rotating between these two jobs between days, and one week rotating during the day. The work demands were assessed by means of systematic observation of tasks and activities. The physical workload was quantified by means of heart rate, estimated percentage of the maximum oxygen uptake, subjective ratings as well as urinary excretion rates of noradrenaline. The mental workload was quantified by means of subjective ratings and urinary excretion rates of adrenaline and cortisol. The recovery was quantified by means of urinary excretion rates of (nor)adrenaline after work.

Job rotation differed from collecting only by a lower percentage of the maximum oxygen uptake and a lower rated perceived exertion during a working day. The other dependent variables did not differ between job rotation and collecting only. Job rotation differed from driving by a higher heart rate, a higher percentage of the maximum oxygen uptake, a higher rated perceived exertion as well as a higher excretion rate of noradrenaline during a working day. In contrast, driving resulted in a higher excretion rate of adrenaline during a working day compared to job rotation. No differences were found on the dependent variables between rotating between days and during the day.

In conclusion, job rotation proved an effective measure to reduce the physical workload compared to refuse collecting only and to reduce the mental workload compared to truck driving only. No effects were seen on recovery. No differences were found between rotating between days and during the day.
5.2.1 Introduction

The Tayloristic principle of division of labour and job specialisation is a fundamental issue in the organisation of work. This principle resulted in many cases in a subdivision of work into small cycles in order to increase productivity. In the last decades, team work in stead of job specialisation is often seen as a superior form of work organisation. For instance, Volpe et al. and Cannon-Bowers et al. showed that training on tasks, duties and responsibilities of other team members resulted in an increase in productivity. A special form of team work is rotating between jobs. Job rotation can be defined as 'regular alternating between different jobs within an organisation on basis of a scheme or spontaneously on basis of a personal appointment'.

A major economic benefit of job rotation is the increase in flexibility. Besides, several studies indicated the possible ergonomic benefits of job rotation in reducing the workload and the risk of musculoskeletal complaints. Especially jobs with a dynamic type of work and great differences in muscular activity should be able to benefit from the introduction of job rotation. Therefore, job rotation is often advised as an effective measure to reduce the workload. Despite its acclaimed effect in the literature, only one study was found that evaluated the effect of job rotation on the workload. In a study performed at a refuse collecting company, the introduction of job rotation between collecting bags, sweeping streets and driving a small cleansing machine, resulted in a marked reduction of the physical workload.

However, in many countries refuse is collected by a team consisting of a truck driver and one or more refuse collectors. Therefore, the introduction of a rotating scheme between these team members might be more feasible in daily working life. This would serve to reduce physical workload as compared to collecting refuse only. However, driving can be a demanding mental task, especially on city streets. Not only should a driver focus on the other traffic, but also steer the large truck in often narrow streets in such a way that the refuse collectors have to transport the refuse over a small distance only. Moreover, in a recent study a slower recovery after work was found in a group with mental and physical demands compared to groups with only physical and only mental demands. Therefore, the first aim of this study was to compare truck driving, collecting refuse and rotating between these two jobs as to physical workload, mental workload and recovery.

Results obtained from a biomechanical energy storage model of the low back indicated that a marked reduction in workload is only achieved if there is a considerable difference in workload between the tasks and the ratio of the task durations is small. Another study on the effects of rotation suggested that, based on characteristics of a lifting task, gender specific lifting capacities and scheduling algorithms, a specific lifting task should not last longer than 7 hours. In a study on the effect of reduced work pace and increased break allowance, it
was concluded that only a restriction in the duration of assembly work during the day would be effective. Consequently, a job rotation scheme was advised in which tasks, consisting of alternative mechanical exposures, were alternated during the day. Hence, it is often suggested that rotating during work shifts is more favourable than across work shifts. To the authors’ knowledge, no studies were published that verified this assumption. Therefore, the second aim of this study was to compare rotating between days and rotating during the day as to physical workload, mental workload and recovery.
5.2.2 Method

5.2.2.1 Participants

Three different refuse management companies in the Netherlands participated in this study. From each waste management company a team of three employees, who all worked for more than one year in a combined function as truck driver and refuse collector, voluntarily participated. Every member of the team was familiar with the route in each district. Before the start of the study, all participants were instructed about the purpose and the content of the study. All participants signed an informed consent. Table 1 presents mean and standard deviation of age, body height, body weight and maximum oxygen uptake (\(\dot{V}O_2^{max}\)) of the participants.

Table 1. Mean and standard deviation (sd) of age, body height, body weight and maximum oxygen uptake (\(\dot{V}O_2^{max}\)) of the participants (n=9). Due to a long-term absence of one of the participants after the study period, the \(\dot{V}O_2^{max}\) involves only eight participants.

<table>
<thead>
<tr>
<th>Number n</th>
<th>Age (years) mean (sd)</th>
<th>Height (cm) mean (sd)</th>
<th>Weight (kg) mean (sd)</th>
<th>(\dot{V}O_2^{max}) (l.min(^{-1})) mean (sd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>38 (6)</td>
<td>180 (5)</td>
<td>80 (10)</td>
<td>3.7 (0.5)</td>
</tr>
</tbody>
</table>

5.2.2.2 Working scheme

Every participant worked as a truck driver, as a refuse collector, as a truck driver/refuse collector rotating between days and as a truck driver/refuse collector rotating during the day. The refuse was collected using two-wheeled containers with a content of 0.240 m\(^3\). During rotating, the ratio of driving and collecting was 1:2. In order to achieve these four working schemes, five study weeks were needed. Three weeks during which one participant only drove the truck – and the other two participants collected refuse -, one week during which a team of three participants rotated between days and one week during which a team of three participants rotated during the day. To ensure that the working schemes only differed in the time a participant drove the truck or collected refuse, the measurements were performed on the same days of the week, in the same domestic area and only in the weeks, so called, grey refuse (non-organic fraction) was collected. This was done to ensure a relative constant amount of refuse. After each week during which grey refuse was collected, a week followed during which green refuse (organic fraction) was collected. Therefore, the total measurement period lasted at least nine weeks. The measurements were performed on the last three workdays of the week, Wednesday, Thursday and Friday. During the first two days of the week, the participants got acquainted to the working scheme. The order of the four working schemes was varied across the three teams. Due to personal circumstances of participants, on
one occasion in every team the working scheme had to be changed. During the week in which the participants rotated on the day, the participants decided together at which times each member started driving the truck or collecting refuse. The starting-point was that every team member had to collect about the same number of two-wheeled containers per day and each member drove the truck during one period per day.

### 5.2.2.3 Task analyses

The time every participant spent performing the different tasks and activities during the day was assessed by observing the tasks, the activities performed during these tasks and the (number of) objects being handled during a full workday, all by means of the TRAC-system (Task Recording and Analysis on Computer; 44). The following variables and categories within variables were observed on a real time basis 42: task (e.g. collecting, driving, dumping 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. [empty or full] two-wheeled containers) and number of objects handled (e.g. one or two two-wheeled containers).

The different working schemes were compared as to the time driving (steering and/or sitting in the truck), the time collecting two-wheeled containers, and the time pushing and pulling (full or emptied) two-wheeled containers. The amount of refuse collected was determined by weighing the truck before and after the refuse was dumped. This information was used to calculate the weight of the total amount of refuse. Depending on the number of refuse collectors, this amount was divided by two (only collecting two-wheeled containers or job rotation between days) or three (job rotation during the day).

### 5.2.2.4 Workload and recovery

The workload was quantified by the heart rate (HR) (beats·min⁻¹), estimated percentage of the maximum oxygen uptake (%\(\text{VO}_2\text{max}\)), urinary excretion rate (ng·min⁻¹) of catecholamines and cortisol, and the perceived workload. The recovery was quantified by the urinary excretion rate of catecholamines after the workday had finished.

#### Heart rate and estimated oxygen uptake

During the workday the HR of each refuse collector was continuously recorded with a sample rate of 15 seconds using the Polar Accurex Plus (Polar Electro, Finland). The oxygen uptake (\(\text{VO}_2\)) during the task loading was estimated by determining the individual relationship between HR and \(\text{VO}_2\) of each refuse collector in the laboratory during their work activities. For the task collecting of two-wheeled containers, a specific sub-maximal treadmill test was developed 42. The protocols of these tests provided for intervals of walking, alternated with
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intervals of pushing. Following the sub-maximal test, the \( \dot{V}O_{2\text{max}} \) was determined by running on a treadmill against an increasing slope \(^{42}\). On the basis of the HR recorded during collecting two-wheeled containers 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 collecting was estimated. The \( \dot{V}O_2 \) was calculated as \( \% \dot{V}O_{2\text{max}} \). To estimate the average \( \% \dot{V}O_{2\text{max}} \) during the workday, equations 1 and 2 were used. The \( \dot{V}O_2 \) during tasks other than collecting was based on the study of Frings-Dresen et al. \(^{43}\) (\( \dot{V}O_2 \) not collecting = 0.38 l.min\(^{-1}\)). The duration of the time ‘collecting’ and ‘not collecting’ was derived from the task analyses in the present study.

\[
\dot{V}O_2 \text{workday} = (C \text{collecting minutes} \times \dot{V}O_2 \text{collecting} + N_{\text{not collecting}} \times \dot{V}O_2 \text{not collecting}) / W \text{workday minutes} \\
W \text{workday minutes} = C \text{collecting minutes} + N_{\text{not collecting}} \text{minutes}
\]

(1) 

(2)

**Catecholamines en cortisol**

The participants were asked to collect all urine during the workdays on which the measurements were performed and to provide samples around 07.00 hrs (i), around 11.00 hrs (ii), around 14.00 hrs (iii), around 17.00 hrs (iv), around 20.00 hrs (v) and before going to bed, around 23.00 hrs (vi). The urine was collected into a jar that contained 0.7 grams of citric acid. The time and the date of the urinations were written on each jar. During the workday, the observer reminded the participants about the time to urinate. Before and after the workday, the participants received a message on provided pagers 5 minutes before the time to urinate. After collection, the jars were kept as cold as possible until further preparation started within 24 hours as described by Sluiter et al. \(^{134}\). The urinary concentrations (ng\-ml\(^{-1}\)) were multiplied by the volume of the corresponding urine sample (ml). This amount (ng) was divided by the period of time (minutes) between this urination sample and the previous urination sample to obtain the mean excretion rate for that period (ng\-min\(^{-1}\)).

Because of the real life character of the study, the participants were not restricted in their consumption of coffee, tea, alcohol, nicotine, and medicine. The data collected on these consumptions did not show any remarkable differences between the measurement days. Furthermore, the subjects did not report any emotional events, such as quarrels or other traumatic events during the measurement days.

In this study, sample ii, iii and, depending on the length of the workday, iv were averaged to reflect the mean excretion rate during the workday. To reflect the degree of recovery after work, sample v was taken. For the degree of recovery during the evening, samples v and vi were averaged.
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Subjective ratings
During the workday, the participant filled in scales for perceived exertion $^{179}$, perceived fatigue $^{14}$, perceived activeness and perceived tenseness. The scale for perceived exertion ranged from 0 ('not at all effortful') to 120 ('tremendously effortful'). After each collecting period and before going to the dump, the perceived exertion was rated. The mean exertion score was calculated by adding up all the scores during the day and dividing the result by the number of collecting periods. The scale for perceived fatigue ranged from 0 ('not at all tired') to 10 ('extremely tired'). The scale for perceived fatigue was filled in at the start of the day and after each collecting period. The mean fatigue score was calculated by adding up all the scores during the day, dividing the result by the number of collecting periods and subtracting the score at the start of the day. The scales for the perceived activeness and the scale for perceived tenseness ranged from 1 ('active' or 'at ease', respectively) to 5 ('exhausted' or 'tense', respectively). These scales were filled in at the start of the day and after each urinary sample time during the workday. The mean value was calculated in the same way as the mean fatigue score.

5.2.2.5 Data analyses
To compare differences in exposure and workload for truck driving, refuse collecting and rotating between the two jobs, the mean values over the three workdays were calculated for each participant. For rotating in general, the mean value of the exposure and workload variables for the three workdays on which rotating between days took place and the mean value for the three workdays on which rotating during the day took place were calculated. Then both values were averaged. Differences were tested using a within subjects multiple dependent measures analysis of variance. To compare differences in workload between the two rotating schemes, differences between the mean values for rotating between days and those for rotating during the day were tested using a paired t-test. A p-value smaller than 0.05 was considered statistically significant. The results are presented in figures $^{48}$. Each figure displays the average values of the nine participants' mean values over the three workdays for the working schemes of interest.
5.2.3 Results
The duration of the workday did not differ between driving, collecting and rotating (figure 1). The workday lasted on average 8.5 hours. The duration of the workday did also not differ between rotating between days and during the day. As expected, driving time during the working scheme collecting only was about 30% of the driving time during the working scheme truck driving only and about 60% of the driving time during rotating. The driving time did not differ between rotating during the day and rotating between days. No two-wheeled containers were collected during the working scheme driving only. The duration of collecting during the working scheme rotating was about 60% of collecting during the working scheme collecting only. The same was found for the activities pushing and pulling of empty and full two-wheeled containers. The collecting time and the duration of pushing and pulling of full and empty two-wheeled containers did not differ between rotating during the day and rotating between days.

![Figure 1. Mean and standard error of the duration of the workday, the tasks driving and collecting and the activities pushing and pulling full and empty two-wheeled containers per day for the working schemes only driving (d), only collecting (c), rotating (r) and rotating between days (rb) and rotating during the day (rd)](image)

As intended, the amount of refuse collected and the number of two-wheeled containers collected differed between collecting only and rotating. The amounts were 9313 kg and 6484 kg, respectively. The number of two-wheeled containers were 432 and 300, respectively (figure 2). No differences were found for rotating between days and during the day.
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Figure 2. Mean and standard error of the amount of refuse and the number of two-wheeled containers collected during a day for the working schemes only driving (d), only collecting (c), rotating (r) and rotating between days (rb) and rotating during the day (rd).

The HR during the workday was the lowest during the working scheme driving only (78 beats-min⁻¹) (figure 3). The HR during a workday did not differ between the working schemes collecting (88 beats-min⁻¹) and rotating (85 beats-min⁻¹). The HR during a workday did not differ between rotating between days and during the day. The %VO₂max during the workday was lowest for driving only (10.4%) and highest for collecting only (23.1%). The %VO₂max during the workday was 19.1% for rotating and did differ from driving and collecting. No difference was found for the %VO₂max between the two rotation schemes. The HR and %VO₂max, both measured during the task collecting, did not differ between collecting and rotating. The HR’s were 96 beats-min⁻¹ and 100 beats-min⁻¹, respectively. The data for %VO₂max were 38% and 40%, respectively. Again, no difference was found for rotating between days and during the day.

The excretion rate of adrenaline during driving was higher than during collecting and rotating (figure 4). The excretion rate of noradrenaline was lower during driving than during collecting and rotating. The excretion rate of these catecholamines did not differ between collecting and rotating. No differences were found in the excretion rate of catecholamines between rotating between days and rotating during the day. The working scheme had no effects on the excretion rate of cortisol.
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**Figure 3.** Mean and standard error of heart rate (HR) and percentage of the maximum oxygen uptake (%VO$_{2}$max) during the day and during the task collecting per day for the working schemes only driving (d), only collecting (c), rotating (r) and rotating between days (rb) and rotating during the day (rd)

**Figure 4.** Mean and standard error of the urinary excretion rate of adrenaline, noradrenaline and cortisol during the working schemes only driving (d), only collecting (c), rotating (r) and rotating between days (rb) and rotating during the day (rd)
The working scheme had an effect on the perceived exertion (figure 5), while no significant differences were found for the other subjective scales. Collecting refuse resulted in a higher perceived exertion than rotating, which on its turn was perceived as higher exerting than driving. No differences were found for rotating between days and during the day.

![Figure 5](image)

**Figure 5.** Mean and standard error of the subjective ratings for exertion, fatigue, activeness and tenseness for the working schemes only driving (d), only collecting (c), rotating (r) and rotating between days (rb) and rotating during the day (rd). The subjective rating for local musculoskeletal discomfort is not shown because the values were nearly zero.

The working schemes had no effects on the degree of recovery after work and during the evening as assessed by the excretion rates of adrenaline and noradrenaline (figure 6).
Figure 6. Mean and standard error of the urinary excretion rate of catecholamines after work (20.00 hrs) and during the evening (20.00 and 23.00 hrs) for the working schemes only driving (d), only collecting (c), rotating (r) and rotating between days (rb) and rotating during the day (rd).
5.2.4 Discussion

5.2.4.1 Validity
To improve the external validity of this intervention study, the measurements were performed in the field. Thereby the risk was introduced that, besides a change in working schemes, other important variables could change between working schemes, such as the amount of refuse collected or the length of the workday. Fortunately, this was not the case as could be concluded from the results of the task analyses. The durations of the tasks and activities were almost exactly as could be expected on the basis of the rotation scheme. The same holds true for the amount of refuse collected and the number of two-wheeled containers collected. Therefore, differences found between working schemes can indeed be attributed to the introduction of job rotation.

It was hard to find volunteers for this study due to the length of the measurement period (fifteen days) and the impact of, in particular, the collecting of the urine before and after work. The participating refuse collectors/truck drivers were probably more interested in their workload and recovery than their colleagues. Assuming that the refuse collectors in this study might be healthier and better trained than their colleagues, it can be speculated that the effect of job rotation on workload and recovery might in fact be more pronounced than found in the present study.

The mean values of \( \dot{V}O_2 \) during collecting, perceived exertion during collecting and excretion of adrenaline during a workday were about the same as found in other studies among Dutch refuse collectors. However, the noradrenaline excretion in the present study was lower than in the aforementioned study among refuse collectors of two-wheeled containers (57 ng-min\(^{-1}\) versus 71 ng-min\(^{-1}\)). An explanation might be that the physical work demands in the study of Stassen et al. were higher. For instance, the collecting time lasted 16% longer, 20% more refuse was collected and 17% more two-wheeled containers were collected compared to the present study.

5.2.4.2 Job rotation
Job rotation resulted in a decrease of the physical workload compared to collecting two-wheeled containers. However, the effect was smaller when compared to a more physically demanding collecting method such as collecting refuse in plastic bags. Job rotation resulted in a decrease in the mental workload compared to truck driving. No increase in mental workload was seen between job rotation and only collecting refuse. However, job rotation increased the physical workload compared to truck driving only. Therefore, the question remains whether the decrease of the physical workload for the refuse collector is more important from a preventive health perspective than the increase of the physical workload of
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the truck driver. Two remarks should be made. First, truck drivers are exposed to whole body vibration and sit behind the wheel in a relatively static posture. Especially for whole body vibration there is strong evidence that it increases the risk of (low) back complaints. To a lesser extent this holds true for a static work posture. On the other hand, pushing and pulling seem to increase the risk of musculoskeletal complaints of the upper extremity rather than of the (low) back. Therefore, job rotation between driving a truck and collecting two-wheeled containers might be an effective measure to reduce the risk of upper extremity and (low) back complaints. Quantifying the exposure of the truck driver due to whole body vibration and static work posture would have given more insight, but would not have provided a definitive answer. The different measurement techniques would have resulted in outcomes that could not be directly compared. Second, job rotation resulted in a more complete job. The possibilities for functional and social interaction increase, while collecting two-wheeled containers with two employees compared to the solitary function of truck driver. Taken these two remarks into account, it is expected that job rotation results in an improvement of the physical and mental workload of truck drivers and refuse collectors.

Wright and Edwards concluded that the introduction of job rotation in the aluminium industry resulted in an increased productivity. In the present study, an increase in productivity due to job rotation only is not likely to occur, because the duration of collecting and the energetic workload did not differ between the rotating and the collecting schemes. Finally, no significant differences in recovery were found between truck driving, refuse collecting and rotating. This is in apparent contradiction with the study by Sluiter et al., in which differences in excretion rates of adrenaline and cortisol during the evening were found between mental work (management and supervisors), physical work (workers at a flower auction, construction workers and refuse collectors) and combined mental and physical work (male nurses and drivers working for a municipal ambulance service). However, the combined group of mental and physical work did not perform the same work as was performed in the mental and in the physical group. Hence, the work is not performed according to a job rotation scheme. Probably typical job characteristics of the ambulance work such as working in shifts and exposure to stressful emotional events also attributed to the less favourable recovery.

This study does not reveal a difference between rotation between or during the day on workload and recovery. This does not mean that the two schemes do not differ on these aspects. Due to the visco-elastic properties of tissues, duration influences the level of exposure and recovery time in a non-linear way. However, this is not reflected in our results. More complex measurements, such as analysis of time dependent effects on the tissues give more insight. From a biomechanical point of view, it can be speculated that a more frequent change might be more favourable. From a psychological point of view,
several studies already have pointed out the beneficial effects of driving only a limited time during the day on fatigue and safety \(^{39,62,135}\). In view of these findings, it seems more desirable to rotate during the day than between days.
5.2.5 Conclusion
Job rotation is an effective measure to reduce the physical workload compared to only refuse collecting and to decrease the mental workload compared to only truck driving. No effects were seen on recovery. No differences were found between rotating between days and rotating during the day.

Acknowledgement
This project was financially supported by the Association for Waste and Cleansing Management (NVRD) and the Association of Dutch Waste Management Companies (VNA). This study could not have succeeded without the dedication and support of the employees and management of the Dutch refuse management companies of Leusden, Opperdoes and Zaandam. The authors thank Sijmen Kuiper, Suzan van Damme and Sharda Ramlal for their analyses of the catecholamine and cortisol samples and Marianne Six Dijkstra and Annieck Ricken for their support in data processing.