Effectiveness of interventions to reduce workload in refuse collectors
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Summary

On the basis of several scientific studies, it is stated in chapter 1 that refuse collectors around the world are at risk for musculoskeletal complaints. The Netherlands forms no exception to this finding. The high physical workload in refuse collecting is seen as an important risk factor for these complaints. Moreover, in The Netherlands the amount of domestic refuse is still increasing. From the year 1993 to 2000 the amount per citizen increased from 478 to about 566 kg. Especially the sick leave due to musculoskeletal complaints have led to the introduction of a unique job specific guideline for refuse collectors in The Netherlands. The guideline has taken effect in 1998 and is enforced by the Labour Inspection Service of the Dutch Ministry of Social Affairs and Employment. Before implementing additional preventive interventions, several refuse collecting organisations wanted to know the effect of these interventions on prevalence of complaints. The ergonomic interventions are:

I. Increase in the number of two-wheeled containers at a gathering point,
II. Redesign of a two-wheeled container with a content of 0.240 m$^3$,
III. Job rotation between collecting bags, sweeping streets and driving a sweeping machine, and
IV. Job rotation between collecting two-wheeled containers and driving a refuse truck.

The main objective of this thesis was to determine the efficacy of four ergonomic interventions on work demands and workload of refuse collectors in The Netherlands. For the fourth ergonomic intervention also the effectiveness was determined in terms of need for recovery and (sick leave due to) musculoskeletal complaints.

In chapter 2 the work demands and the workload of refuse collectors in three different time periods are described to find out whether earlier interventions have been as effective as expected. The work demands and physical workload of refuse collectors in Haarlem in 1997 were compared with the results of a study performed in Haarlem in 1985, and with the results of a national study performed in 1993. The study consisted of a field study, a simulation experiment in the laboratory, and a questionnaire concerning work demands and health effects among eighteen refuse collector who collected bags and two-wheeled containers.

The work demands and the energetic workload were not more favourable in Haarlem in 1997 when compared to Haarlem in 1985 or the national study conducted in 1993. On several important parameters, such as the time carrying plastic bags or pushing two-wheeled containers, amount of refuse collected and percentage of the maximum oxygen uptake during a working day, the results in Haarlem 1997 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.
Summary

In conclusion, the earlier interventions had been little effective in reducing the work demands and physical workload of the refuse collectors.

In chapter 3 the effect of the number of two-wheeled containers at a gathering point on the energetic workload and work efficiency was studied in order to design an optimal gathering point for two-wheeled containers. Three sizes of gathering points were investigated, i.e. with 2, 16 and 32 two-wheeled containers at a gathering point. The collecting of two-wheeled containers was simulated in a test circuit. Eighteen men participated in the experiment. The energetic workload was quantified by the parameters oxygen uptake and heart rate. Besides, the perceived exertion was measured. The work efficiency was quantified as the time it took to collect 32 two-wheeled containers. The maximum acceptable number of two-wheeled containers collected during an 8-hour working day was estimated using the energetic criterion of 30% of the maximum oxygen uptake.

The size of the gathering point had no effect on the oxygen uptake, heart rate or perceived exertion. However, the work efficiency and the maximum acceptable number of two-wheeled containers during an 8-hour working day were higher in the conditions with 16 and 32 two-wheeled containers at a gathering point compared to the condition with 2 two-wheeled containers at a gathering point.

In conclusion, the increase in the number of two-wheeled containers at a gathering point from 2 to 16 or 32 resulted in a reduction of the time collecting, but did not affect the physical workload during collecting.

Chapter 4 illustrates the effect of a redesign of a two-wheeled container of 0.240 m$^3$. § 4.1 describes the effect of variations in the centre of mass (COM) and handle location of a two-wheeled container on exerted forces at the handles and joint loading. Exerted forces at the handles and joint loading were quantified in four participants during steady, two-handed pushing and pulling of two-wheeled containers with nine COM locations and eleven handle locations. Kinematics and exerted forces were assessed as input for an upper body static 2D linked segment model. Using standard linked segment mechanics, reactive forces and net moments at the elbow, shoulder and low back were calculated.

The COM location turned out to have a major influence on exerted forces and joint loading, whereas the influence of the handle location was moderate. Participants adapted the tilt angle of the two-wheeled container in response to variations in handle location, but hardly did so in response to variations in COM location.

In conclusion, it is expected that the current design of Dutch two-wheeled containers can be improved by moving the COM of the loaded two-wheeled container in the direction of the axis of the wheels and by slightly increasing the height of the handles.
Subsequently, in § 4.2 the mechanical and perceived workload were compared between working with a two-wheeled container redesigned according to these recommendations and working with a standard two-wheeled container in a mock up situation. The three changes of the redesigned two-wheeled container were 1) a displacement of the location of the COM in the direction of the axis of the wheels, 2) a slight increase of the handle location in vertical and horizontal direction towards the refuse collector and, 3) an increase in diameter of the wheels. The content of the two-wheeled container remained 0.240 m$^3$. Nine refuse collectors performed the most frequent daily activities with both two-wheeled containers in the laboratory. Kinematics and exerted hand forces were assessed as input for detailed 3D biomechanical models of the low back and shoulder to estimate net moments at the low back and shoulders, compressive forces at the low back and contact forces at the glenohumeral joint. Also, the refuse collectors rated the ease of handling the two-wheeled containers on a five-point scale.

The use of the redesigned two-wheeled container resulted in a decrease of the exerted hand forces, a decrease of net moments at the low back and shoulders, and a decrease of the contact forces at the glenohumeral joint compared to the standard two-wheeled container. However, pulling an empty redesigned two-wheeled container onto the pavement resulted in an increase of the net shoulder moment. No differences between both two-wheeled containers were found for the compressive forces at the low back. Pushing and pulling the redesigned two-wheeled container was rated as easier than pushing and pulling the standard two-wheeled container. No differences in subjective ratings were found for rotating the two-wheeled container and for pulling an empty two-wheeled container on the pavement.

It was concluded that, provided that empty two-wheeled containers are placed back on the pavement as little as possible, the introduction of the redesigned two-wheeled container could result in a reduction of the low back and shoulder load.

Chapter 5 describes the effect of job rotation on the workload in two types of refuse collecting. In § 5.1 the effect of job rotation between collecting polythene bags, sweeping streets and driving a sweeping machine is evaluated on the physical workload in male employees working at a refuse collecting department. Before the introduction of job rotation, an employee worked as a street sweeper, as a refuse collector, or as a driver. After the introduction of job rotation, every employee was enabled to alternate between two out of the three possible jobs during the day, i.e. refuse collecting/street sweeping, refuse collecting/driving, or street sweeping/driving.

Sixteen employees voluntarily participated in this study. To increase the number of employees in each group, four of the six possible jobs were studied. Eight employees worked according to a non-rotation scheme. The two most physically demanding jobs were selected:
four men worked as refuse collectors and four men worked as street sweepers. The other eight employees worked according to a rotation scheme. The most and least physically demanding jobs were selected: four men worked as refuse collectors/street sweepers and four men worked as street sweepers/drivers. The work demands were assessed by means of systematic observation of tasks, activities and working postures. The physical workload was assessed measuring the energetic load and perceived load during a full working day. The work demands and physical workload of the refuse collectors were higher than the work demands and physical workload in the other three studied jobs. The other three jobs only seemed to differ on the time the trunk was flexed. This occurred more frequent in the rotating job of refuse collector/street sweeper than in the other two jobs.

In conclusion, the results indicated that job rotation resulted in a overall reduction of the physical workload of the employees of the refuse collecting department.

In § 5.2 job rotation between truck driving and collecting two-wheeled containers was studied. Besides, rotation between days and rotating during the day were compared. Three teams of three workers participated in this study. The physical workload, mental workload and recovery after work were assessed. 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.
In chapter 6, the effectiveness of job rotation between truck driving and refuse collecting was evaluated on need for recovery, 12-month prevalence of musculoskeletal complaints (low back, neck, shoulder, hand/wrist and knee) and sick leave due to musculoskeletal complaints. A one-year prospective study among male refuse collectors working with two-wheeled containers was performed, using standardised questionnaires. The reference group consisted of employees who worked as non-rotating refuse collectors at t₀ and at t₁ (group NR-NR). The experimental group consisted of employees who rotated between refuse collecting and truck driving at t₀ and at t₁ (group R-R). During the study, an intermediate group was formed. This group consisted of employees who were non-rotating refuse collectors at t₀ and rotated between refuse collecting and truck driving at t₁ (group NR-R). The questionnaire was presented to 280 employees working at 23 different companies. At t₀, 87% of the questionnaires was completed and at t₁ 66%: 46 from group NR-NR, 63 from group R-R, and 21 from group NR-R. Difference scores were calculated for need for recovery and prevalence rate ratios (PRs) for (sick leave due to) musculoskeletal complaints. The dependent variables were controlled for confounding.

The adjusted need for recovery of group R-R was marginally significantly lower than need for recovery of the reference group. Group NR-R did not differ from the reference group on need for recovery. Groups R-R and NR-R had a more than two times higher risk for complaints of the low back than the reference group. The adjusted PRs for the other body regions of the groups R-R and NR-R were not significant. The adjusted PRs for sick leave due to musculoskeletal complaints of the groups R-R and NR-R were also not significant.

In conclusion, job rotation between collecting of two-wheeled containers and driving a truck seemed to coincide with a reduced need for recovery and was associated with an increased risk of low back complaints. Job rotation had no effect on sick leave due to musculoskeletal complaints. These results, however, might be influenced by the healthy worker selection effect in the reference group of non-rotating refuse collectors and its inverse in the rotating groups.

Chapter 7 firstly addresses the issue of a careful selection of dependent variables for work demands and workload in intervention studies. Only if epidemiological evidence exists for a relationship between a dependent variable and an associated health complaint, an improvement in the dependent variable can be interpreted as predictive of a reduction in the associated health complaint. Unfortunately, only for a few dependent variables of work demands and workload such a relationship has been established. Therefore, we should be careful when using work demands and physical workload as predictors of possible health complaints.
Summary

Secondly, the question is answered which one of the four ergonomic interventions would have the highest efficacy. Despite the use of different dependent variables in the four intervention studies, an educated guess is made with the help of the workload dimensions level and duration. It was concluded that a combined intervention that reduces simultaneously the time collecting and the peak workload during collecting probably is most effective. This can be obtained by simultaneously implementing a redesigned container and a job rotation scheme. Finally, recommendations are formulated for practice, for instance that refuse collecting organisations should play an active role to secure that health issues are taken into account when new production systems are developed and implemented, and for research, for instance that more good quality studies should be performed in which the effectiveness of ergonomic interventions is at stake.