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Effect of Job Rotation on Work Demands, Workload, and Recovery of Refuse Truck Drivers and Collectors

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Job rotation is often advocated to reduce workload, but its efficacy has seldom been investigated. The aim of this study is to compare the work demands, workload, and recovery among truck driving, refuse collecting, and rotating between these two jobs, between days and during the day. Three teams of 3 employees each participated in this study. Work demands were assessed by systematic observation of tasks and activities. Workload was quantified by means of heart rate, oxygen uptake, subjective ratings, and urinary excretion rates of catecholamines. Recovery was quantified by excretion rates of catecholamines after work. Job rotation between driving and collecting is an effective measure to reduce physical workload as compared with collecting only and to decrease mental workload as compared with driving only. However, job rotation resulted in increased physical workload as compared with driving only. Job rotation did not increase mental workload as compared with collecting only. No effects were seen on recovery. No differences were found between rotating between days and during the day. Actual or potential applications of this research include the recommendation that before job rotation is introduced, its efficacy be determined in terms of well-chosen workload measures because a reduction in work demands does not directly imply a reduction in workload. Therefore, job rotation might be less effective than expected.

INTRODUCTION

The Tayloristic principle of division of labor and job specialization is a fundamental issue in the organization of work. This principle resulted, in many cases, in a subdivision of work into small cycles in order to increase productivity. In recent decades teamwork, not job specialization, has often been seen as a superior form of work organization (Frieling, Freiboth, Henniges, & Saager, 1997). A special form of teamwork is rotating between jobs. *Job rotation* can be defined as "regularly alternating between different jobs within an organization on the basis of a scheme or spontaneously alternating on the basis of the workers' personal needs.

A major economic benefit of job rotation is the increase in flexibility. Also, several studies have indicated possible ergonomic benefits of job rotation in reducing workload (Hinnen, Laubli, Guggenbuhl, & Krueger, 1992; Rodahl & Vokac, 1977) and the risk of musculoskeletal complaints (Hinnen et al.; Roquelaure et al., 1997). Jobs with a dynamic type of work and great differences in muscular activity should be able to benefit especially from the introduction of job rotation (Jonsson, 1988). Therefore, job rotation is often advised as an effective measure to reduce workload (Carnahan, Redfern, & Norman, 2000; Kuijer, Frings-Dresen, De Looze, Visser, & Van der Beek, 2000; Van Wendel de Joode, Burdorf, & Verspuy, 1997). Despite its

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acclaimed effect in the literature, only one study was found that evaluated the effect of job rotation on workload. In a study performed at a refuse collecting company, the introduction of job rotation among collecting bags, sweeping streets, and driving a small cleansing machine seemed to result in a marked reduction in physical workload (Kuijer, Visser, & Kemper, 1999).

In many countries (Frings-Dresen, Kemper, Stassen, Crolla, & Markslag, 1995; Luttmann, Laurig, & Jäger, 1992; Poulsen et al., 1995; Robazzi, Moriya, Favero, Lavrador, & Luis, 1997), 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, in comparison with only collecting refuse. However, driving can be a demanding mental task, especially on city streets (Zeitlin, 1995). The driver must not only 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 only a small distance.

Moreover, in a recent study (Sluiter, Frings-Dresen, Van der Beek, Meijman, & Heisterkamp, 2000), slower recovery after work was found in a group with both mental and physical work demands as compared with groups with only physical or only mental work demands. Recovery was measured by the excretion of catecholamines in the urine. Therefore, the first aim of this study was to compare truck driving, collecting refuse, and rotating between these two jobs with regard to physical workload, mental workload, and recovery. The hypotheses are that job rotation, as compared with collecting refuse only, results in reduced physical workload and increased mental workload and recovery and that compared with truck driving only, it results in an increase in physical workload and recovery and a decrease in mental workload.

Results obtained from a biomechanical energy storage model of the low back (Van Dieën & Oude Vrielink, 1994) indicated that a marked reduction in workload is achieved only if there is a considerable difference in workload between the tasks and if 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 hr (Carnahan et al., 2000). 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 (Mathiassen & Winkel, 1996). 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 favorable than rotating across work shifts (Ellis, 1999). To our knowledge, no studies have been published that verified this assumption. Therefore, the second aim of this study was to compare rotating between days and rotating during the day with regard to physical workload, mental workload, and recovery. Based on the limited number of studies, the hypothesis is that job rotation during the day is more favorable in terms of physical and mental workload and recovery than is job rotation between days.

METHOD

Participants

Three different refuse management companies in the Netherlands participated in this study. From each refuse management company, a team of 3 male employees, all of whom had worked for more than 1 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 form. For the 9 participants, mean age was 38 years (SD = 6), mean height was 180 cm (SD = 5), mean weight was 80 kg (SD = 10), and mean maximum oxygen uptake (VO_{2max}, L/min) was 3.7 (SD = 0.5). Note that because of the long-term absence of 1 participant, the VO_{2max} values involve only 8 participants.

Working Schemes

The following working schemes were compared: truck driving only, refuse collecting only, and “rotating in general.” The rotating in general working scheme consisted of two working schemes: rotating between truck driving and refuse collecting during the day, and rotating between truck driving and refuse collecting between days. Every participant worked at least 1 week as a truck driver, 1 week as a refuse collector, 1 week as a truck driver/refuse collector rotating between days, and 1 week 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, 5 study weeks were needed: 3 weeks during which 1 participant only drove the truck and the other 2 participants collected refuse, 1 week during which a team of 3 participants rotated between days, and 1 week during which a team of 3 participants rotated during the day.

To ensure that the working schemes differed only 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 during the weeks in which so-called grey refuse (nonorganic fraction) was collected. This was done to ensure a relatively 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 9 weeks. The measurements were performed on the last 3 workdays of the week, Wednesday, Thursday, and Friday. During the first 2 days of the week, the participants got acquainted with the working scheme. The order of the four working schemes was varied across the three teams. Because of participants' personal circumstances, on one occasion in every team the working scheme had to be changed. During the week in which the participants rotated during 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 that each member would drive the truck for one period per day.

Work Demands

The work demands were assessed by means of a task analysis. The time each 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 Task Recording and Analysis on Computer system (TRAC-system; Frings-Dresen & Kuijer, 1995). The following variables and categories within variables were observed on a real-time basis (Frings-Dresen, Kemper, Stassen, Crolla, et al., 1995): task (i.e., collecting, driving, and pausing, defined as the time during which an employee took a break from his work); activity (i.e., walking, pushing, pulling, throwing, or sitting); load handled (i.e., empty or full two-wheeled containers); and number of objects handled (i.e., one or two two-wheeled containers).

The different working schemes were compared with regard to the following work demand variables: duration of the working day, time driving (steering and/or sitting in the truck), time collecting two-wheeled containers, time pushing and pulling (full or emptied) two-wheeled containers, and number of collected two-wheeled containers. In addition, 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 (when only collecting two-wheeled containers, or when job rotation was between days) or three (when job rotation was during the day).

Workload and Recovery

Physical workload was quantified by heart rate (HR) (beats/min), estimated percentage of the maximum oxygen uptake (%VO_{2max}), urinary excretion rate of noradrenaline (nanograms/min), and perceived workload. Mental workload was quantified by the urinary excretion rate of adrenaline (nanograms/min) and the perceived workload. Recovery was quantified by the urinary excretion rate of noradrenaline (nanograms/min) and adrenaline (nanograms/min) after the workday and during the evening.

Heart rate and estimated oxygen uptake. During the workday the HR of each refuse collector was continuously recorded with a sample rate of 15 s using the Polar Accurex Plus (Polar

Electro, Finland). The oxygen uptake (VO_2) during the collecting task was estimated by determining the individual relationship between HR and VO_2 of each refuse collector in the laboratory during his work activities. For the task of collecting two-wheeled containers, a specific submaximal treadmill test was developed (Frings-Dresen, Kemper, Stassen, Crolla, et al., 1995). The protocols of these tests provided for intervals of walking alternated with intervals of pushing. Following the submaximal test, VO_{2max} was determined by running on a treadmill against an increasing slope (Frings-Dresen, Kemper, Stassen, Crolla, et al., 1995). On the basis of the HR recorded during collection of two-wheeled containers at the workplace and the individual relationship between HR and VO_2 from data of the submaximal treadmill test, the VO_2 during collecting was estimated. The VO_2 was calculated as $\%VO_{2max}$. To estimate the average $\%VO_{2max}$ during the workday, Equations 1 and 2 were used. The VO_2 during tasks other than collecting was based on the study of Frings-Dresen, Kemper, Stassen, Markslag, et al. (1995): $VO_{2\text{not collecting}} = 0.38$ L/min). The duration of the time collecting and not collecting was derived from the task analyses performed.

$$VO_{2\text{workday}} = (C_{\text{ollecting minutes}} \times VO_{2\text{collecting}} + N_{\text{ot collecting minutes}} \times VO_{2\text{not collecting}})/W_{\text{orkday minutes}} \quad (1)$$

$$W_{\text{orkday minutes}} = C_{\text{ollecting minutes}} + N_{\text{ot collecting minutes}} \quad (2)$$

Catecholamines. The participants were asked to collect all urine during the workdays on which the measurements were performed and to provide samples at approximately 07:00 (Sample 1), 11:00 (Sample 2), 14:00 (Sample 3), 17:00 (Sample 4), 20:00 (Sample 5), and before going to bed, at about 23:00 (Sample 6). The urine was collected in a jar that contained 0.7 g of citric acid. The time and 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 min before the time to urinate. After collection, the jars were kept as cold as possible until further preparation started, within 24 hr, as described by Sluiter, Van der Beek, and Frings-Dresen (1998). The urinary concentrations (in nanograms/milliliter) were multiplied by the volume of the corresponding urine sample (in milliliters). This amount (in nanograms) 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 (nanograms/min).

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

Most teams started working between 07:00 and 07:30. Therefore, Sample 1 was taken to make a valid comparison possible within and between participants for Sample 2. Otherwise, the time until the former urination might have varied between participants and/or days. Samples 2, 3, and, depending on the length of the workday, 4, were averaged to reflect the mean excretion rate during the workday. To reflect the degree of recovery after work, Sample 5 was taken. For the degree of recovery during the evening, Samples 5 and 6 were averaged.

Subjective ratings. During the workday, the participant filled in scales for perceived exertion (Zijlstra, 1993), perceived fatigue (Borg, 1990), perceived activeness, and perceived tenseness. The scale for perceived exertion ranged from 0 (*not at all effortful*) to 120 (*tremendously effortful*). Perceived exertion was rated after each collecting period and before going to the garbage dump. 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 collection 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 perceived activeness and 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.

Data Analyses

To compare differences in work demands, workload, and recovery for the driving-only, collecting-only, and rotating in general work schemes, we calculated the mean values over the 3 workdays during truck driving only and refuse collecting only for each participant. For rotating in general, we calculated the mean value of the variables for work demands, workload, and recovery for the 3 workdays on which rotating between days took place and the mean values for the 3 workdays on which rotating during the day took place. Then both values were averaged.

Next, a multivariate analysis of variance (MANOVA) for repeated measures was used to test differences among the driving-only, collecting-only, and rotating in general working schemes for work demands as a whole – that is, duration of the working day, time driving (steering and/or sitting in the truck), time collecting two-wheeled containers, time pushing and pulling (full or empty) two-wheeled containers, amount of refuse collected, and number of collected two-wheeled containers.

A MANOVA for repeated measures was also used to test differences for the different combinations of workload variables – that is, HR during the working day and $\%VO_{2max}$ during the working day, excretion of catecholamines during the working day, perceived exertion and perceived fatigue during the working day, and perceived activeness and tenseness during the working day. During the driving-only working scheme, the collecting task was not performed. Therefore, differences between the collecting-only and rotation in general working schemes for HR and $\%VO_{2max}$ during the collecting task were tested using paired *t* tests.

Finally, a MANOVA for repeated measures was used to test differences among working schemes for the two types of recovery – that is, catecholamine excretion rates after work and catecholamine excretion rates during the evening.

The results of the MANOVA tests are presented in Table 1. When a significant main effect was found for a MANOVA test, differences among the three working schemes were post hoc tested using the LSD procedure. In addition, the mean values of the work demands, workload, and recovery variables for the driving-only, collecting-only, and rotating in general working schemes will be presented graphically in figures, which will show the relations among those variables more clearly than can a table of absolute values (Gillan, Wickens, Hollands, & Carswell, 1998). Each figure displays the average values of the 9 participants' mean values over the 3 workdays for the working schemes of interest as well as the standard error.

To compare differences in work demands, workload, and recovery between the two working schemes of rotating between days and rotating during days, we used paired *t* tests. For all tests, a *p* value smaller than .05 was considered statistically significant. Significant *p* values of the post hoc tests and *t* tests will be mentioned in the text.

RESULTS

As expected, the working schemes had an effect on work demands (Table 1). Post hoc tests revealed no difference in duration of the working days among driving only, collecting only, and rotating in general (Figure 1). The workday lasted on average 8.5 hr. The duration of the workday did also not differ between rotating between days and rotating during the day. The driving time during the collecting-only working scheme was about 30% of the driving time during the driving-only working scheme ($p < .001$) and about 60% of the driving time during rotating in general ($p < .001$). Driving time did not differ between rotating during the day and rotating between days. No two-wheeled containers were collected during the driving-only working scheme. The duration of the collecting task during the rotating in general working scheme was about 60% of the collecting task during the collecting-only working scheme ($p < .001$). About the same effect size was found for the activities pushing an empty container ($p < .001$), pushing a full container ($p < .001$), pulling an empty container ($p = .007$), and pulling a full

TABLE 1: MANOVA Test Results for the Three Working Schemes (Driving, Collecting, and Rotating in General) on the Work Demands, Workload, and Recovery Variables

	F	*df* 1	*df* 2	*p*
Work demands				
Overall	6.73	18	18	<.001*
Length of working day	0.48	1[a]	16	.520
Driving	113.44	1[a]	16	<.001*
Collecting	162.47	1[a]	16	<.001*
Pushing full container	126.57	1[a]	16	<.001*
Pushing empty container	171.96	1[a]	16	<.001*
Pulling full container	203.51	2	16	<.001*
Pulling empty container	69.38	2	16	<.001*
Amount of refuse	281.61	1[a]	16	<.001*
No. of containers	523.04	2	16	<.001*
Workload				
Overall	5.89	4	28	.001*
Heart rate	12.41	2	14	.001*
$\%VO_{2max}$	66.38	2	14	<.001*
Overall	3.76	4	28	.014*
Adrenaline	8.78	2	14	.003*
Noradrenaline	4.62	2	14	.029*
Overall	3.83	2	32	.020*
Perceived exertion	5.85	2	16	.012*
Perceived fatigue	2.53	2	16	.110
Overall	1.27	2	32	.302
Perceived activeness	2.00	2	16	.168
Perceived tenseness	0.88	2	16	.436
Recovery after work				
Overall	0.33	4	28	.854
Adrenaline (20:00)	0.41	2	14	.675
Noradrenaline (20:00)	0.31	2	14	.737
Recovery during evening				
Overall	0.46	4	28	.762
Adrenaline (20:00 & 23:00)	0.35	2	14	.711
Noradrenaline (20:00 23:00)	0.73	2	14	.501

[a]Refers to Greenhouse-Geisser test.
*p < .05.

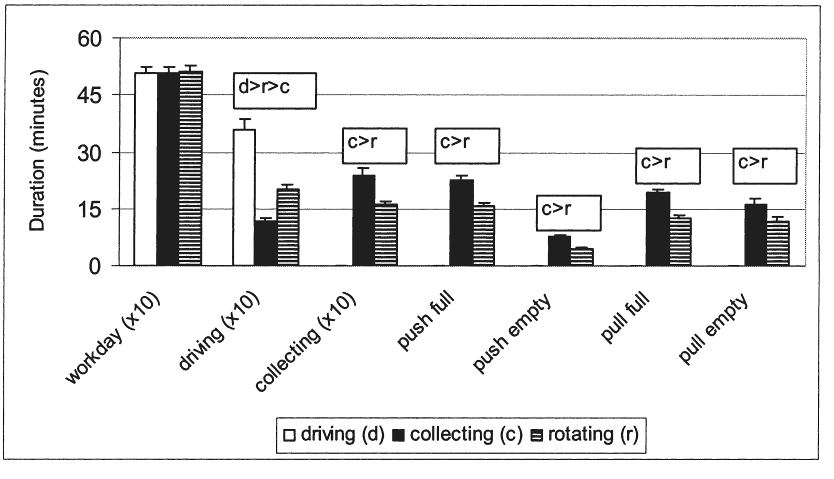

Figure 1. Means and standard errors of workday duration, driving and collecting tasks, and the activities of pushing and pulling full and empty two-wheeled containers per day for the driving-only, collecting-only, and rotating working schemes.

two-wheeled container ($p < .001$). The collecting time and the duration of pushing and pulling full and empty two-wheeled containers did not differ between rotating during the day and rotating between days.

As intended, the amount of refuse collected and the number of two-wheeled containers collected differed between collecting only and rotating in general. The amounts were 9313 and 6517 kg ($p < .001$), respectively. The number of two-wheeled containers were 432 and 300 ($p < .001$), respectively (Figure 2). No differences were found for rotating between days and during the day.

The working schemes had an effect on HR and $\%VO_{2max}$ during the working day (Table 1). The HR during the workday was the lowest during the driving-only working scheme (78 beats/min), as compared with the collecting-only (88 beats/min; $p = .004$) and rotating in general working schemes (85 beats/min; $p = .018$; Figure 3). The HR during a workday did not differ between the collecting-only and rotating in general working schemes. The HR during a workday did not differ between rotating between days and during the day. The $\%VO_{2max}$ during the workday was lowest for driving only (10.5%; $p < .001$) and highest for collecting only (23.1%; $p < .001$). The $\%VO_{2max}$ during the workday was 19.1% for rotating in general and did differ from driving only ($p < .001$) and collecting only ($p = .001$). No difference was found for the $\%VO_{2max}$ between the two rotation schemes. The HR and $\%VO_{2max}$, both measured during the collection task, did not differ between collecting and rotating: The HRs were 96 beats/min and 100 beats/min, respectively, and the data for $\%VO_{2max}$ were 38% and 40%, respectively. Again, no difference was found for rotating between days and during the day.

The working schemes had an effect on the excretion rate of catecholamines during the working day (Table 1). The excretion rate of adrenaline during driving only was higher than during collecting only ($p = .018$) and rotating in general ($p = .006$; Figure 4). The excretion rate of noradrenaline was lower during driving only than during collecting only ($p = .046$) and rotating in general ($p = .029$). The excretion rate of noradrenaline did not differ between collecting only and rotating in general. No differences were found in the excretion rate of catecholamines between rotating between days and rotating during the day (Table 1).

The working scheme had an effect on perceived exertion (Figure 5; $p = .020$), whereas no significant differences were found for the other subjective scales (Table 1). The collecting-only working scheme resulted in higher perceived exertion than did rotating in general ($p = .039$) and driving only ($p = .027$). These last two working schemes did not differ. No differences were found for rotating between days and during the day.

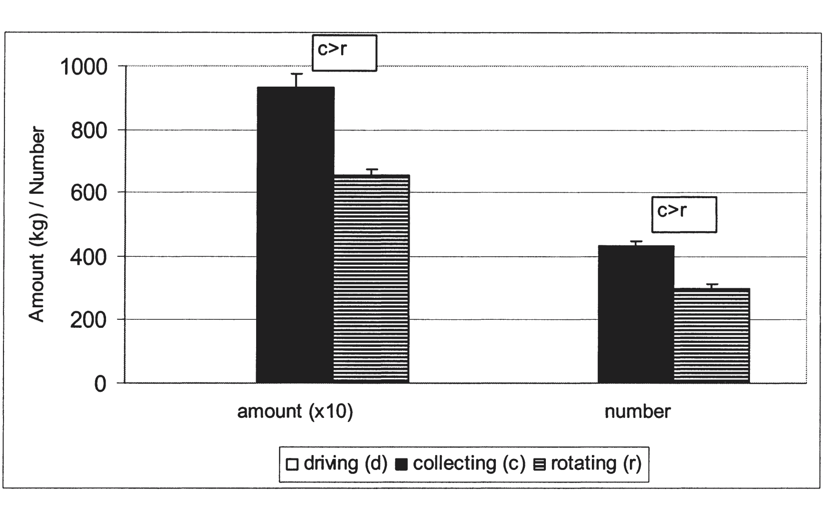

Figure 2. Means and standard errors of the amount of refuse and the number of two-wheeled containers collected during a day for the driving-only, collecting-only, and rotating working schemes.

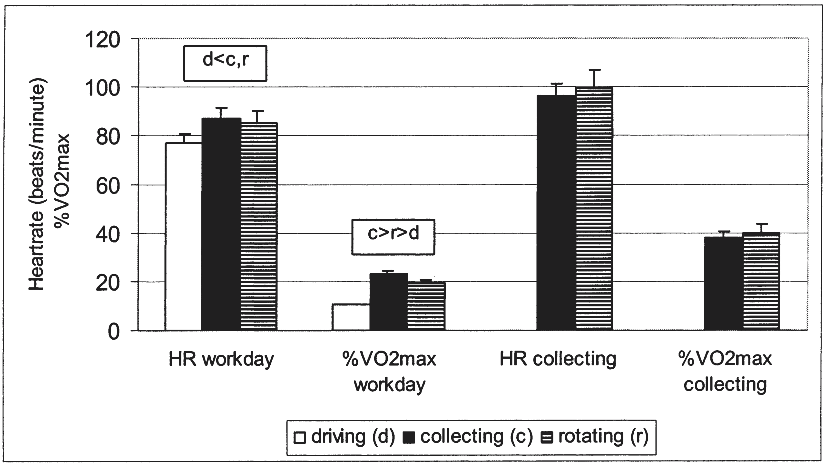

Figure 3. Means and standard errors of heart rate (HR) and percentage of the maximum oxygen uptake (%VO_{2max}) during the day and during the collecting task per day for the driving-only, collecting-only, and rotating working schemes.

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 (Table 1; Figure 6).

DISCUSSION

Validity

To improve the external validity of this intervention study, the measurements were performed in the field. Thereby the risk was introduced that other important variables, in addition to a change in working schemes, 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 can be concluded from the results of the task analyses. The durations of the tasks and activities were almost exactly what would 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

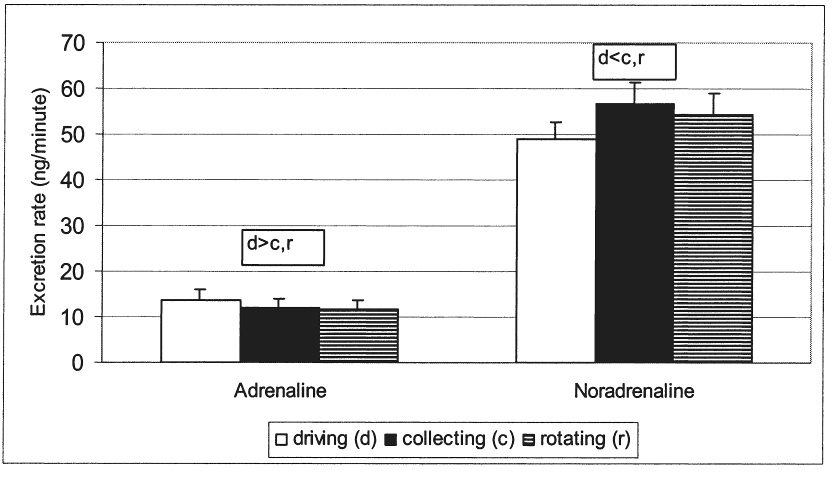

Figure 4. Means and standard errors of the rates of urinary excretion of adrenaline and noradrenaline during the driving-only, collecting-only, and rotating working schemes.

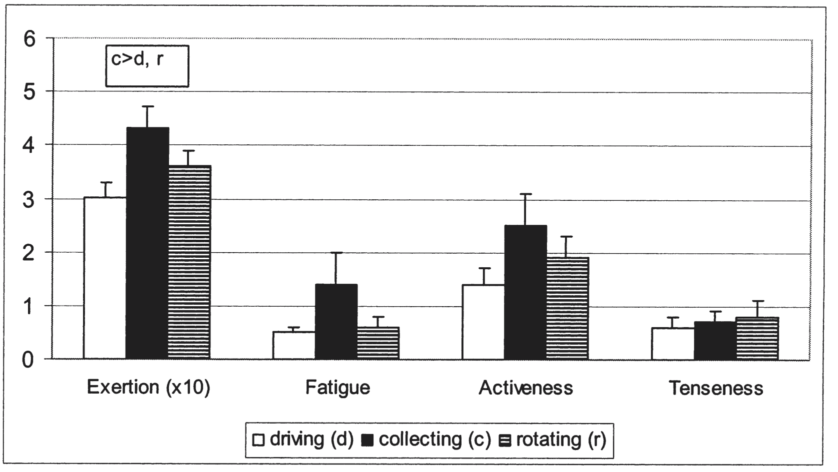

Figure 5. Means and standard errors of the subjective ratings for exertion, fatigue, activeness, and tenseness for the driving-only, collecting-only, and rotating working schemes. The subjective ratings for local musculoskeletal discomfort are not shown because the values were nearly zero.

differences found between working schemes can indeed be attributed to the introduction of job rotation.

The mean values of VO_2 during collecting, perceived exertion during collecting, and excretion of adrenaline during a workday were about the same as were found in other studies among Dutch refuse collectors (Sluiter et al., 2000; Stassen et al., 1993). However, the noradrenaline excretion in the present study was lower than that in the Stassen et al. study of refuse collectors using two-wheeled containers (57 vs. 71 ng/min, respectively). An explanation might be that the physical work demands in the Stassen et al. study were higher. For instance, the collecting time lasted 16% longer, 20% more refuse was collected, and 17% more two-wheeled containers were collected as compared with the present study.

Job Rotation

Job rotation resulted in decreased physical

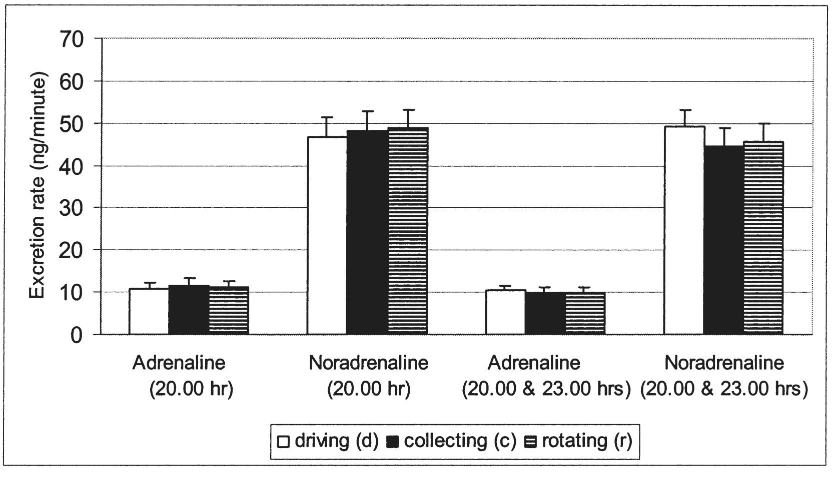

Figure 6. Means and standard errors of the urinary adrenaline and noradrenaline excretion rates after work (20:00) and during the evening (20:00 and 23:00) for the driving-only, collecting-only, and rotating working schemes.

workload, in terms of %VO_{2max} and perceived exertion, as compared with collecting two-wheeled containers only. The effect was smaller when compared with a more physically demanding collecting method, such as collecting refuse in plastic bags (Kuijer et al., 1999). Moreover, job rotation resulted in decreased mental workload, in terms of the excretion rate of adrenaline, as compared with driving only. These findings were only qualitatively in line with the observed reduction in work demands as compared with collecting two-wheeled containers only and driving only. For instance, during the rotation in general working scheme, the time spent on the collecting task decreased about 33% as compared with the collecting-only working scheme. However, quantitative effects were quite different. The reduction in HR, percentage oxygen uptake, and noradrenaline excretion rate during the working day was about 4% (*ns*), 17% (significant difference), and 4% (*ns*), respectively. Therefore, a significant reduction in work demands does not always result in a similar significant reduction in all aspects of workload. Hence, before introducing job rotation as a preventive measure, an efficacy study with well-chosen outcome measures should be performed.

A possible negative effect of the introduction of job rotation was that physical workload increased as compared with driving only. Therefore, the question remains as to whether the decreased physical workload for the refuse collector is more important, from a preventive health perspective, than the increased physical workload for the truck driver. Two remarks should be made:

First, on one hand, truck drivers are exposed to whole-body vibration and sit behind the wheel in a relatively static posture. There is strong evidence that whole-body vibration increases the risk of low-back complaints (Bernard, 1997; Burdorf & Sorock, 1997; Hoogendoorn, Van Poppel, Bongers, Koes, & Bouter, 1999), and this also holds true, though to a lesser extent, for a static work posture (Burdorf & Sorock, 1997). On the other hand, pushing and pulling seem to increase the risk of musculoskeletal complaints of the upper extremities, rather than of the low back (Hoozemans, Van der Beek, Frings-Dresen, Van Dijk, & Van der Woude, 1998; Van der Beek, Frings-Dresen, Van Dijk, Kemper, & Meijman, 1993). Therefore, job rotation between driving a truck and collecting two-wheeled containers might be an effective measure to reduce the risk of low-back and upper extremity complaints. Quantifying the exposure of the truck driver 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 with the physical workload measures used in the present study.

Second, job rotation probably resulted in a more complete job. The possibilities for functional and social interaction increase when two employees collect two-wheeled containers, as compared with the solitary function of truck driver. Taking these two remarks into account, it might be expected that job rotation would result in an improvement in the physical and mental workload of truck drivers and refuse collectors.

No significant differences in recovery were found among truck driving, refuse collecting, and rotating. This is in apparent contradiction with the study by Sluiter et al. (2000), in which differences in excretion rates of adrenaline during the evening were found among 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 (mental and physical work) did not perform the same work as that performed by the mental work group and the physical work group. Hence, the work was not performed according to a job-rotation scheme. It is also probable that typical job characteristics of the ambulance work, such as working in shifts and exposure to stressful emotional events, also attributed to the less favorable recovery.

This study does not reveal a difference between rotation between days and rotation during the day on workload and recovery. This does not mean that the two schemes do not differ on these aspects. Because of the viscoelastic properties of tissues, duration influences the level of exposure and recovery time in a nonlinear way (Kumar, 2001). However, this is not reflected in our results. More complex measurements, such as analysis of time-dependent effects on the tissues, could give more insight. From a biomechanical point of view, it can be speculated that more frequent changes might be more favorable (Van Dieën & Oude Vrielink, 1994). From a psychological point of view, several studies have pointed out the beneficial effects on fatigue and safety of driving only a limited time during the day (Feyer, Williamson, Jenkins, & Higgings, 1993; Horne & Reyner, 1999; Sluiter, Van der Beek, & Frings-Dresen, 1999). In view of these findings, it seems more desirable to rotate during the day than between days. However, in the present study no differences were found between rotation during the day and between days.

In conclusion, job rotation between truck driving and refuse collecting is an effective measure to reduce physical workload, as compared with refuse collecting only, and to decrease mental workload, as compared with truck driving only. However, job rotation resulted in increased physical workload, as compared with truck driving only. Job rotation did not increase mental workload in comparison with refuse collecting only. No effects were seen on recovery. In only qualitative terms, these findings were in line with the observed reduction in work demands for collecting refuse only and truck driving only. No differences were found between rotating between days and rotating during the day.

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