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Evaluation of work-rest schedules with respect to the effects of postural workload in standing work

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The influence of four work-rest schedules (60-min shift – 15-min break, 45 – 15, 30 – 15, 30 – 30) on acute effects of physical workload in the back and legs due to standing work was investigated in 12 poultry inspectors. Subjective discomfort in the legs and back, and swelling in the distal lower leg were significantly affected, with the 60 – 15 schedule leading to a higher postural load as compared with the other schedules. No effect on spinal shrinkage was found. It was concluded that the 60 – 15 schedule should be avoided. An optimal work-rest schedule considering visco-elastic deformation of the spine would probably involve frequent short breaks, whereas longer breaks would seem more effective considering leg swelling.

1. Introduction

In recent decades mechanization and automation have greatly reduced the prevalence of physically demanding jobs. In general, this development appears not to have been accompanied by a decrease in the prevalence of work-related disorders. In spite of the lower intensity of workload, the incidence of most notably musculoskeletal disorders remains high. Several explanations for this apparent disparity have been proposed. As a part of the development mentioned above, many functions have become more monotonous and static in nature. Some authors have suggested possible mechanisms for tissue damage, while in these situations overall load on the musculoskeletal system may be low. For instance, in low-intensity muscle contractions, type I motor units are recruited preferentially. Consequently, they are continuously active during static tasks and may be at risk of injury (Hägg 1991, Vøllestad 1993). In addition, prolonged low-intensity loads could increase the likelihood of tissue damage, due to the visco-elastic, time-dependent behaviour of biological tissues (Goldstein *et al.* 1987, van Dieën and Tousaint 1995). For instance, prolonged axial loading of the spine and the resulting visco-elastic deformation cause stress concentrations in the intervertebral disc, putting it at a higher risk of failure (Adams *et al.* 1996). A third explanation might be that the prolonged low-intensity loads do not provide an adequate stimulus for adaptation, leaving the tissues vulnerable to incidental high loads (Vøllestad 1993).

In addition, the incidence of another class of health problems, circulatory disorders in the lower extremities, can be attributed to the static nature of such tasks.

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Due to the vertical working posture, either sitting or standing, in combination with the absence of dynamic leg muscle activity, venous return will be hampered (Dupuis and Rieck 1980, Winkel 1985), through this mechanism chronic vascular insufficency may develop in the long-term (Dupuis and Rieck 1980, Winkel 1985, Hebeda *et al.* 1993).

Each of the proposed mechanisms suggests that prevention of tissue damage should not so much be sought in further lowering the peak intensities of the work load, but possibly in reducing the time integrated (cumulative) load and in allowing for more variation and periodic recovery (Vøllestad 1993, van Dieën and Oude Vrielink 1994). The administration of work-rest schedules might provide a means to these ends. The aim of the present study therefore, was to study the influence of different work-rest schedules on the effects of physical work load. The study was performed on poultry inspectors working at conveyor belts in slaughterhouses.

The development towards relatively light but monotonous jobs is clearly exemplified in many functions in Dutch slaughterhouses. The production process has to some extent been automated. However, in view of the nature of the product many steps in the process still require human decisions and actions, an example of which is the task of the poultry inspector, who checks the quality of each of about 70 broilers passing each minute on a conveyor belt. This task requires the inspector to be standing at the conveyor belt for a major part of the working time. In view of the mental work load involved in the inspection of poultry, the inspectors alternate every 30 min between working at the conveyor belt and resting or performing other (usually administrative) tasks. Recently, however, an increase was suggested in the work-rest ratio of these inspectors to increase efficiency. Instead of 30-min shifts alternating with 30-min breaks, longer or equally long shifts (30, 45, or 60 min), alternating with shorter breaks (15 min) have been proposed. The study presented here was part of a larger project in which the effects of these work-rest schedules on performance, mental workload and physical workload were investigated. The present paper deals exclusively with the physical workload.

This study consisted of two parts. In the first part a questionnaire was administered to all poultry inspectors in The Netherlands to establish what the focus of the second part of the study should be. This second part consisted of an experimental study on the effects of various work-rest schedules. In the following paragraph the results obtained from the questionnaire study will be briefly outlined, after which the main part of the paper deals with the experimental study.

2. Questionnaire study

To gain insight in the prevalence of work-related disorders in the population of poultry inspectors, a slightly modified version of a standard questionnaire (Hildebrandt and Bongers 1991, Hildebrandt 1992) was used. A total of 366 questionnaires was sent by mail to everyone licensed to work as a poultry-inspector in The Netherlands. Of these 238 (65%) were returned. Of these, 115 respondents were for the major part of their worktime involved in poultry inspection. Only the data obtained from the latter respondents were used for the present analysis.

The mean age of the respondents, among whom there were only four women, was 42 (SD 11) years; mean number of years experience on the job was 15 (SD 7) and the mean number of hours worked at the conveyor belt was 27 (SD 10) per week and 6 (SD 2) per day. Figure 1 gives an overview of the 12-month prevalence of some potentially work-related health complaints.

As can be seen, low back pain is common among the respondents (58%). Also pain in the neck and shoulder area show a relatively high prevalence (36 and 38%). In addition, the number of respondents reporting pain in the lower extremities, especially around the ankle and foot is high (30%).

Figure 2 represents the percentage of respondents who reported experiencing discomfort related to various aspects of the physical workload. As seen, standing, working with the trunk bent and repeated arm movements appear to cause discomfort in a large percentage of the respondents.

In conclusion, repetitive arm movements and potentially related neck and shoulder pain and static work load (bent trunk, standing) and potentially related back and leg complaints are of interest in this group. It was decided to focus the experimental study primarily on these aspects of the physical workload. The topic of the present paper is restricted to the effects of the postural load on the back and legs.

3. Methods

3.1. *Subjects*

Twelve male poultry inspectors working in two poultry processing plants were recruited. Their mean age was 40 (SD 12) years and mean number of years as inspectors was 9 (SD 7). When comparing these subjects with the group of respondents in the survey, no consistent differences in age, health status or experienced work load were discernible. Only the number of years as inspectors was somewhat, though not significantly, lower among the group of subjects. On this basis the subjects were considered representative for the total population of poultry inspectors.

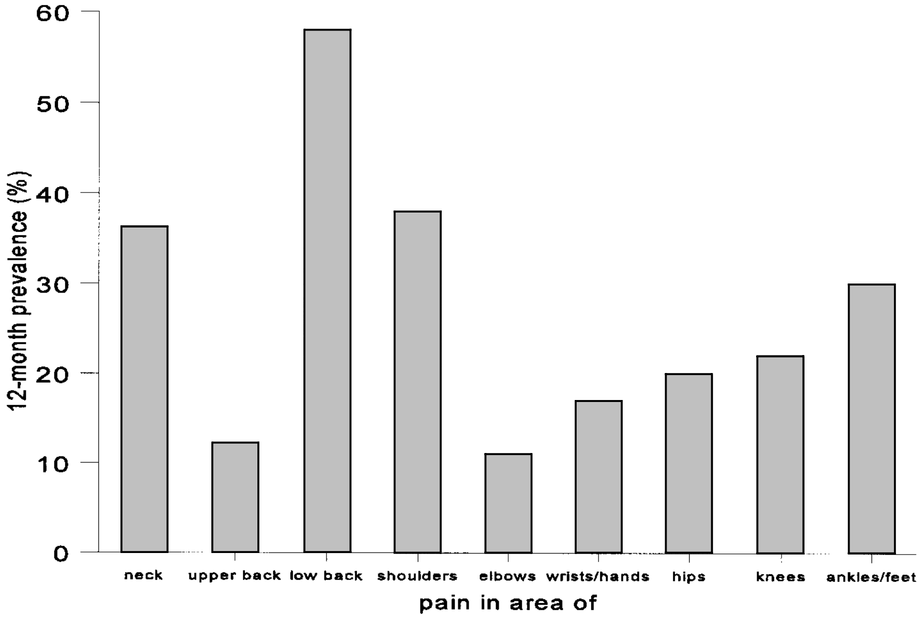

Figure 1. Prevalence of some potentially work-related complaints in poultry inspectors.

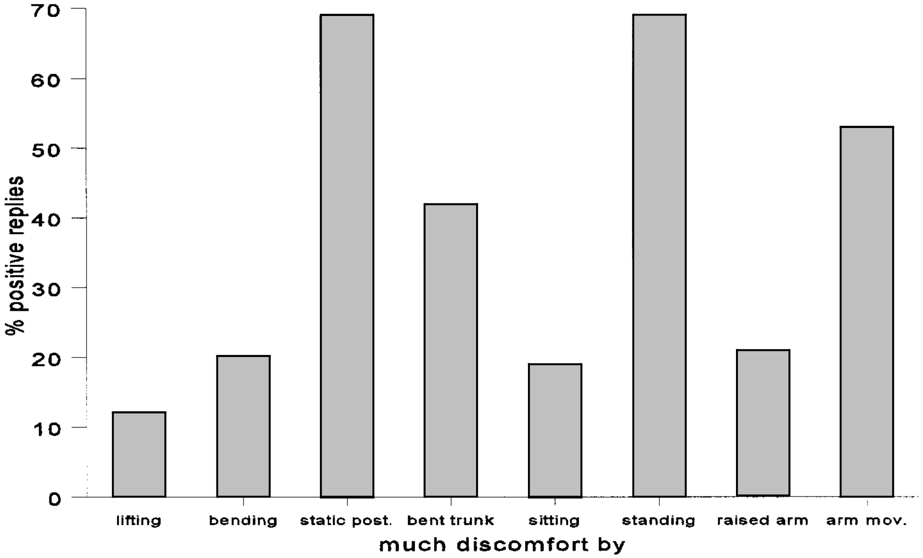

Figure 2. Percentage of the responding poultry inspectors experiencing much discomfort during work as a consequence of aspects of physical load.

3.2. *Measurements*

As an objective indicator of the time-dependent (visco-elastic) effect of back load, spinal shrinkage was measured. As a consequence of compressive forces acting on the spine, spinal structures, especially the intervertebral discs, lose height. Due to the visco-elastic nature of this process this heightloss is time-dependent. It is thought to reflect the interacting effects of load intensity and load duration, and as such provides unique information on spinal workload (Eklund 1986, van Dieën and Toussaint 1993). The stadiometer designed to measure spinal shrinkage, which is reflected in a loss of stature, has been described extensively previously (van Dieën *et al.* 1994). In short, the instrument was designed to obtain an accurate control of the posture of the subject, which allows for reproducible measurements of stature. Before the actual experiments the subjects were trained in using the instrument according to the protocol described by van Dieën *et al.* (1994). Length changes were determined by averaging the results of five measurements in each set and expressing the results as a percentage change from the average of the five measurements made before the first shift.

The effects of prolonged standing on leg circulation were studied by means of the measurement of swelling of the lower leg, using an optical leg volume meter (Volometer, Bösl, Aachen, Germany; Hebeda *et al.* 1993). During measurements the subjects sat facing the instrument, with their right leg stretched horizontally and the lower leg and foot supported in the instrument. The supports were designed to ensure as much as possible a constant position of the leg in the instrument. Three measurements were taken each time. Between each measurement the leg was completely removed from the instrument and subsequently replaced on the supports. The instrument determines the circumference at each centimetre of lower leg length, starting at 10 cm above the sole of the foot to 40 cm upwards, by means of an optical technique. The series of circumferences were interpolated by means of a spline function, such that an estimate of the circumference at each millimetre was obtained. Subsequently, a cross-correlation function was used to correct the measurements for errors in replacing the leg in the instrument. Based on an assumed cylindrical shape of each 1 mm section of the leg the cross-sectional area at each millimetre was calculated. Subsequently the volume of the middle 30 cm of the measured volume was calculated by numerical integration. This was considered the volume of the total lower leg/foot segment. In addition, the volumes of the ankle (distal 15 cm) and calf area (proximal 15 cm) were determined separately. The resulting volumes of each set of three single measurements were averaged within these sets. Swelling was determined by expressing the results of each set of measurements as a percentage change from those of the set taken before the first shift.

Subjective ratings of discomfort experienced were obtained by means of the diagram described by Corlett and Bishop (1976). In addition to the diagram, a 10-point rating scale (Borg 1982) was used to estimate the degree of discomfort. Subjects were first asked to mention the body parts, if any, in which they experienced discomfort and subsequently the intensity of it in each part mentioned. Scores obtained for selected body parts in the diagram were summed to get an overall score for the back and the legs.

3.3. *Procedure*

Four work-rest schedules were studied, the schedule in use at present, consisting of a 30-min shift with a 30-min break (30 – 30), and three schedules with a break of 15 min, one of which with the same shift duration (30 – 15), and two with longer shifts (45 – 15 and 60 – 15). The schedules were studied in sequence of shift duration, with 60 – 15 first and 30 – 30 last. Each new schedule began with a training period. Before testing the 60 – 15 schedule, the most severe change compared with the usual work-rest schedule, a 3 week training was provided. Before each of the other schedules training was 1 week.

The experiments were carried out in 1 week per plant, for each work-rest schedule, on the first 3 days of the week. During the breaks the subjects walked quietly from their work place at the conveyor belt to a room where they took rest, usually in a seated posture. On each day, five sets of all measurements were taken on two of the inspectors. The first set was taken before the first shift (approximately 06:00 and 07:00 h in the two plants respectively; except for the local discomfort ratings, which were made directly following the first shift), the second halfway through the morning (approximately 08:30 and 09:30 h), the third in the hour before the lunchbreak (approximately 10:30 and 11:30 h), the fourth in the first rest period after lunch (approximately 13:30 and 14:00 h) and the last at the end of the working day (approximately 15:30 and 16:00 h).

3.4. *Statistics*

All variables were tested for an effect of the time of day and of the experimental conditions using a repeated measures analysis of variance. For this analysis the dependent variables were logarithmically transformed to enhance conformity with the distribution assumptions made in the analysis of variance. *Post-hoc* comparisons were made by means of a paired *t*-test. Relationships between selected variables were investigated by means of Pearson's coefficient of correlation. In all tests a 5% significance level was used.

4. Results

Figure 3 represents the spinal shrinkage during the day for the four experimental conditions, averaged across subjects. As can be seen during the day a loss of stature occurs ($p < 0.001$). The overall average height loss at the end of the day was 8.1 (SD 3.7) mm, or 0.45 (SD 0.21)% of stature. No effect of the work-rest schedule could be found.

In 17 of a total of 48 series of measurements (each series representing a full working day of one subject), discomfort in the back during at least one shift was reported. Figure 4 represents the averaged discomfort rating obtained in each of the experimental conditions. The analysis of variance revealed no significant effect of time of day, whereas the effect of the work-rest schedule was highly significant ($p < 0.001$). *Post-hoc* testing revealed significant differences only between the 60 – 15 work-rest schedules (mean 1.7 (SD 2.5)) on one hand and the 45 – 15 (0.5 (1.1)), 30 – 15 (0.8 (1.8)), and 30 – 30 (0.2 (0.6)) schedules on the other hand. In addition, it appeared that with a higher work-rest ratio more subjects experienced discomfort in their back: six of 12 subjects in the 60 – 15 condition, five in the 45 – 15 condition, four in the 30 – 15 condition and only two when working according to the 30 – 30 schedule.

No relationship between back discomfort and spinal shrinkage was found. The volume of the lower legs clearly increased throughout the day. The average increase in total lower leg volume at the end of the day was 1.4 (SD 2.4)%, the effect of the time of day being highly significant ($p < 0.001$). The proximal volume increased also by 1.4 (3.0)% ($p < 0.001$), whereas the distal volume increased by 1.6 (2.0)% on average ($p < 0.001$). Only the volume of the distal leg (ankle area) was significantly affected by the work-rest schedule ($p = 0.039$). Figure 5 represents the volume increase in this part of the lower legs for each of the experimental conditions. The

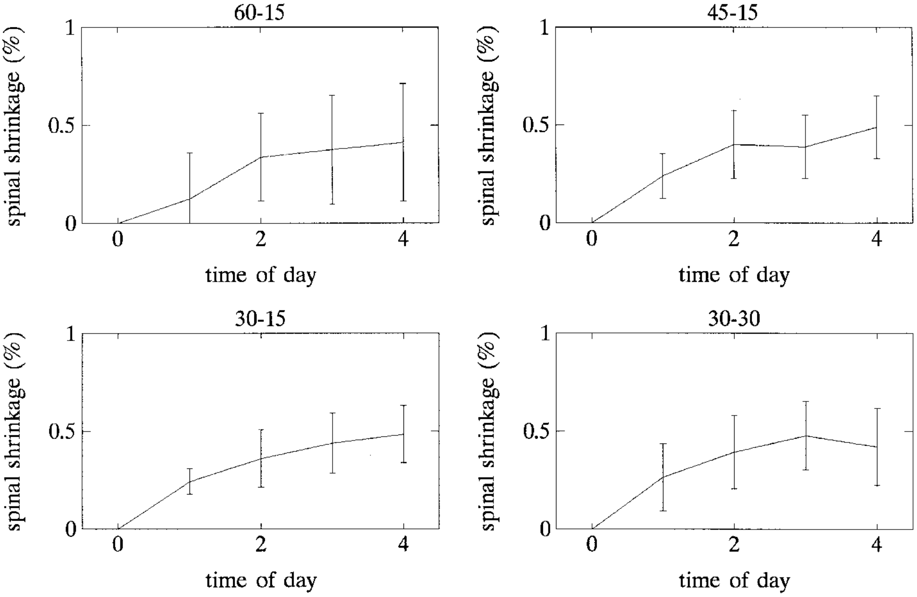

Figure 3. Spinal shrinkage as a percentage of stature over the working day in each of the work-rest schedules (60 – 15, 45 – 15, 30 – 15 and 30 – 30) averaged across subjects. Vertical bars indicate ±1 SD.

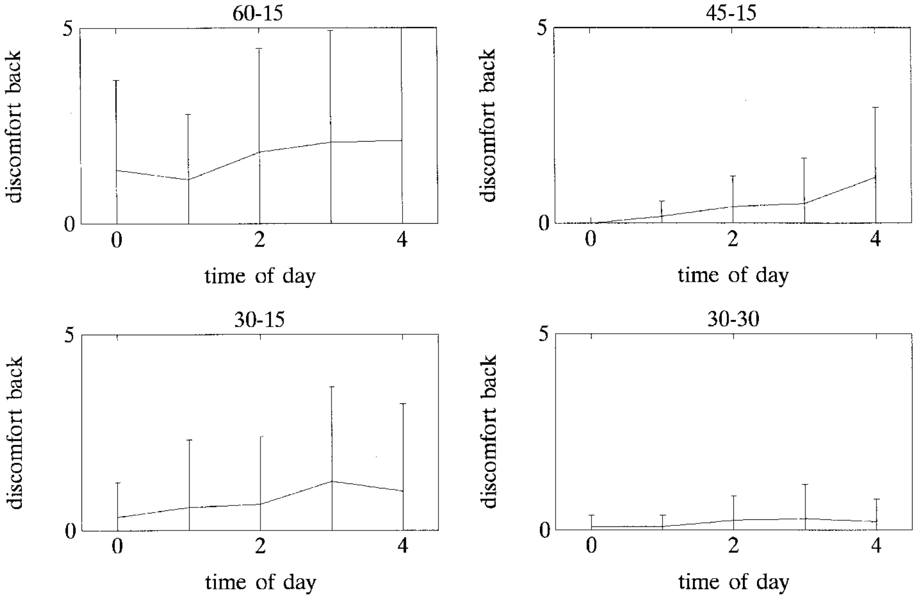

Figure 4. Back discomfort rating over the working day in each of the work-rest schedules (60 – 15, 45 – 15, 30 – 15 and 30 – 30) averaged across subjects. Vertical bars indicate ± 1 SD.

distal volume increase at the end of the day was 2.4 (SD 1.5)% in the 60 – 15 condition, 1.5 (2.1)% in the 45 – 15 condition, and 1.0 (2.5)% and 1.4 (1.8)% in the 30 – 15 and 30 – 30 conditions respectively. *Post-hoc* testing revealed a significant difference between the 60 – 15 and 30 – 30 condition. For the total and proximal volume a non-significant tendency towards more leg swelling in the 60 – 15 condition was found (total volume increase: 2.1 (SD 1.7)%, $p = 0.417$, proximal volume increase: 2.0 (2.5)%, $p = 0.226$).

Distal and proximal volume change were only weakly correlated ($r = 0.55$). The correlation of the distal volume change to the total volume change was somewhat stronger ($r = 0.76$), whereas a strong relationship existed between the proximal volume change and the total volume change ($r = 0.96$).

Subjective discomfort in the legs was reported after at least one shift in 25 of 48 series of measurements, each representing a full working day. Both the time of day ($p < 0.001$) and the experimental condition ($p < 0.001$) affected the discomfort experienced in the legs (figure 6). On average, the score ranged from 0.3 during the first shift to 2.5 during the final shift. In the 60 – 15 condition the average score was 2.7 (SD 3.1), which was significantly higher than in all other conditions, in which the average scores were 0.9 (1.7), 0.8 (1.7), and 0.2 (1.0), for the 45 – 15, 30 – 15 and 30 – 30 conditions respectively. Also the difference between the 30 – 30 condition and all other conditions was significant. In addition, the number of subjects experiencing discomfort in the legs depended on the work-rest ratio, with nine of 12 cases being positive in the 60 – 15 condition, eight in 45 – 15, four in 30 – 15 and one in the 30 – 30 condition.

No clear relationships between any of the leg swelling parameters and the discomfort experienced in the legs were found.

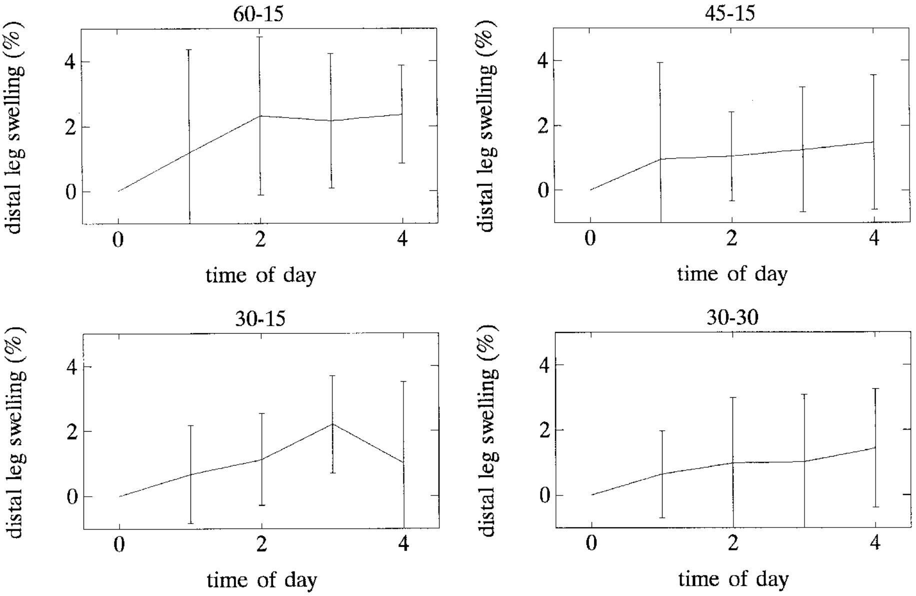

Figure 5. Distal leg volume increase as a percentage of the initial volume over the working day in each of the work-rest schedules (60 – 15, 45 – 15, 30 – 15 and 30 – 30) averaged across subjects. The vertical bars indicate ±1 SD.

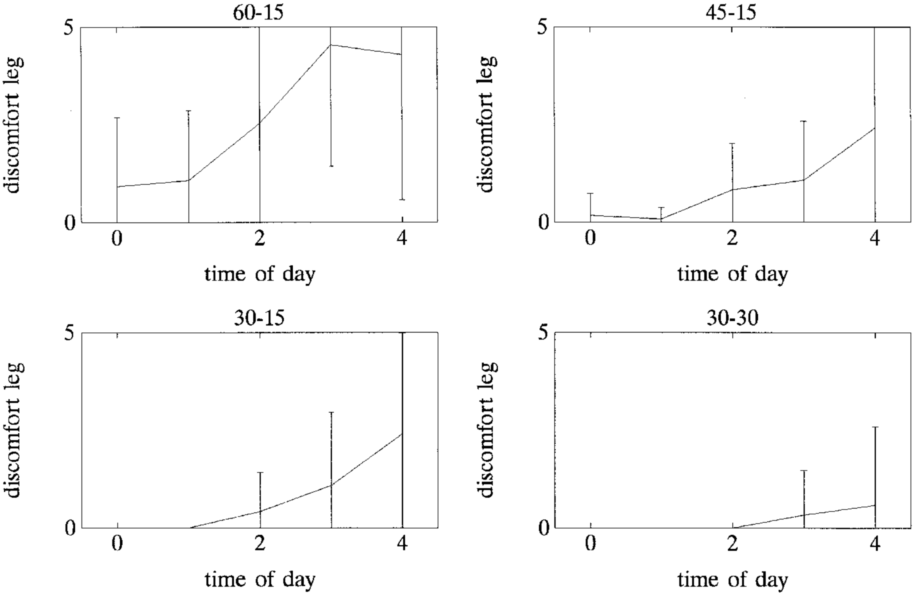

Figure 6. Leg discomfort rating over the working day in each of the work-rest schedules (60 – 15, 45 – 15, 30 – 15 and 30 – 30) averaged across subjects. The vertical bars indicate ±1 SD.

5. Discussion

The aim of the study was to evaluate the influence of work-rest schedules on the effects of postural work load. Significant effects of the work-rest schedule were found on subjective ratings of discomfort and on swelling of the distal lower leg. *Post-hoc* tests revealed that in general the 60 – 15 schedule caused stronger postural load effects, as compared with the 45 – 15, 30 – 15 and 30 – 30 schedules. On this basis it seems advisable in this specific situation not to increase the work-rest ratio above 3 : 1, as obtained in the 45 – 15 schedule.

Visco-elastic deformation of the spine as evidenced by the stature measurements, was not affected by the work-rest schedule. In contrast, discomfort ratings indicated a higher load in the 60 – 15 schedule. There did not appear to be a relationship between the two effects of back load. Some studies have shown weak or moderate correlations between subjective work load or discomfort ratings and spinal shrinkage (Troup *et al.* 1985, Eklund and Corlett 1987). However, in line with the present study, others have not found such a relationship (Boocock *et al.* 1990, Burton *et al.* 1994, Garbutt *et al.* 1994), or have found it only in some situations (Bourne and Reilly 1991). Several factors might contribute to this disparity. First, the subjective ratings in the present study may have been influenced by preconceptions about the work-rest schedules on the part of the subjects, since clearly the subjects had an interest in the outcome of the study. Second, discomfort is not only related to the load on the spine, which is reflected in spinal shrinkage, but also and probably more so to effects on the back muscles.

The mean spinal shrinkage at the end of the work day was 8.1 mm or 0.45% of stature. From an overview of various studies, the diurnal shrinkage between rising and going to bed appears to range from 0.8 to 1.1% of stature (van Dieën and Toussaint 1993). The physical activity during the day in these studies is not known; therefore, these figures cannot be directly compared. In a more comparable study on aircraft loaders, the average stature loss was 6.8 (SD 11.3) mm (Stålhammar *et al.* 1990). The stature loss found in the present study seems large when compared with that in such a physically demanding task as aircraft loading. However, in view of the large interindividual variability of spinal shrinkage, direct comparison across different populations is difficult.

The absence of an effect of the work-rest schedule on spinal shrinkage might be due to a limited difference in compressive load on the spine during the shift and the break. A previous study has shown that breaks in heavy physical work (aircraft loading) reduce spinal shrinkage (Leskinen and Stålhammer 1990). In light administrative work, however, work-rest schedules have also been shown to affect spinal shrinkage (Helander and Quance 1990). Moreover, Althoff *et al.* (1992) have shown spinal shrinkage to recover during sitting after a period of standing, a loading regime which is comparable with the alternation between shift and break in the present study. It seems more likely, therefore, that the absence of an effect is caused by the fact that spinal shrinkage and its recovery stabilize fairly rapidly. The time-course of spinal shrinkage under a constant load is exponential with a time constant of about 4 min in 40-year-old subjects (i.e. half of the shrinkage under a given load has occurred after 4 min; van Dieën *et al.* 1994). Assuming a similar time-constant for the recovery, this would suggest that increasing either shift or break duration beyond about 10 min would have little influence on spinal stature. This observation is supported by a simulation study which implied a higher efficiency with respect to spinal load of frequent short breaks, as compared to longer breaks of an equal total duration (van Dieën and Oude Vrielink 1994).

The load on the legs was affected by the work rest-schedule. Both the swelling of the distal lower leg and the discomfort experienced in the legs indicated that the 60 – 15 schedule induced a higher load than did the other schedules. The 30 – 30 schedule caused significantly less discomfort as compared with the other schedules and a similar tendency can be found when looking at the swelling of the distal lower leg. Nevertheless no relationship between swelling and discomfort was found. This is in contrast with previous studies (Shvartz *et al.* 1982, Winkel and Jørgensen 1986). Again, the discomfort ratings may have been confounded by preconceptions of the subjects and by other physical factors not related to swelling such as muscle fatigue. The latter seems a likely cause, since the relationships found between discomfort and swelling in previous studies were found in sitting, where muscle fatigue is less likely to play a role.

Proximal and total volume increase were highly correlated and can therefore be considered to be interchangeable. This is not unexpected since the proximal volume contributes about 66% to the total volume. The distal volume contains a considerable amount of independent information, considering the correlation of 0.76 with the total volume. Of the three parameters used to quantify lower leg swelling, the distal volume increase appeared to distinguish best between the experimental conditions (both time of day and work-rest schedule). This could be explained by a higher vascular strain and a relatively low efficacy of the 'muscle pump' in the distal leg, where the muscle volume is low. Moreover, variability of the volume might be introduced due to variable muscle activity during the measurements. This is less likely to occur distally, again due to the lower muscle volume in this part of the leg. In addition, the distal volume is more comparable to the volume measured in previous studies by means of water plethysmography (Dupuis and Rieck 1980, Winkel 1985).

The overall averaged increase of the distal lower leg volume was 1.6% ; in the 60 – 15 schedule it was 2.4% . For 'normal dynamic' work an increase of 1.4% (with a confidence interval of 0.95 – 1.80%) has been proposed as a reference value (Winkel 1985). Compared with this the swelling in the 60 – 15 condition was considerable. Dupuis and Rieck (1980) found much more swelling (mean 4.5%) when their subjects stood for 75% of a total of 10 h. When the subjects were sitting for 90% of the 10 h, a volume increase of 3.2% was found. In normal sedentary work, increases of 2.4 and 2.1% were found (Winkel 1985, Hebeda *et al.* 1993), which seem comparable with the results obtained in the 60 – 15 schedule. Thus although the work studied was done standing the increase of the leg volume appears to be limited. Kilbom (1971), using a method more comparable with the total volume measurement in the present study, found increases in leg volume over the working day of 1.8 and 2.3% in the left and right legs of female sales staff. This again is high as compared with the 1.4% increase in total volume in the present study. The relatively limited swelling may be caused by the fact that poultry inspectors have to perform an action on one of the broilers on average four times per min. Due to the speed of the conveyor belt, this involves taking one or several steps. In this respect, the task is not fully static in nature. Oude Vrielink *et al.* (1994) even found leg swelling to be absent in 4 h of standing work during which regular movements occurred.

The breaks in the present study were filled partly with dynamic activity (walking) and partly with seated resting. The work-rest schedule was shown to influence the swelling of the distal lower leg. In contrast, short breaks of up to 5 min filled with either dynamic activity or rest did not significantly affect leg swelling in the study by Dupuis and Rieck (1980). It has been shown that, except for the swelling occurring during the first 2 min after verticalization, swelling and recovery of swelling are slow processes, which do not level off within about 15 min (Stick *et al.* 1993). Thus it can be understood that increasing the duration of a break 15 min, or in contrast increasing shift duration > 30 min, does affect the swelling, whereas short breaks do not have a discernible effect.

In conclusion, the work-rest schedule did influence the postural load as experienced by the subjects and as evidenced by an increase in distal leg swelling. The findings in this study suggest that the 60 – 15 schedule should be avoided. Considering spinal shrinkage, the proposed new schedules do not seem to cause a higher load as compared with the usual 30 – 30 schedule. If a further reduction in back load is desired, it seems advisable to introduce more frequent short breaks in view of the low time constant of spinal shrinkage. Also with respect to muscle fatigue, frequent short breaks are considered more effective than infrequent long breaks (Björkstén and Jonsson 1977). However, when considering leg swelling, the contrary should be advised due to the higher time constants of this process. Alternatively, the back load could be reduced by using a sit – stand seat (Eklund 1986), which is indeed done by some inspectors. This is only feasible for a part of the shift duration, since the speed of the conveyor belt will force the inspector to make several steps when performing an action on one of the broilers. More importantly the use of sit – stand seats has been shown to have an adverse effect on leg swelling (Oude Vrielink *et al.* 1994), probably related to the further reduction of leg muscle activity (Winkel and Jørgensen 1986). It seems difficult to obtain a reduction in both the load on the back and the legs in the present task of the poultry inspector. This dilemma is expected to be a common feature of standing work. Therefore, either priorities will have to be set with respect to which of these two is the most important, or preferably a fundamentally different design of the task is called for. Such a task design would probably have to include short breaks as well as dynamic activity.

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