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The effects of an ergonomic-educational course

Postural load, perceived physical exertion, and biomechanical errors in nursing

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Abstract ***Objectives:*** To evaluate the results of an ergonomic-educational course for nurses we assessed the number and percentage of harmful postures and of ergonomic and biomechanical errors made before and after the course. We also studied the perceived physical exertion. ***Means and methods:*** In all, 12 nurses who had participated in the course (trainees) and 12 who had not (controls) were recorded on video while performing standardized nursing tasks. The wards from which the two groups of nurses came were comparable, as were the patient populations. The nurses were also comparable in some personal characteristics. The tasks they performed included washing, lifting, and repositioning a patient as well as certain tasks other than patient handling. Video recordings were made once before (1–2 weeks) and twice after the course (after 3 months and after 15 months). The harmful postures, the errors made, and the ratings of perceived exertion were measured by means of the Ovako Working-posture Analysis System (OWAS), a checklist, and Borg scores, respectively. ***Results:*** When the first and last measurements of all the above tasks taken as a whole were analyzed the trainees showed a significant improvement in the number and percentage of harmful postures and errors, whereas the controls did not. The same could be concluded for lifting alone. After the course the new work routine did not appear to have caused any extra perceived physical exertion. ***Conclusion:*** It can be concluded that the course was successful, although it should be carefully investigated as to whether nurses remain capable of working safely in daily practice. The work pressure that nurses experience during their normal duties could prevent them from working safely during everyday work.

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Introduction

In the last decade, several intervention strategies to reduce back pain and physical workload in health care have been designed and evaluated, mainly focusing on lifting and moving of patients (Wood 1987; Garg and Owen 1992, 1994; Hersey et al. 1996). It was concluded that training and ergonomic improvements in the transfer of patients could lead to a reduction in the physical workload (Hersey et al. 1996). Possibly, an intervention focusing on other nursing tasks may contribute to a further reduction in physical effort. It is obvious that tasks such as moving and lifting of patients impose a high level of postural strain (Andersson 1985; Gagnon et al. 1986; Garg and Owen 1994), although comparatively little time is spent on these activities in the course of an average workday (Engels et al. 1994). Tasks that involve bending and stooping (e.g., bed making) seem to rank lower in terms of physical stress than do lifting activities (Garg and Owen 1992). However, such activities account for most of the poor work posture because they tend to be the more time-consuming tasks carried out during an average workday (Engels et al. 1994). It may be worthwhile to try to lessen the burden on the musculoskeletal system during nursing activities other than lifting alone. Therefore, we developed an ergonomics-educational course for a small group of nurses so as to decrease the physical workload engendered by nursing activities (Engels et al. 1998).

In this study we investigated as to whether postural load as established by means of the Ovako Working-posture Analysis system (OWAS; Karhu et al. 1977, 1981) and ergonomic and biomechanical errors as established with a checklist (Engels et al. 1997), show a decline when nurses who have completed the course (trainees) are compared with nurses who have not (controls), on the basis of pre- and postintervention results. We also evaluated by means of the Borg CR-10 scale (Borg 1978, 1982) as to whether the perception of physical exertion changes when nurses adjust their behavior to a safer method of working.

Subjects and methods

The ergonomic educational course

A small group of nurses (two from every intervention ward) were trained in safe practice and ergonomic awareness as based on the principles established in previous studies. In a course consisting of 10 meetings, attention was given to a reduction in the physical workload inherent in patient lifting and other nursing activities (i.e., washing of patients, household activities, and administration).

To ensure the acceptance of the proposed ergonomic improvements and guidelines the nurses were trained to work with them (Engels et al. 1998). They also learned to inculcate the necessity of following these safe working guidelines in their own wards. These ergonomically trained nurses (or ET nurses) met on a regular basis once the training course was over and tried to solve minor ergonomic problems on their own. Their main task was to transmit relevant skills and knowledge, to teach their colleagues about safer working habits, and to help increase compliance with new procedures. The program was based mainly on the theories of planned behavior and on concepts of habitual behavior. Key persons (such as the physiotherapists at the nursing homes) were recruited and supervised to become the experts for the program and to back up the ET nurses. Also, steering committees were installed in each of the nursing homes with the task of directing the implementation of the program and taking care of those problems that the ET nurses could not handle themselves (Engels et al. 1998).

Subjects and tasks

In all, 12 Licensed Practical Nurses (LPNs; 10 women and 2 men) selected from the same nursing home were asked to attend the course and to repeat 4 standardized nursing tasks at the following 3 time points: shortly (1–2 weeks) before the start of the course, 3 months after the conclusion of the course, and, finally, 15 months after the course. The mean age, body weight, height, and years in profession of these trainees were 26.5 (SD 5.0) years, 66.1 (SD 7.7) kg, 166.7 (SD 8.6) cm, and 7.2 (SD 4.8) years, respectively. Likewise, 12 female LPNs who did not participate in the course performed the same tasks. These nurses functioned as a control group. Their mean age, body weight, height, and years in profession were 25.9 (SD 5.9) years, 67.3 (SD 12.8) kg, 167.9 (SD 8.0) cm, and 5.7 (SD 2.9) years, respectively. No significant difference between trainees and controls existed in these variables. Furthermore, the wards from which the nurses came were comparable with regard to patient population, ergonomic lay-out, and equipment.

The following tasks were performed by all 24 participating nurses:

1. Washing of the back of a patient and washing of the leg located farthest away while the patient is lying in bed (referred to as *washing*).
2. Transfer of the patient from bed to a wheelchair and vice versa (*lifting*).
3. Assistance of the patient in rising from a curled-up position to lie fully stretched out in the bed and elevation of the patient from a lying position to a comfortable sitting position (*repositioning*).
4. Preliminary activities such as fetching towels, water, and soap; clearing away of used materials; and instruction of the assisting nurse, among others (*non-patient-handling activities*).

The patient role was played by a male volunteer. A female registered nurse played "colleague" to the observed nurse. The tasks were carried out in the same room at all three time points. To guarantee a standardized procedure, written protocols were made for the content of the tasks and the roles of the patient and the colleague. By means of these protocols and the verbal explanations given, the nurses were informed about the particulars of the tasks, which were day-to-day activities for them, just before their performance. The nurses were not restricted in terms of the time required for completion of the tasks, but they were asked to work as much as possible as they were used to in the ward. The "patient" was instructed to act as if he had no leg function whatsoever but was capable of using his arms. His weight was standardized at 73 kg for all occasions with the help of a smock filled with small sand bags. Both patient and colleague were notified not to help the observed nurse unless they were explicitly asked to do so. The same instructions were given before all three moments of measurement. The layout of the room and the equipment that the observed nurses would use (e.g., a lifting device, a rotation disk, a high-low bed, a washbasin, towels, and a pedestal cupboard) were identical for each of the measurements.

Video-recording procedure

The performed tasks were recorded on video tapes, all obtained with the same recorder (Panasonic camcorder type M40E). To achieve as good a view of all the body areas of the subject as possible, the camera-to-subject distance was 4.5 m. The camera was placed in a fixed spot at an angle of 30° with respect to the longitudinal direction of the bed. All nurses wore black tights and a black leotard. White markers measuring 2 cm across were placed on both of their acromions, lateral epicondyli, lateral malleoli, and lateral epicondyli of the femur. Four white markers were placed on their spines (one in the neck area, two thoracally and one lumbally) and three on the abdomen (one on the sternum, one on the umbilicus, and one in between) while the subject was being placed in an anatomically straight-up position. In this way it was possible to follow the movements of the nurses as accurately as possible during evaluation of the video tapes. After the recording, all video tapes were edited and observed in a random sequence so as to blind the observer to the trainee or control status of the nurse and to the moments of measurement. Before the actual evaluation took place, four randomly chosen videos were studied for training purposes by the observer-to-be.

Assessment of physical load

Working-posture load

For observation and evaluation of working postures, basic OWAS (Karhu et al. 1977, 1981) was used. The method is based on "work sampling" (i.e., observations made) at short intervals, assessing the frequency of and the time spent in each posture. A total of 252 different combinations of positions of the back, arms, and legs and of the external load can be defined. The original method was developed by the Ovako Oy Steel company in Finland (Karhu et al. 1977). The method has been described elsewhere in detail (Burdorf 1992; Kant et al. 1991; Engels et al. 1994). An evaluation of the load of occurring postures was done with the aid of four so-called action categories (ACs) as defined by Karhu et al. (1977, 1981). Postures categorized in AC 1 are defined as normal postures. Harmful postures are defined as those postures categorized in OWAS ACs 2–4 (more or less harmful for the musculoskeletal system).

The adopted work postures accessory to the nursing tasks were observed and evaluated twice from the video recordings, with intervals of 30 s elapsing between work-posture observations. To avoid repetition in the moments of work-posture observation, in the second round the initial starting point was shifted to another position in sequence. Observations were made with a hand terminal (Psion Organizer LZ64) and a bar-code registration system (Kant 1994). All external forces that could occur during the performance of the tasks were categorized in advance into the three OWAS categories for external load [(1) below 10 kg, (2) between 10 kg and

20 kg, and (3) over 20 kg]. For example, transfer of the patient by one nurse without a lifting device was classified as category 3. The OWAS data were analyzed using a special computer program (Kant 1994).

Perceived physical exertion

For determination of the perceived exertion the Borg CR-10 scale was used (Borg 1982, 1990). This scale was developed to meet both the requirements of subjective ratio scaling and those of level estimations. In this validated scale, verbal expressions are anchored to the corresponding positions on a ratio scale. Numbers ranging from 0 to 10 are used (from "very, very light exertion" to "very, very hard exertion, almost maximal"), with a defined maximal anchor lying outside the scale (Borg 1990). Using this scale it is possible to gain subjective information per individual from a single response variable (Garg and Owen 1992) and to compound these variables and work with group mean scores for perceived physical stress (Borg 1982). Immediately after the task performance, subjects were asked to write down their scores of perceived exertion for each individual task.

Biomechanical and ergonomic errors

Errors against biomechanical and ergonomic principles – referred to as errors made (such as lifting of a patient weighing 70 kg out of bed alone without the use of a lifting device) – were scored by means of a checklist especially developed for this particular study (Engels et al. 1997). Scores were given by a trained observer of the video recordings, who was allowed to see all video tapes two times at most and then had to complete the checklist. Questions were framed as objectively as possible and answers were to be given as yes or no. In all, 65 questions had to be answered that were equally divided over the tasks.

Data analysis

The time spent on the tasks is expressed in minutes. The differences in mean time spent on a task by trainees and controls were compared by means of an unpaired t-test ($\alpha < 0.05$) for all three moments of measurement.

Mean values for harmful postures, ratings of perceived exertion, and errors made were computed per group and per moment of measurement. By means of an unpaired t-test ($\alpha < 0.05$) a check was made to search for disparity in these outcomes between the trainee group and the control group at the first moment of measurement. The results of the three measurements are shown in Figs. 1 and 2, but only the differences observed between the first and the last measurement for both groups separately were analyzed by means of a paired t-test ($\alpha < 0.05$). This was done to test the maximal achievable contrast. The statistical packages SPSS-PC + 4.1 (OWAS and Borg results) and SAS (checklist results) were used to analyze the results in this way.

Results

Participation

A total of 24 subjects participated at the first moment of measurement. At the second measurement, two trainees and four controls could not perform the tasks owing to sick leave, holiday, or pregnancy. At the third measurement, two trainees had taken up work in another nursing home and two were on holiday. Also, one of the controls was absent. She was the only participant to miss both postintervention measurements.

For the establishment of possible bias due to loss of follow-up, the results recorded at the first moment of measurement for those subjects who missed the second or third measurement were compared with the results noted for nurses who participated in all three measurements. The OWAS scores, Borg scores, and percentage of errors were quite similar. For example, the Borg score at the first moment of measurement was 3.00 for the total experimental group ($n = 12$); for the group who participated at the last moment of measurement ($n = 8$)

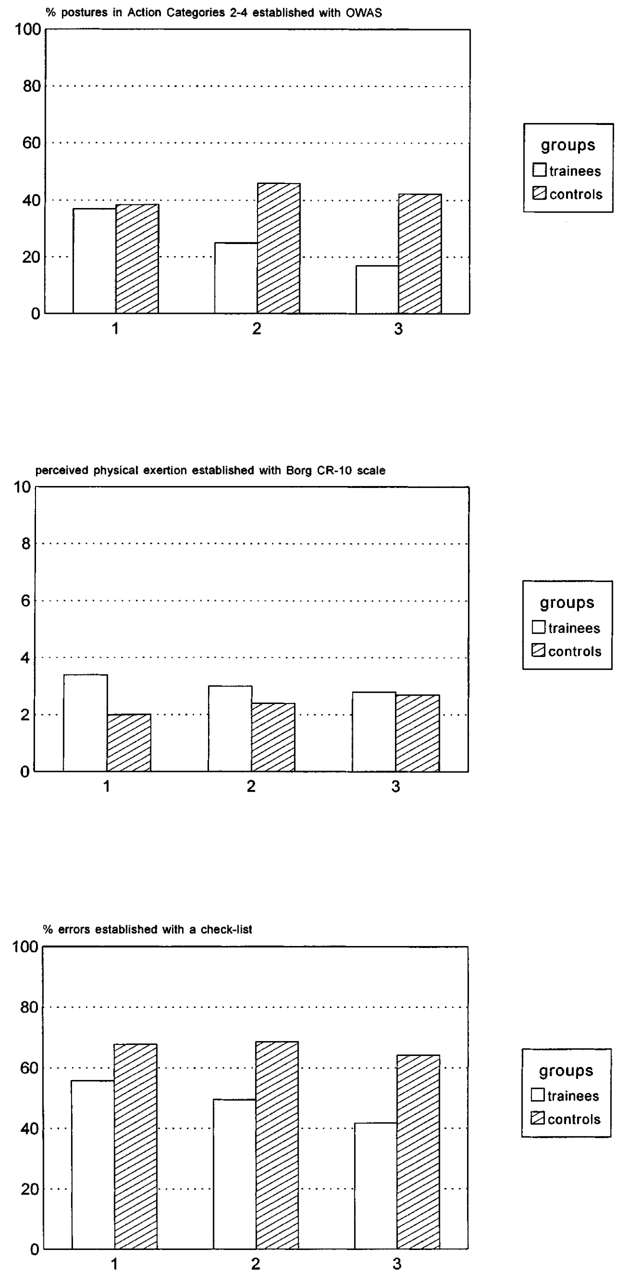

Fig. 1 Postural load, perceived physical exertion, and ergonomic errors made by trainees and controls for all tasks together as determined before (*1*) and two times after (*2,3*) an ergonomic educational course by means of OWAS the Borg CR-10 scale, and a checklist

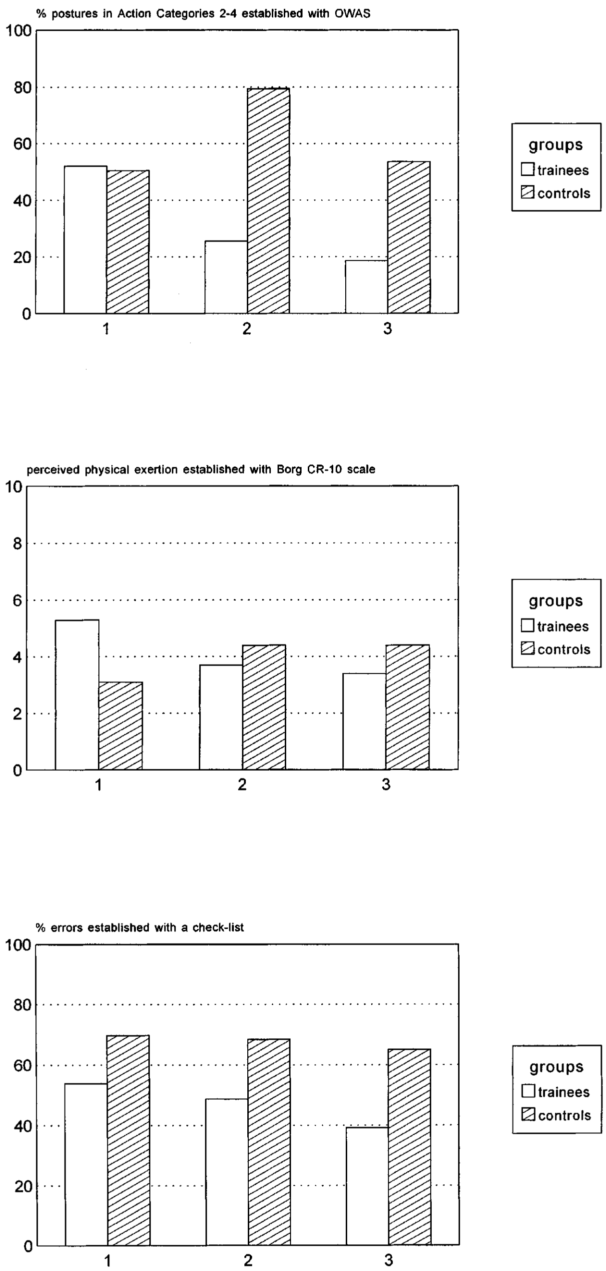

Fig. 2 Postural load, perceived physical exertion, and ergonomic errors made by trainees and controls for "lifting" as determined before (*1*) and two times after (*2*,*3*) an ergonomic educational course by means of OWAS, the Borg CR-10 scale, and a checklist

this score was 2.74 at premeasurement. For the controls these values were 1.74 ($n = 12$) and 1.75 ($n = 11$), respectively. The control who dropped out after the first measurement was excluded from analysis altogether.

Mean time spent on the tasks over the three measurements

In Table 1 the mean time spent and the standard deviation is given for all tasks together and for separate tasks for the group of trainees as well as for the controls per moment of measurement. The mean time the trainees spent on all tasks together was 11.6, 11.5, and 14.6 min for the successive measurements, whereas the controls spent 8.1, 7.0, and 7.8 min, respectively. The differences observed in performance time between trainees and controls, which were statistically significant at all three measurements, are the consequence of more time being spent on lifting by the trainees.

Because the time spent on the specific activities was relatively short, we decided to analyze the results as follows. For the tasks together, comparisons were made between the two groups and three measurements. Additionally, lifting was analyzed as such. Washing and repositioning were taken together and analyzed further as *other patient-handling activities*. The non-patient-handling activities could not be evaluated separately because the time spent on this category was too short to yield conclusive detail (Table 1).

All tasks together

No significant difference existed between trainees and controls in the percentage of harmful postures observed at the first moment of measurement for all tasks together (Fig. 1). However, the ratings of perceived exertion and the percentage of errors differed significantly. Controls made more errors than the trainees, and their Borg scores were lower before the start of the ergonomic educational course. When the results of the first and last measurements of the controls were compared, no statistically significant difference was found in any of the three outcomes. However, for the trainees the percentages noted for both harmful postures and errors made in all tasks together were significantly lower at the third moment of measurement than at the precourse measurement. The mean percentage of harmful postures decreased from 37% to 17% ($P < 0.01$) and the errors made, from 56% to 42% ($P < 0.01$).

The perceived exertion scores showed a different pattern. At the first point of measurement the trainees perceived their exertion more strongly than did the controls. Although there was a slight decrease in the mean scores recorded for the trainees between the first and the last measurement, this trend was not statistically significant. In the trainee group, for all three values a decline could be discerned at the second point of measurement, although less clearly than at the third point (Fig. 1).

Because the time spent on all tasks taken together differed significantly between trainees and controls, a check was made to see whether the *number* of harmful postures found also differed between the two groups. Trainees had a higher number of harmful postures than did the controls at the first measurement (mean number per person 17.1 versus 12.4), but at the last point of measurement the value noted for harmful postures was lower in the trainee group (mean number per person 9.9 versus 13.2) despite their having spent almost double the

Table 1 The mean time (SD) spent on all tasks together and separately for the two groups per moment of measurement in minutes

	Washing	Lifting*	Repositioning	Non patient handling	Overall*
Trainees:					
Measurement 1	2.5 (0.5)	5.1 (3.4)	0.7 (0.4)	1.7 (1.1)	11.6 (3.6)
Measurement 2	2.1 (0.4)	6.2 (2.5)	0.4 (0.3)	1.8 (0.6)	11.5 (3.2)
Measurement 3	2.1 (0.3)	8.8 (1.2)	0.5 (0.2)	2.3 (0.6)	14.6 (1.9)
Controls:					
Measurement 1	2.4 (0.6)	2.2 (2.3)	0.5 (0.3)	1.8 (0.7)	8.1 (3.3)
Measurement 2	2.3 (0.5)	2.0 (0.9)	0.4 (0.2)	1.8 (0.8)	7.0 (1.9)
Measurement 3	2.1 (0.4)	2.5 (3.2)	0.4 (0.3)	1.6 (0.8)	7.8 (4.0)

* Significant differences in time spent between trainees and controls at all three moments of measurement as established by unpaired *t*-test ($\alpha < 0.05$)

time on all tasks together (14.6 versus 7.8 min on average).

Lifting

The percentage of harmful postures did not differ between trainees and controls at the first moment of measurement for lifting (Fig. 2), but the percentages of errors made and the ratings of perceived exertion did ($P < 0.01$). A comparison of the results noted for the controls at the first and the last measurement revealed no statistically significant difference in the percentages recorded for harmful postures or errors made. However, the mean ratings of perceived exertion increased from 3.0 to 4.4 ($P < 0.05$). In the trainee group there was a significant decrease in the percentage of harmful postures (in AC 2–4), in the errors made, and in the perceived exertion at the last point of measurement as compared with the first measurement.

The time spent on lifting was significantly different for trainees and controls. In the case of the number of harmful postures observed at the first moment of measurement, trainees assumed 9.0 and controls, 5.4 harmful postures per person. At the last measurement the numbers were 6.5 versus 5.5 per person during an average period of 8.8 and 2.5 min, respectively. In a comparison of the first and the last measurement, neither for the trainees nor for the controls could any statistically significant difference be found. It was noted that at the first moment of measurement, 6 of the 12 trainees used a hoist when lifting the patient into and out of bed as opposed to only 1 person from the control group. In the second measurement, 8 of 10 trainees used the device, as did 8 of 8 at the last measurement. None of the controls used the hoist at the last two measurements.

Within OWAS scores it is possible to analyze postures of separate regions of the body. The back can be categorized as *straight*, *bent*, *twisted*, or *bent and twisted*. When the last three were classified as harmful the mean number of harmful postures of the back observed in the trainees decreased from 19.2 to 11.3 per person between the first and the last measurement. The values noted for the control group were 13.8 and 14.5 per person at these moments.

Other patient-handling activities

OWAS scores and errors made did not statistically significantly differ at the first moment of measurement between trainees and controls for *other patient-handling activities*, but the perceived exertion did (specific data not shown). Percentages of harmful postures, errors made, and ratings of perceived exertion in the control group show no difference when the first and last measurements were compared. For the trainees the percentages of harmful postures and Borg scores did not show any statistically significant improvement. However, the percentage of errors made was significantly lower at the last moment of measurement.

Discussion

Our study shows a reduction in the percentages and numbers of harmful postures and of errors made during standardized nursing tasks by a group of nurses who participated in an ergonomic educational course. Nurses who had not attended the course did not show any such improvement. Adoption of a new working behavior did not lead to an increase in perceived physical exertion. Trainees needed more time for the execution of the tasks as a whole than did the controls. Further analysis showed that the time spent on lifting was the main cause of this difference, which was probably due to the frequent use of a lifting device by the trainees. Working with a hoist is more time-consuming than manual lifting of a patient, as has also been found by Garg and Owen (1992). The differences in time spent made it necessary to analyze also the number of harmful postures that were observed during lifting. Trainees displayed a significantly higher number of harmful postures at the first moment of measurement than did the controls. This number decreased in the trainees, albeit not significantly, but did not decrease at all in the controls.

Although trainees and controls did not differ in terms of the personal characteristics analyzed or of the lay-out and equipment of the wards they worked in and although the types of patients they cared for were comparable, it is possible that at the preintervention measurement, trainees are more eager to work safely than are controls. The trainees were selected on the basis of their enthusiasm for the topic "working safely" and of their ability to transfer their own knowledge and skills to colleagues in the ward after the completion of the course. Although they might seem to know how to avoid basic ergonomic errors, with regard to the results obtained with the checklist they did not yet know how to adopt safe working postures.

Also, the number of postures in which the back was not held straight during lifting can be analyzed with OWAS. It has previously been demonstrated that any deviation from an anatomically neutral trunk posture increases the load on the lumbar spine (Burdorf 1992). The numbers of nonneutral back positions decreased when the results noted for the first and third measurements in the trainee group were compared, but they did not do so in the case of the control group.

The increased time spent on all tasks put together and on lifting in particular, in addition to the high number of harmful postures observed in the preintervention measurement, might explain the higher value recorded for perceived physical exertion in the trainee group. This observation is in line with the finding of Dehlin and Jäderberg (1982) that the time needed to lift a patient into a wheelchair correlates most strongly with the perceived exertion. As stated above, another explanation could be that trainees are more aware of their working postures from the beginning because they start with a course designed to decrease or prevent physical problems. Therefore, their sense of perceived exertion might be sharpened.

It is not easy to translate the results of this study, which was conducted in a laboratory setting so as to reach standardized conditions, into daily practice. It can be concluded that after the ergonomic educational course the trainees *know* how to perform tasks in such a way that the postural load decreases and ergonomic errors are avoided as much as possible. They are also capable of applying this knowledge in an experimental situation. However, it would be a little rash to conclude that they would actually perform these tasks in a similarly safe way when working in the wards. Although the new work routine did not appear to have caused any extra perceived exertion, the work pressure that nurses experience during their normal duties (Engels et al. 1997) could prevent them from working safely during everyday work. Work pressure was not an issue in the recording situation. Time restraint, for instance (Engels et al. 1994), might be a reason to prefer manual lifting to the use of a hoist in daily practice. In other tasks a trend toward a reduction in harmful postures and perceived exertion and a statistically significant reduction in errors made were established in the trainee group without the time spent on these tasks having changed over the measurements.

An interesting finding is that the trainees showed a further improvement at 15 months after the course when a comparison was made with the situation existing at 3 months after the course. It is likely that the trained nurses had been capable of improving their skills in safer working further during 1 year of practice in the wards.

There are several problems in intervention research in the field of occupational health (Goldenhar and Schulte 1996; Schulte et al. 1996). For example, a problem that we encountered in this study was that formal randomization of the subjects over the experimental or control condition was not possible. In the nursing home where this study was conducted, six of the wards could participate in the intervention program. The remaining six wards (which were comparable with respect to ergonomic layout, types and numbers of patients, and numbers and experience of nurses) did not participate and were available for use as controls. The trainees were selected on the basis of several abilities, such as having sufficient authority and enthusiasm for safer working (Engels et al. 1998). Controls were chosen on the basis of their willingness to participate in the investigation and were selected for age, sex, length, weight, and years in profession. They matched well with the trainees with regard to all of these variables except sex. Because subjects were compared with themselves over the measurements, we decided that men would not be excluded from the trainee group.

An unavoidable problem in intervention studies carried out over a long period is the loss of subjects to follow-up. This also holds for our study. Therefore, we checked for the possibility of selective nonparticipation. The results of those who did not participate in all measurements appeared to be quite similar to the results of those who did.

To establish possible effects after the intervention we decided to use three outcome measures: the number and percentage of harmful postures, the percentage of biomechanical and ergonomic errors, and the perceived physical exertion. In this study we used the OWAS method to evaluate the working-posture load. Although the method has frequently been applied (Karhu et al. 1981; Kant et al. 1991), to our knowledge this is the first time it has been used for analysis of work postures from videotapes.

The recording by videotape was necessary to blind the observer to the moment of observation and to the trainee or control status of the subject. However, video recording has the disadvantage that it reduces a three-dimensional view to two dimensions, which can be problematic in OWAS scoring. To overcome this disadvantage, markers were placed on the subjects to facilitate the observation of rotations and lateroflexions of the body. A recording distance of 4.5 m from the subject was maintained to avoid perspective error and to ensure a full view of all body segments (Paul and Douwes 1993). Only the feet and the head continue to need special attention at this distance. These segments are not used in the OWAS scores for the combination of work postures. An angle of 30° with respect to the longitudinal direction of the bed was chosen to fix the position of the camera. This was done to diminish the confrontation of the subject with the camera and to allow the nurse to perform the tasks as nearly "usually" as possible. Although OWAS observation from a videotape can be biased for postures that involve rotation and/or lateroflexion, this should not influence the results because it may occur at all three measurements and for both trainees and controls alike.

The errors made were established with a checklist, which we have described elsewhere in more detail (Engels et al. 1997). The pros and cons of the recording situation described for the OWAS observation were also relevant for registration with the checklist, although the checklist did not include any element for which a three-dimensional view would have been necessary (Engels et al. 1997).

From this study it can be concluded that the postural load of and the ergonomic and biomechanical errors made by trainees decrease in an experimental setting after an ergonomic educational course. Perceived physical exertion does not increase due to a different way of working. The change for the better noted after the eradication of errors made in "other patient-handling activities" fits with our proposition that efforts to decrease the postural load so as to prevent musculoskeletal problems should not be confined to lifting activities.

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