Diurnal variations in spinal loading and the effects on stature: a preliminary study of nursing activities

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Summary

A new method for recording the postures and activities of nurses has been developed. Using a simple coding system, each change in posture or activity was entered on a portable microcomputer and the results stored on cassette, thus creating a real time-based, permanent record for subsequent analysis of the frequency and duration of each posture and activity. Twelve nurses from six different wards were observed throughout two full working shifts. At intervals during the working shifts, stature of the nurses was measured to an accuracy of at least 1 mm and, for comparison, the diurnal change in stature on their days off.

Overall loss of stature was greater during the 8-h working shifts than during a 12-h period on their days off. There were significant correlations between loss of stature and both the total duration of lean/stoop postures and the total duration of lifting.

Relevance

Both measures reported have been shown to be suitable for the analysis of the physical work-load of nurses. They are applicable, alone or together, to any studies aimed at the prevention of musculoskeletal disorders at work, either by ergonomic intervention or by improvement in the levels of patient handling skill.

Key words: Ergonomics, Nursing, Patient handling, Posture, Prevention, Stature, Work analysis

Introduction

Fitzgerald[1] suggested that measurements of change of stature would provide an objective method of assessing the levels of spinal loading and, once a reliable method of measurement had been found, a number of studies have been completed[2–11]. The rate of change in stature in a variety of postures has been shown to be related to the levels of spinal compression[2]. In addition, changes in stature vary according to the perception of both comfort/discomfort for given postures and of the perception of exertion after periods of exercise[5].

Measurements have been made on a variety of subjects, predominantly healthy males of less than middle age. The total diurnal change in stature is of the order of 1%, the greatest losses occurring in the hour or so after getting out of bed; while recovery of stature occurs most rapidly in the 1st hour or so after returning to bed[3]. But within this framework for diurnal change, stature appears to fluctuate considerably according to the temporal pattern of loading and unloading[2,4,6,7]. Predictably, however, the loss in height from a given period of exertion has been shown to be less just before going to bed at night than when performed immediately after getting up in the morning[6]. There appears to be no difference in the patterns of change of stature between males and females, the amounts being proportional to stature itself[7,8].

The apparatus, though bulky, can readily be transported. Wherever subjects from whom repeatable measurements can be obtained are available, the method can be applied to the assessment of spinal loading at work: and this applies to the majority of volunteers[9,10]. The procedure is, first, to familiarize subjects with the apparatus (Figure 1). The maximal erect standing height in which the individual is most comfortable is established and the positions of support from the head to the sacrum are recorded so that they can be reproduced for all subsequent observations. Ten repeat measurements are then made to ensure that all are within 1 mm and that the standard deviation for the ten does not exceed 0·5 mm.

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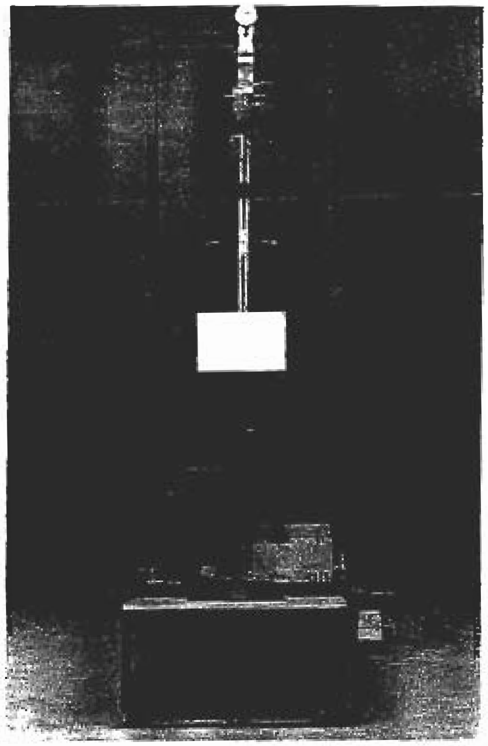

Figure 1. General view of the apparatus for measuring stature.

Figure 2. Subject in position for measurement of stature, inclined back at 13°. The microswitch display box in front of the subject provides postural feedback to the subject. The infra-red receiver mounted on the display box is aligned to the infra-red transmitter fixed to the spectacle frame.

Most of the studies so far reported have been conducted on a short-term basis: 10–30 min either exercising or in a recovery position and up to 1·5 h in a seated posture. The question, therefore, was whether the method could be used to assess the levels of spinal loading over a normal working shift. In order to answer this question, and at the same time test the hypothesis that the loss of stature during a complete working shift is related to the actual work load, it was necessary to have a reliable measure of the work load. Unfortunately, the systems of work analysis that are available[11–16] tend not to record data relevant to the static and dynamic stresses to which the vertebral column is subject: and this is essential when the job in question, nursing, is associated with high levels of back trouble.

Though it is possible to measure, say, trunk inclination and monitor changes at work[17–19], these methods give no record of motion in planes other than the sagittal nor any clue of what the hands are doing: whether they are lifting, pushing or just offloading the spine with a hand resting on the table. One attempt to solve the problem was to use a system of direct observation based on a 15-s sampling time, but the maximal period for which observations could be maintained proved to be 20 min; moreover, agreement on the occurrence of, for example, lifting actions proved to be unsatisfactory[20], most lifts being completed within a second or two and therefore liable to be missed with a 15-s sampling time.

In order to test the hypothesis that the loss of stature in the course of a complete working shift is related to the total workload, a new method of work analysis was therefore developed. The criteria for the new method were that it should:

(1) be inexpensive,
(2) be easy to learn and quick to use,
(3) be portable,
(4) include a time-base,
(5) and be applicable for a full working day.

A pilot study was then made of 12 nurses, observations being made in the course of two working shifts.

Methods

Subject material

Twelve nurses from six different wards, including pupil, student and staff nurses, volunteered for the study (four males aged 19–23 years and eight females aged

22–24 years). Posture/activity analysis only was made on one female nurse.

MEASUREMENT OF STATURE

The apparatus is shown in Figures 1 and 2. The technique of measurement and the methods adopted to ensure repeatability of results have been previously described[H].

ASSESSMENT OF WORKLOAD DURING NURSING

Work assessment was based on the system of recording every change in posture and activity as it occurred. Postures and activities were accordingly classified, using two-character coding as shown in Table 1. At each change in posture or activity, the next code was entered. Thus a real-time record of the sequence could be stored on micro-cassette. Leaning postures were defined as forward inclination of the trunk of at least 15°. Stooping postures were defined as forward inclination of the trunk with one or both hands at or below knee level.

The method rapidly proved itself practicable. In addition, there was time to make shorthand notes on the details relevant to patient handling (e.g. 'shoulder lift' up bed, two nurses, 90 kg patient).

Equipment. An Epson HX20 portable microcomputer was used to record and store the observed data. A program was written in BASIC to list the frequency and duration of each activity and posture. These data were later analysed using a personal computer (IBM PCXT).

Intra-observer reliability. A trained observer (A) with approximately 90 h of experience and an inexperienced observer (B), after 2 h training, used the posture classification system to observe videotapes of 41 patient transfers. The videotapes were evaluated independently by both observers in separate sessions with an interval of several days between them. The results are presented in Table 2.

Inter-observer reliability. These data are also given in Table 2.

Procedure

Each subject was observed for two full working shifts (0745–1630 and 1130–2030 hours), a total of 24 shifts. During the shift, each patient transfer was recorded independently of the posture/activity coding (in terms of type of transfer, weight of patient and number of nurses).

Stature was measured immediately before the shift, at the beginning and end of the meal-break and before going off duty: and this applied to both 'early' and 'late' shifts. Two additional measurements were made during the 'early' shift at tea or coffee break. There were

Table 1. Coding system for nurse activity analysis

Standing		*Sitting*	
Erect	ET	Sit	ST
Erect offload	EO	Sit offload	SO
Erect twist	EW	Sit twist	SW
Erect reach unilateral	EU	Sit reach unilateral	SU
Erect reach bilateral	EB	Sit reach bilateral	SB
Erect lift	EL		
Erect hold	EH		
Erect push	EP		
Forward leaning		*Stooping*	
Lean forward	LF	Stoop (implies bilateral)	SP
Lean forward precision hold	LP	Stoop reach unilateral	SR
Lean forward reach unilateral	LU	Stoop lift	SL
Lean forward reach bilateral	LB	Stoop hold	SH
Lean forward offload	LO		
Lean forward lift	LL		
Lean forward hold	LH		
Squatting		*Kneeling*	
Squat	QT	Kneel	NL
Squat reach unilateral	QU	Kneel reach unilateral	KU
Squat reach bilateral	QB	Kneel reach bilateral	KB
Squat lift	QL	Kneel lift	KL
Squat hold	QH	Kneel hold	KH
Walking		*Miscellaneous*	
Walk	WK	Pull	PL
Walk push	WP	Crank	CK
Walk pull	WU	Pedal	PD
Walk support	WS	Break	BB
Walk carry	WC		

Table 2. Inter- and intra-observer reliability analyses (% agreement)

	Intra-O A	*Intra-O B*	*Inter-O A/B*
Frequencies			
Walking	98·5	95	97
Standing	92	87	87
Leaning	98	99·5	91
Stooping	92	75	90
Squatting	100	89	67
Lifting	100	78	91
Durations			
Walking	95·5	86	95
Standing	93	92	88
Leaning	90	93	94
Stooping	88	76	61
Squatting	74	98	79
Lifting	92	81	65

therefore six measurements in the 'early' shift and four in the 'late' shift, thus giving, respectively, five and three periods over which a change of stature was observed. These measurements were made on 11 of the nurses: ten of them were also measured five times on one of their days off between 0800 and 2030 hours.

Results

Changes in stature

The mean total losses in height from the beginning to the end of the shift for the 11 subjects were 10·2 mm (SD 2·8) for the 'early' and 9·8 mm (SD 3·8) for the 'late' shift, the difference not being significant. The total height lost during the 12 h.30 min period on their days off was less than during the course of the 'early' shift (8 h.45 min) in eight out of ten subjects and in seven out of ten for the (9 h) 'late' shift (see Table 3). The results for one of the subjects are shown plotted out in Figure 3.

Assessment of workload during nursing

In order to summarize the results for the frequencies

Table 3. Overall losses in stature (mm)

Subject	*Sex*	*Day off*	*0745–1630*	*1130–2030*
GM	m	6·96	9·44	6·45
RS	m	8·89	10·95	6·78
CS	m	4·65	10·44	10·69
PW	m	3·52	7·70	9·82
MR	f	—	4·69	4·80
AR	f	13·79	11·12	13·43
AC	f	4·28	9·42	5·26
LM	f	9·85	15·16	13·79
CB	f	8·38	12·94	15·45
NP	f	9·13	8·02	7·53
TB	f	11·97	12·26	13·55
Means (s.d.) [excl. MR]		8·14 (3·35)	10·74 (2·29)	10·28 (3·65)

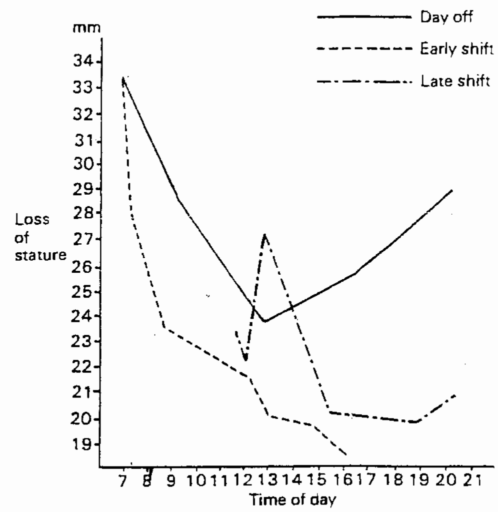

Figure 3. Diurnal changes in stature (in mm) in one subject on the day off, the day of early shift and the day of late shift. The time of day is shown from 0700 to 2100 hours.

and durations of each of the 43 possible postures/activities, they are shown in Table 4 as the total number of lifts (distinguishing the frequency of patient-lifts from the other lifts) irrespective of the postures in which they were observed, the sum totals of both leaning and stooping postures, walking, standing and sitting. As this analysis is selective, it will be noted that the sums of the durations fall short of the total shift duration.

Individual results for the summed durations of all leaning and stooping postures, of all lifting actions and of all postures in which the spine was off-loaded (i.e. sitting back in a chair or leaning forward and supporting the trunk with a hand on a table) are given in Table 5.

Relations between loss of stature and workload

The relationships between variables were studied using Pearson correlation coefficients in SPSSX. For the overall results from the beginning to the end of the shift, the only significant relations arose in the 'late' shift between loss of stature and the duration of total lean/stoop postures ($r = 0{\cdot}57$, $P < 0{\cdot}05$) and between loss of stature and total lifting duration ($r = 0{\cdot}66$, $P < 0{\cdot}02$).

Relationships were then studied, using data obtained at each measurement session. The results are shown in Table 6. Here the significant correlations arose in the 'early' shift, though they also appeared when data from 'early' and 'late' shifts were pooled. The duration for which the spine was off-loaded was inversely related to loss of stature, particularly in the 'early' shift. Also in the 'early' shift, the durations of lean/stoop and lifting were related to loss of stature.

Table 4. Mean frequencies and durations of activities for the two nurses on each ward by shift and ward

	Early shift							Late shift						
Ward	Pat. L.	Oth. L.	Lean fwd.	Stoop	Walk	Stand	Sit	Pat. L.	Oth. L.	Lean fwd.	Stoop	Walk	Stand	Sit
Med.														
Freq.	9	42	541	19	377	809	169	19	25	424	30	368	722	108
Dur. (min)	1·5		51·3	1·2	61·1	169·3	126·6	2·2		41·5	1·4	61·2	164·4	120·4
Surg.														
Freq.	3	90	583	18	408	886	115	9	34	458	12	398	768	80
Dur. (min)	3·4		61·1	0·9	62·1	168·5	75·2	1·8		52·7	0·6	64·9	190·5	77·7
Geri.														
Freq.	12	71	658	32	415	947	133	10	44	462	45	433	712	135
Dur. (min)	6·5		58·5	1·7	69·1	194·2	66·7	1·3		40·1	2·4	77·0	146·3	134
CCU														
Freq.	3	8	281	16	281	562	149	4	6	196	16	228	440	121
Dur. (min)	0·2		36·3	0·4	43·5	133·1	189·3	0·3		30·5	0·5	38·6	119·6	209·9
Cas.														
Freq.	2	3	232	28	409	750	9	11	35	269	29	439	715	10
Dur. (min)	0·1		27·2	0·9	72·0	234·6	30·6	0·5		40·6	1·1	80·6	274·8	15·2
Admis.														
Freq.	0	44	228	11	320	555	45	12	8	340	7	425	804	51
Dur. (min)	0·6		10·2	0·6	66·0	155·4	150·0	0·4		24·6	1·6	95·3	181·3	117·6

Table 5. Duration (min) of lifting actions, lean/stoop and off-load postures for individual nurses in early and late shifts

		Early			Late		
Subject	*Sex*	Lift	Ln/St	Off-Ld	Lift	Ln/St	Off-Ld
GM	m	0·67	9·09	36·08	0·58	12·18	44·18
RS	m	0·07	11·76	76·58	0·40	25·73	28·11
CS	m	1·71	55·73	112·09	1·39	34·30	119·81
PW	m	0·57	5·87	63·27	0·40	22·22	67·07
MR	f	2·66	51·30	51·98	0·17	28·10	118·23
AR	f	1·14	62·05	60·47	2·24	60·61	79·31
AC	f	0·15	28·59	123·78	0·53	28·86	123·91
LM	f	1·58	36·42	56·66	3·60	38·85	44·51
CB	f	4·60	27·50	52·71	1·28	34·99	38·42
NP	f	0·18	23·61	84·12	0·13	15·21	80·67
TB	f	1·21	59·77	9·45	1·06	25·79	46·18

Table 6. Correlation coefficients between all measurements of loss of stature and the durations of lean/stoop and offloading postures and durations of lifting, for the periods between measurements

	Durations		
Shift	Lean/stoop	Off-load	Lifting
Early	$r=0{\cdot}52$, $P<0{\cdot}001$	$r=-0{\cdot}41$, $P<0{\cdot}01$	$r=0{\cdot}43$, $P<0{\cdot}01$
Late	$r=0{\cdot}17$, n.s.	$r=0{\cdot}09$, n.s.	$r=0{\cdot}22$, n.s.
Both	$r=0{\cdot}36$, $P<0{\cdot}001$	$r=-0{\cdot}16$, n.s.	$r=0{\cdot}35$, $P<0{\cdot}001$

Discussion

In order to carry out this study, it was necessary to develop a new system for assessing workload. The method used to observe changes in posture and activity has been shown to satisfy each of the original criteria. It requires that the observer is familiar with keyboard operation and also with critical evaluation of movement patterns. Although no difficulties were experienced in monitoring the activities of a single nurse for a complete shift, the task rapidly became easier as the observer became familiar with the pattern of nursing prac-

e. It would, however, have been an advantage if a rness for holding the keyboard had been available.

Studies of the repeatability of the method were made ng video-tape, for two reasons. First, two observers one nurse in the ward would have interfered with rsing practice and might have raised the question of ıether the two observers could see equally well. :condly, intra-observer reliability could only be tested repetition of the activity and that would have been ıcticably impossible. The results were satisfactory and imilar method would be feasible for establishing the iability of any other would-be observers.

The original aim of this project was to test the pothesis that losses of stature observed over a full rking shift would be related to the total workload. me evidence has emerged in support but more sigıcant correlations between the two variables have erged from the more frequent observations. When full working shift was observed the relation be:en loss of stature and workload was more evident in 'late' shift but when all measurement periods in the ırse of the shift were accounted for, the relationship stronger in the 'early' shift. This may seem a adox but it would be idle to speculate too deeply. ture is very rapidly regained in positions for reery and it would only take a relatively short spell of k or rest immediately before measurement to in:nce a result.

The workload of nursing and the probability of exiencing back pain appears to be related to patient ıdling[21] and young nurses in the 1st year of practical k are at particular risk[22]. The wards in which the s are greatest are clearly those where the number of ıendent patients is highest[23]. Wherever such risks e there is an overwhelming case for ergonomic rvention but this does not rule out the potential ıe of training in safer patient handling[24]. There is evidence that those with poor handling skills are e likely to report back injury[22] and improvements ıandling skills can be achieved by means of an nsive educational approach that includes basic hing in ergonomics and biomechanics. This has ı shown by means of subjective skill evaluation by pendent assessors[25], but it would be a clear advanto have more objective methods of evaluation.

wo questions arise: whether the methods reported —posture/activity analysis and measurement of ıge of stature—can usefully be applied to assessing ıurses' workload; and whether they are suitable for ng the assertion that reductions in the duration of ıg actions and in the time spent leaning forward and ped down can be achieved by ergonomics or by ns of education. Previous experience of measuring ıges in stature shows that it is most effective when rvations can be made immediately an activity is ɜd. This could apply to the analysis of nursing , particularly when redesigning ward furniture or a work station for nurses; or when testing a new ng procedure.

study the total workload of a nurse throughout the shift may be necessary whenever the number of dependent patients is high. It may also be necessary when assessing the patterns of movement and the skills of nurses during patient handling. In such instances, a full analysis of the workload may be unavoidable. However, given the cost of one observer making a posture/activity analysis of a single nurse, measurement of stature has a clear advantage, provided that there is information on the duration of the activities that precede the measurement and that there is no delay before the measurement is made. In many instances the results might usefully be amplified by using psychophysical ratings of exertion or comfort/discomfort assessments.

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