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The physical effect of lumbar spinal supports

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Abstract

A study has been performed to investigate the physical effects of lumbar spinal supports. Two groups were studied, a group of normal male subjects and a group of male low back pain patients. Five different spinal supports were investigated and their effects upon the skin temperature, spinal movements and intra-abdominal pressures of these individuals were examined. The results show surprisingly similar patterns for the widely varying designs of support. The findings also suggest that the longer term wearing of a spinal support results in a degree of physical dependence. The results of this study are aimed at improving the prescription and use of spinal supports in the treatment of low back pain.

Introduction

Lumbar spinal supports form a major part of the treatment of low back pain to the extent that each year over quarter of a million are prescribed in England and Wales. Supports available for prescription fall into the general categories of spinal brace and fabric corset, although there are many types and constructions. The basis upon which a support is prescribed is unclear because little is known about the performance of such orthoses in terms of their mechanical and other effects upon the wearer. Perry (1970) showed that almost all orthopaedic surgeons prescribed external supports at least occasionally in their treatment of low back pain. The most common diagnosis for which a corset is prescribed was found by Ahlgren and Hansen (1978) to be chronic lumbago and the main reason for the patients using this form of treatment was that it provided "support", with or without the relief of pain.

The following possible effects of spinal supports may have an important role in terms of their therapeutic value:

(a) Limitation of movement.
(b) Alterations of intra-cavity pressures.
(c) Modification of muscle actions.
(d) Warming of skin.

The use of a rigid brace for restriction of movement and stabilization is widespread (Perry, 1970) but even the more flexible supports are obviously intended to modify movements in some way. The efficacy of spinal braces has been questioned (Norton & Brown, 1957) in particular with regard to intervertebral movements. While gross movements are prevented, individual vertebral movements are sometimes increased.

The abdominal cavity, sometimes in conjunction with the thoracic cavity, is pressurized voluntarily when the spine is put under stress (Bartelink 1957; Eie & Wehn 1962; Davis & Snoup, 1964; Kumar & Davis 1973). This activity has a direct effect on the spinal loading by introducing a distending force anteriorly. This force produces an extension moment about the lumbar spine which reduces the tension required in the posterior spinal muscles. An inflatable corset increases the resting abdominal cavity pressure by about 10–15 mm Hg, but does not raise the peak pressures seen during a controlled lift (Morris et al, 1961). The effect of normal spinal supports was studied here.

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The effects upon muscle activities of wearing a spinal brace have been investigated using EMG (Waters & Morris, 1970). The findings were not consistent and indicated little or no change in activity. The effect of an inflatable corset is to reduce muscle activity considerably, especially during activities which apply high loads to the spine (Morris et al, 1961).

Dixon et al. (1972) showed that some forms of chronic low back pain respond as well to the wearing of a woolly belt as to an ordinary corset.

They concluded that an increase in the lumbar skin temperature was the cause of this symptom relief. Lumbar and thoracic skin temperatures were recorded in the tests of corsets and braces made in this study.

Materials and methods

The supports which were studied are described in Table 1. Eight patients and 10 healthy volunteers were studied while wearing these supports. The 10 healthy men who did not suffer from low back pain had ages ranging from 25 to 46 years, with a mean of 37 years. The patient group was composed of eight men who suffered chronically from low back pain, whose symptoms had settled and who had been wearing lumbar spinal supports regularly for at least three months. Their ages ranged from 30 to 61 years, with a mean of 42 years.

Table 1. Description of the supports tested.

Symbol	Description
NS	No support
SE	Semi-elasticated, narrow corset. Padded lumbar insert semi-conforming to lordosis. Rigid anterior section.
NF	Narrow fabric corset with some posterior strengthening.
LF	Long fabric corset extending from pelvis to thorax. Some steel posterior strengthening and some padding.
RB	Leather covered steel brace. Pelvic and thoracic hoops linked by longitudinal members. Anterior abdominal pad.
PJ	Polythene jacket.

Each subject performed the tests first of all without a lumbar spinal support to enable base line readings to be made, and then repeated the tests wearing a variety of supports. The study sought to answer the following questions:

(a) How do the individual support types influence the measured parameters and can they be characterized in terms of their effects upon the wearer?

(b) Are low back pain patients for whom a spinal support is a regular part of treatment affected in a different manner to the normal group?

Three parameters were chosen for measurement, these being range of lumbar spinal movement, skin temperature, and intra-abdominal pressure.

Lumbar spine movement

Lumbar spine movements are difficult to measure because they are usually accompanied by hip movements. These must either be measured separately and taken into account, or prevented. The latter course was decided upon and the method adopted uses a pelvic constraint frame (Fig. 1). It is accepted that by adopting this approach, the movements being measured were not strictly normal, but nevertheless would represent the degrees of immobilization provided by the orthoses. Another feature of the technique was that, because it isolated the movements of the lumbar spine, the results were more likely to be repeatable. The movement of the lumbar spine was measured by means of the vector stereograph (Morris & Harris, 1976). This instrument records movement of a selected point by electrical recording of the lengths of string attached to that point. In this study two strings were used and a two-dimensional recording was used to record the movement in a horizontal plane (Fig. 2). The errors involved in this simplification were minimized, as described by Grew and Harris (1979). The stereograph strings were arranged to intersect at the level of the spinous process of T12 and were held in place on the back by a belt (Fig. 1). Once held in the

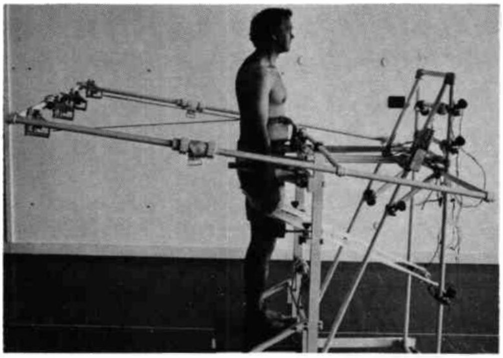

Fig. 1. The pelvic constraint frame.

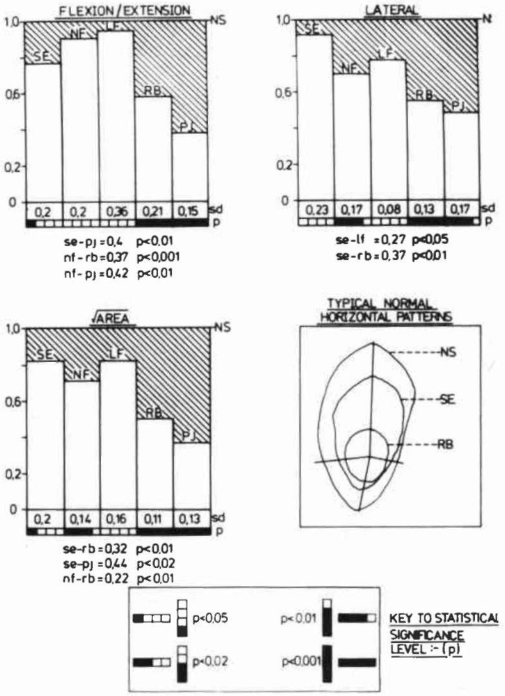

Fig. 2. Normalized spinal movement results from normal subjects.

frame with the stereograph attached, the subject performed a sequence of movements listed in Table 2.

All movements were to the limit of comfort and in all but the circumductions the subject passed through and paused at the neutral, upright posture. The stereograph outputs were recorded on a tape recorder for subsequent playback into a computer.

Table 2. Sequence of spinal movement instructions.

Terminology	Instruction
Neutral	Stand comfortably
Flexion	Flex fully forward
Circumduction	Move to your left rotating forward-left, left, backward-left, back, backward-right, right, forward-right, forward
Extension	Lean back
L. Lateral Bend	Lean left
R. Lateral Bend	Lean right
Circumduction	Flex forward and then move to your right rotating forward-right, right, etc to forward position
Neutral	Stand upright comfortably

Recording of pressure and temperature data

Intra-abdominal pressures and skin temperatures were recorded continuously throughout a sequence of activities. In order that the subject remained free to carry out these activities a portable tape recorder (Oxford Medical Systems "Medilog") was used. This was a four-channel cassette device, three channels being used for data recording as detailed below, and a fourth recording a voltage step change, controlled by a switch on the recorder and used as an event marker.

Intra-abdominal pressure

Previous studies of the pressure within the abdominal cavity have investigated both muscle-induced and hydrostatic pressure changes at various levels. Because the abdominal cavity is largely fluid-filled, hydrostatic pressure differences exist which are consistent with an average fluid density similar to that of water (Rushmer, 1946). Previous measurements of active abdominal pressure have been made in both the stomach and rectum, a constant hydrostatic difference being noted between the two measurements during each activity (Adno, 1956). The technique adopted in this study was measurement in the rectum by means of a catheter with a strain gauged pressure transducer at its tip (Gaeltec type 3EA/ICT). The catheter was inserted to a distance of about 15 cm, to ensure that the tip was within the abdominal cavity.

Maximum baseline drift of pressure measurement was about 1 mm Hg per test, but sensitivity was unaltered. Calibration was performed before each test by means of a graduated water column.

Skin temperature

To assess the warming effects of each support, skin temperatures were measured at two sites, one in the lumbar region directly under the support, and a second in the thoracic region well above the area of influence of the support and used as a control. Thermistors (Oxford Medical Systems type YS1) were taped to the skin in these areas, porous tape being used to minimize its influence upon the local skin temperature. Recording on to the cassette was via amplifiers, set to cover temperature ranges of 26°C–37°C (lumbar) and 21°C–36°C (thoracic). Calibration was by means of a thermostatically controlled water bath and negligible drift was observed.

Experimental procedure

The subject was instrumented for temperature and pressure recording. Once reclothed and acclimatized to the feel of the measurement apparatus he performed a sequence of timed activities (Table 3), lasting approximately 20 minutes, once without a support and then again while wearing a variety of lumbar spinal supports. A spinal movement study was performed under each condition.

Table 3. Sequence of timed activities.

Symbol	Activity	Time
L	Lying supine	3 min
	Standing from lying	
W	Walking on a horizontal surface	2 min
	Ascending and descending stairs	
S	Sitting in an upright high-backed chair	2 min
	Lifting 5kg between high and low shelves	
FL	Lifting 15kg with legs straight, flexing at hips	
UL	Lifting 15kg with torso upright, flexing knees and hips	
H	Holding 15kg while standing upright	30 sec
	Lifting 15kg from the side	
Then S, W, and L repeated in that order		6 min

Each subject underwent a single measurement session. This was important to ensure that results from each condition would be most readily comparable. Unfortunately, this meant that a long session was required in order that a complete set of measurements could be made from one subject wearing all of the supports in turn. For reasons of time, only four out of the "normal" group completed such a session. In the case of the patient group each subject, in addition to being measured without a support, was measured while wearing his prescribed support (usually a rigid brace) if a suitable one could be found. It was found that patients could not readily tolerate more than three corset tests, each of which took about 20 minutes. Two patients did not take part in the movement studies.

Data analysis

Movements

The recorded vector stereograph readings were played back into a computer file through an analogue to digital converter, and transformed into Cartesian coordinates. A further program used the data to plot out the movements of the top of the lumbar spine, as seen from above, also calculating the mean area enclosed by the circumduction manoeuvres (Fig. 2). The scale of the plot being known, any further measurements could be made by hand from the locus of movement.

Temperature and pressures

The cassette recordings were stored on computer file for analysis. The event marker channel was used to identify periods of controlled activity and for each of them print out the length of time the event took, the mean intra-abdominal pressure, the standard deviation, the maximum and minimum pressures. Over the combined periods of activity the mean, maximum and minimum temperatures at the lumbar and thoracic levels were also calculated and printed out. A further program displayed the pressure pattern from any selected event on a visual display unit and the operator then identified special features within the activity, such as pressure peaks on lifting. For each of these sub-events the time, mean, maximum and minimum pressures were printed out.

Averaged results are used throughout this report and where the effects of spinal support or posture within a group are examined the mean of the differences is given. This enabled the paired 't' statistical test to be used. Where results from different groups were being compared the difference of the means was used and in this case the straightforward 't' test was adopted.

Results

Table 4 gives complete averaged results from both normal and patient groups and results from a further spinal movement study.

Lumbar spinal movements

Three measurements of the movement locus were made to characterize each pattern; the total lateral range (L), the total flexion/extension range (F/E), and the square root of the mean area enclosed by the circumduction loci (A). The first two define the movement in specific directions, while the latter is a linear measure of overall functional range (Fig. 2). To establish the repeatability of the technique adopted, 15 normal male subjects were measured while wearing no support. Each subject was measured four times in all on separate days. The scatter of results showed variations of less than 10%

Because the linear ranges of movement are dependent upon the anatomical dimensions of the subject as well as the support being worn, the measurements for each subject were normalized by dividing them by the corresponding value when no support was worn. Figure 2 illustrates the averaged, normalized results from the normal group; the smaller the bar the greater the restraint imposed by the corresponding support.

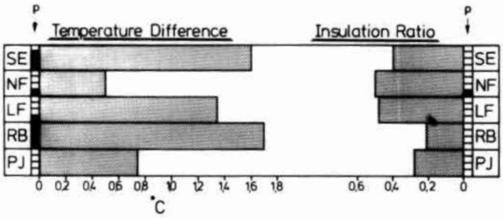

Fig. 3. Mean skin temperature results normalized by subtraction of "no support" figures.

Skin temperatures

It was assumed that for the purposes of analyzing skin temperature results all subjects could be taken as a single group, low back pain not being associated with local rise in skin temperature. To determine the degree of warming in each test the difference between the mean lumbar and thoracic skin temperatures was recorded (TD), being positive with a higher lumbar temperature. The thoracic skin temperature served to allow for the effects of ambient conditions upon the skin. By comparing for each individual the differences from each test involving a support with that from the test when no support was worn, the influence of the supports upon lumbar skin temperature could be seen. Figure 3 illustrates the mean of the temperature differences after subtraction of the corresponding value when no support was worn. The longer the bar the greater the warming effect. Figure 3 also illustrates the means of the differences in a factor termed "insulation ratio" (IR). This is a measure of the relative extent to which the lumbar skin is insulated from temperature changes seen at the thoracic level. It was calculated for each test by dividing the range of temperatures measured at the thoracic level (IR). Thus if both had the same range the ratio would be unity and the lumbar skin would not have been insulated at all. The mean insulation ratio when no support was worn was greater than unity (see Table 4) and this indicates that in normal clothing the lumbar skin saw more temperature variation than the thoracic over the sequence of activities. However, the corresponding mean temperature difference was zero and this indicates that the two skin temperatures were not consistently different. In Figure 3 the values illustrated are averages of the insulation ratios after the subtraction of the corresponding value derived from the tests when no support was worn. The longer the bar, the greater the insulation.

Intra-abdominal pressures

There are two possible ways in which the supportive influence of the intra-abdominal pressure could be affected by a spinal support. The first is passive and involves the increase of resting or mean pressure levels, and the second is active and involves the modification of the reflex pressurization when the spine is put under mechanical stress. For the purposes of examining the passive influence four activities were selected from the sequence performed by each subject, these being lying, sitting, walking and holding a weight whilst standing upright (L, S, W, and H respectively). For each subject the mean intra-abdominal pressure during each of these activities in each test was determined. The averaged results are given in Table 4.

In order to examine the influence of supports upon the reflex abdominal pressurization two types of lift were examined, these being lifting with legs straight, bending at the hips, and lifting with an upright torso whilst flexing the knees and hips (FL and UL). From the results from each subject each time they performed these lifts, the peak pressures recorded were noted. The average values appear in Table 4.

The averaged results from the two groups are given in Figure 4. In this figure both results from wearing no support and the averaged effects of spinal supports are given. The longer the bars the higher the pressures, the dotted lines being the results from the recordings made while spinal supports were being worn. Where significant, other results are also listed.

Table 4. Summary of averaged results.

			Normal Group						Patient Group				Trial
			NS	SE	NF	LF	RB	PJ	NS	NF	LF	RB	NS
Spinal Movement (cm)	√A	m	12·6	10·0	9·0	10·6	6·0	4·4	7·4	7·8	9·0	6·0	12·7
		sd	3·7	3·5	2·8	1·2	1·4	1·1	4·6	2·9	3·2	2·0	2·2
	L	m	11·7	10·6	8·0	9·5	6·0	4·9	9·2	8·0	9·5	6·7	13·9
		sd	3·4	4·0	2·8	2·8	1·1	1·1	3·4	3·1	0·7	2·3	2·9
	F/E	m	19·3	14·4	16·8	17·5	11·0	6·8	14·4	14·0	14·0	9·5	21·3
		sd	5·5	3·1	4·8	0·7	4·4	1·5	5·4	5·6	7·1	4·1	2·6
		n	10	9	6	2	9	5	6	4	2	3	15
Intra-Abdominal Pressure (mm Mercury)	L	m	16·9	19·3	20·0	19·5	19·5	19·4	8·0	16·0	11·0	17·0	Mean
		sd	13·6	16·8	15·9	16·2	15·1	16·7	2·5	5·5	5·7	10·0	
	S	m	28·7	32·6	32·6	36·0	33·9	35·5	24·0	28·0	25·0	32·0	
		sd	13·5	17·3	19·8	20·7	16·4	19·3	5·0	8·0	7·8	5·5	
	W	m	29·0	34·3	32·3	32·3	33·5	33·8	24·0	26·0	24·0	33·0	
		sd	14·1	16·2	19·5	16·2	15·8	18·6	5·5	6·0	8·4	5·0	
	H	m	30·7	33·8	32·4	33·1	34·2	37·0	30·0	33·0	30·0	38·0	
		sd	17·4	18·0	19·7	16·2	17·4	20·5	6·0	9·0	6·4	11·0	
	FL	m	49·0	47·0	47·0	44·0	47·0	45·0	62·0	64·0	84·0	73·0	Peak
		sd	24·0	22·0	29·0	15·0	17·0	19·0	33·0	28·0	41·0	26·0	
	UL	m	58·0	50·0	55·0	54·0	55·0	51·0	63·0	70·0	86·0	70·0	
		sd	25·0	21·0	21·0	12·0	18·0	26·0	21·0	22·0	13·0	24·0	
		n	10	10	8	6	10	7	8	5	2	6	
Skin Temperature (C°)	TD	m	0·0	1·24	0·56	1·3	1·46	0·50					
		sd	1·10	0·60	0·62	0·57	0·74	0·39					
	IR	m	1·15	0·73	0·72	0·67	0·69	0·69					
		sd	0·60	0·39	0·18	0·23	0·35	0·10					
		n	14	9	11	7	12	5					

Differences between supports

The results from the normal group are taken as representing the properties of the supports in terms of their effects upon an individual at first encounter and without the influence of pain. The latter influence is considered insignificant in the case of the surface temperature measurements. Therefore, when considering this question the results from the two groups are combined for the purposes of discussing the skin temperatures, whereas the results from the normal group are only discussed where intra-abdominal pressure and spinal movements are concerned.

The supports all warmed the lumbar skin, but those with added padding over this area warmed the most (Fig. 3). However, the greater the difference in temperature between the skin and the outside environment, the more difficult it was to maintain, and this was reflected in the insulation results (Fig. 3) which are much the same for all the supports.

The relationship between skin temperatures and symptom relief is an area which requires clarification. Dixon et al. (1972) assumed that the link between the wearing of a woolly belt and relief of low back pain in some cases was due to an increase in the lumbar skin temperature. It would be preferable to repeat their type of study using objective temperature measurement to seek to establish the mechanism by which such relief is provided.

All the lumbar spinal supports tested reduced the range of movement of the lumbar spine in the normal group. Again it was possible, to some extent, to predict their effects by considering their individual construction. The plastic jacket and rigid brace were different from the corsets which had little inherent rigidity and relied more upon elastic restraint. The rigid supports therefore restricted spinal movement considerably. The fabric based supports all gave less restriction, with the long fabric support having least effect (Fig. 2). It could be that the long corset had least influence upon movements because it bore upon rib cage and pelvis and gripped neither particularly strongly. The narrower supports, however, caused a "waisting" of the subject, thereby preventing movements by the impingement of the support's edges upon pelvis and rib cage. The influence of strategic stiffening of the corset can be seen by comparing the lateral and anteroposterior movements allowed by the elasticated and narrow fabric supports. The latter had stiffening members which were effective in reducing lateral movements while the former had a rigid frontal pad which restricted anteroposterior movement.

All the spinal supports raised the resting level of intra-abdominal pressure in all postures. Individually these increases were only significant in four instances; the elasticated support when walking, and the plastic jacket, long fabric and rigid brace when sitting (Fig. 4). However, there were no significant inter-support differences. The three supports which increased the pressure on sitting all extend between thorax and pelvis, while the one which increased pressure on walking was the only elasticated one tested. Taken as a whole, the supports had a significant effect in raising intra-abdominal pressure in the two postures of walking and sitting. Under

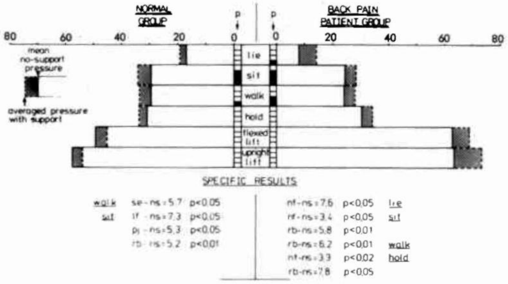

Fig. 4. Mean intra-abdominal pressure results.

normal circumstances without the presence of a spinal support, intra-abdominal pressure is generated by the compression of the abdominal cavity involving the diaphragm, pelvic floor, and muscles of the abdominal wall. Of these latter, transversus and the obliques are most active. By their very nature the action of the oblique muscles produces a disadvantageous mechanical moment which in part offsets that generated by the raised intra-abdominal pressure. Morris et al (1961) showed that a spinal support tends to raise resting pressure levels while reducing EMG activity in the abdominal wall. Thus the pressure increases measured do not act against a disadvantageous muscle activity. This makes them more effective at spinal load relief than those generated normally by muscle effort.

During exercises when the intra-abdominal pressure reflex is excited, spinal supports had no significant effect upon peak pressure levels; however both individually and as a whole their tendency was to reduce the pressures. This may be as a result of some of the axial load being transmitted from pelvis to rib cage directly through the supports, thereby reducing the lumbar spinal load which is probably the stimulus for the reflex. It is surprising that the supports had such a uniform effect upon the intra-abdominal pressure considering the variety of types which were tested.

Differences between patients and controls

Low back pain causes reduced spinal mobility both as a direct result of discomfort and because of apprehension. The response of a low back pain patient to a spinal support is likely to differ widely from that of a normal person. Some subjects moved no more without their familiar support than when wearing it. Presumably the further a support keeps someone away from areas of painful movement the less pain and apprehension will affect the way they move. The subjects with pain had varying levels and types of painful movement so the results cannot be analyzed closely. Nevertheless, the mean effect of the long fabric support (PH) which proved least effective on the normal group was to have no influence on the mobility of the low back pain patients who wore it; pain still dominated their movement pattern (Table 4). The narrow fabric support (S) had some effect but the mean ranges of movement were still less than for the normal group, indicating a combined effect of corset and pain. The rigid brace (G) had the most effect and the mean ranges of movement were similar to those for the normal group, indicating that the effect of the support was the dominating feature. Therefore, while the supports influenced the spinal movements of the patient group in a manner similar to the normal group, the effects were modified by the added influence of pain.

The intra-abdominal pressure results showed some less predictable differences. Considering first the mean pressure levels, it became apparent that the mean level when lying supine was 9 mm Hg higher in the normal group (Fig. 4). Since the pressure in this posture is largely a result of muscle tone in the abdominal wall, this observation indicated that the patient group had generally less active muscles in this region. The patients had all been wearing spinal supports regularly as part of the treatment for their low back pain. Morris et al, (1961) showed that a reduced abdominal muscle activity results when a corset is worn. It seems likely that, despite exercises, the long term effect upon the patient group of wearing corsets had been a loss of tone in the abdominal muscles. One patient only had a resting intra-abdominal pressure comparable with the normal group. He still maintained a physically demanding job and when questioned appeared well educated about how to use his spine in lifting, etc., and was complying with physiotherapist advice.

The spinal supports raised mean intra-abdominal pressures by similar amounts in the patient group when compared to the normal group. However, because of the lower pressures recorded when no support was worn, the effect of the supports was to raise the mean pressures only to those of the normal group without supports.

It was observed in this study, as elsewhere (Fairbank et al, 1980), that patients suffering from low back pain develop much higher reflex intra-abdominal pressures than pain-free controls. This is believed to be a response to back pain which attempts to protect the spine still further from load by increasing the load bearing role of the anterior compartments.

When wearing a spinal support the patient group tended to develop still higher pressures (7 mm Hg higher on average) compared with the normal group which tended to produce lower pressures (4 mm Hg on average). This indicated that the patient group was using the greater support an orthosis provides to the abdominal wall in order to increase the effect of the intra-abdominal pressure reflex and reduce further the mechanical stresses on the spine.

Conclusions

1. This study confirms that spinal supports influence the movement, intra-abdominal pressure and skin temperature of the wearer. Considering the wide variety of supports tested, the differences between the effects of each support are few. However, some characteristic patterns of effect, particularly in the spinal movement restriction, were found.

In order to reduce spinal movements by an appreciable amount, a rigid form of bracing is required, although a well fitting brace (RB) is better than a plastic shell (PJ) in this respect. Fabric and elasticated corsets provide little restriction of movement although the location of strengthening can enable specific painful movements to be influenced above others. The shorter corsets performed better than the longer in respect of movement restraint.

Where low back pain is temperature sensitive, the presence of thicker or padded material over the lumbar skin can be used to raise its temperature by almost 2°C. However, the material must be held in contact with the skin. Several subjects commented that the plastic jacket had a tendency to provide a cooling "funnel" which reduced its effectiveness in this respect.

No clear patterns emerge from the intra-abdominal pressure results, except that the longer supports provide significant increases in pressure when the wearer is seated, and the elasticated support increases the pressure significantly when the wearer is walking.

2. The patient group responded in a predictably different manner to the normal group in respect of spinal movement, but not of intra-abdominal pressure. The results suggest that over the period of treatment a patient becomes accustomed to his orthosis and subconsciously adopts it as part of his spinal support mechanism. Thus, under activities where the spine is lightly stressed, the presence of the support reduces the need for activity of the muscles of the abdominal wall. Under more stressful activity the orthosis strengthens the wall and enables the wearer to enhance the pressures developed during the intra-abdominal pressure

reflex. This indicates a need to plan the use of a spinal support in the context of other treatments, such as exercise regimes, especially when the patient ceases to wear his corset.

3. The study highlights the need to establish more clearly the mechanisms by which a spinal support acts upon the wearer and how the physical effects it induces are effective in providing symptom relief and a healing environment.

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