Cutaneous patterns of sympathetic activity in clinical abnormalities of the musculoskeletal system (1964)

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In previous investigations we have reported on regional and segmental variations in sympathetic activity as revealed by cutaneous sudomotor and vasomotor manifestations[1, 2]. In studies of topographical variations in electrical skin resistance (ESR), we have observed persistent areas of low electrical skin resistance in most "normal" resting individuals[1]. The topographical distribution, or "pattern", of these low resistance areas (LRA) was found to be characteristic for a given individual and remained relatively constant for weeks or months. Studies by *Thomas* and others in our laboratories[3–5] have shown that these measurements and patterns of ESR, as recorded by our methods, reflect variations in activity in the sympathetic fibers. Studies of regional and segmental variations in cutaneous vasomotor activity also showed topographical "patterns" in the skin temperature, "red response" and apparent blood content of the skin; and, like the ESR patterns, the vasomotor patterns showed a high degree of constancy and reproducibility in any given individual[2].

These studies, on apparently well and resting subjects, however, did not reveal the physiologic origins and functional significance of these cutaneous manifestations of sympathetic activity. Preliminary evidence obtained in our laboratories[6, 7] and reports of areas of sudomotor and vasomotor dysfunction reflexly related to painful myofascial and visceral conditions (cited in detail in our previous paper[8]), suggested that these patterned differences in sudomotor and vasomotor activity were related in some individuals to visceral and myofascial disturbances. We undertook investigation, therefore, of factors which might contribute to these local asymmetries and variations in sympathetic activity.

A detailed report on the changes in sudomotor patterns in the skin of the human trunk produced by experimentally induced irritation and stresses in the musculoskeletal tissues has already appeared in this journal[8]. New areas of low electrical skin resistance appeared in areas of referred pain and in segmentally related dermatomes when the paravertebral tissues were injected with small quantities of hypertonic saline. Postural stresses produced exaggeration of existing LRA patterns or elicited new areas of LRA according to the stress, the individual's vertebral adaptation to the stress and his discomfort.

In this paper we report our observations of sudomotor patterns in clinical subjects with known musculoskeletal disturbances, myofascial stresses and pain syndromes.

Methods

1. Methods for evaluation of musculoskeletal abnormalities.

Methods of examination utilized in this study included radiographic studies of posture and skeletal abnormalities, electromyographic assessment of the activity of postural muscles, and palpatory testing for areas of cutaneous and deep tenderness. Postural radiographic studies of the spine and pelvis, taken with the patient in the standing position according to methods which have previously been described[12], were made on some of the patients. Our electromyographic procedures are described in the legend of Fig. 8 c. The palpatory methods were those conventionally utilized in clinical practice.

2. ESR Explorations.

Since the methods used for the study of cutaneous sudomotor activity which have been used in these studies have been previously described[1, 9, 10], they will be only briefly characterized here.

The experiments reported in this paper were done over a period of several years. During this time three methods for recording ESR were used, each yielding a different type of record. However, all three methods are based on conventional principles of skin resistance measurement.

Essentially, each method consists of measuring or recording, in correct spatial relationship to the explored area, the momentary current flow through the skin in contact with a constantly moving exploring electrode, at known voltages. The voltages were tapped stepwise from a series of dry cells and applied to an electrode fixed to an earlobe and an exploring electrode. Resistance of the skin of the earlobe was minimized by means of electrode paste. Area-to-area differences in current flow at a given voltage, therefore, were due to differences in the "resistance" of the skin under the exploring electrode.

a) Explorations with hand-held electrode.
In our earlier studies we used an instrument similar to that described by *Jasper*[11]. Current flow was read from a microammeter as the electrode was moved over the subject's skin.

b) Automatic explorations.
In later studies two types of automatic dermometers were developed[9, 10]. With the first[9], differences in current flow through the skin were converted into variations in the brightness of a light over the exploring electrode which was propelled over the skin at a constant speed. A camera recorded strips of light which varied in brightness according to the ESR (inversely as current flow) along strips of skin.

To eliminate the disadvantages of photographic recording, however, we developed a dermometer with which skin resistance patterns on large areas of the trunk were recorded directly on paper by a recording galvanometer whose amplitude of oscillations is related, through an amplifier, to the skin current[10]. The position of the galvanometer writing-point on the chart was related to the position of the exploring electrode on the subject by means of a pantograph.

The explorations were conducted in a quiet room maintained between 23° and 25° C. The body was unclothed above the level of the sacrum. The tips of the spinous processes were identified by palpation and numbered. In these studies, "segmental" level refers to the topographical level on the trunk as identified by the corresponding spinous process, rather than the dermatomes. There is, however, close correspondence between topographical and segmental levels for paravertebral skin, except at the uppermost thoracic segments.

c) Interpretation of ESR charts.
In the figures showing ESR patterns the dark areas represent areas of low electrical skin resistance. The darkness of shading in the hand-drawn charts (Fig. 4, 5, 8 b[i]) and in photographic records (Figs. 1—3, S b[ii]) is in proportion to current flow at exploration voltage; the darker the area the lower the resistance. White areas: 1 μa or less (resistance, in ohms, at least 1 million times the number of volts); black areas: 20 μa or more; i. e. less than 1 20 of basic resistance; gray areas: intermediate values. (Reproduction of these figures has darkened the gray areas and the darker shades have become indistinguishable from the black areas.)

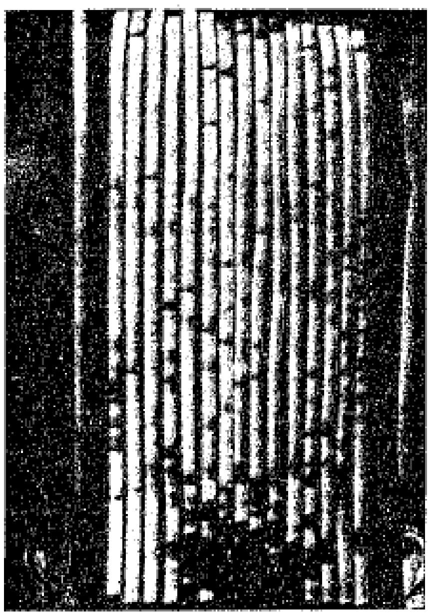
In the pantographic records (Figs. 6 b, 7 b, 8 b[iii]) amplitude of oscillations of the recording galvanometer is related to current flow through the skin. The thin vertical lines (no oscillation) represent areas permitting 0 to 1 μa at exploration voltage; widest oscillations represent current flows of 30 μa or more, in these charts, therefore, the darkest areas represent 1 30 the basic resistance or less.

Tips of spinous processes and the sacral base are marked in photographic (light points and lines) and pantographic charts (short horizontal lines). In the figures both the photographic and pantographic charts are spatially related, by superimposition, to the subject's body.

Results
ESR explorations were conducted on more than 130 persons presenting complaints referable to postural and musculoskeletal disturbances, such as pain, tenderness, severe and persistent backache and limitations in motion, or in whom anomalies or other potentially stressful musculoskeletal problems were discovered. Such problems and complaints as gross inequality in leg-length, vertebral anomalies, injuries to the spine, pelvis or shoulder, abnormal spinal curvatures, herniations of intervertebral discs, spondylolistheses, etc., were included.

Fig. 1 a. Radiograph of patient D.C.R., standing (see text, Case 1). The white vertical line appearing in this and succeeding radiographs is the upward projection of the subject's mid-heel line[11]. All radiographs, as well as other figures in this paper, are to be viewed as though the patient were being seen from the back; i.e., left side is on the reader's left hand side.

Fig. 1 b. The ESR pattern of patient D.C.R. shows low resistance areas in the region of the lumbosacral junction. Recorded with the photographic method of ESR exploration.



Eight are presented to illustrate the type of information revealed in our studies.

Case 1. Patient D.C.R., Male, 49 years (Fig. 1).

Complaint: Severe ache in low back, of long standing, beginning in childhood; often incapacitating. Patient complains of difficulty in "straightening up" after being seated for prolonged periods and after stooping over.

Radiographic and physical examination. Antero-posterior X-ray films of the pelvis and lower lumbar spine, taken with the patient standing (Fig. 1 a) revealed a) an inequality of leg length (heights of femur heads), the right being 5/8 inch (approximately 16 mm.) shorter than the left; b) a considerable displacement of the pelvis to the right of the mid-heel line; c) tilting of the sacral base-plane toward the right; d) scoliosis of the lumbar spine, convex to the right, with considerable rotation of the vertebral bodies toward the convexity; and e) congenital, unilateral anomalies of the first sacral segment.

Electrical skin resistance (Fig. 1 b). The ESR pattern, obtained with the photographic method, reveals the predominance of low-resistance areas in the region of the lumbosacral junction.

Case 2. Patient H.M., Male, 34 years (Fig. 2).

Complaint: This man also complained of backache and "stiffness" beginning in childhood and reported several incidents of painful back injury and strain, due to lifting and pushing in the course of his work as a farmer. Although palpatory examination revealed generalized tenderness over the back, pain, tenderness and muscular rigidity were most severe in the vicinity of the lower lumbar spine and lumbosacral junction, particularly on the left side.

Radiographic examination (Fig. 2 a) of the spine revealed failure of fusion of the neural arch of the fifth lumbar vertebra and anomalous, rudimentary or asymmetrical articulations in the lower lumbar spine and lumbosacral junction. The discrepancy in leg length, the right leg being 3 8 inch (approximately 1 cm.) shorter than the left, seems not to have produced significant tilt of the sacral base or lumbar scoliosis.

Electrical skin resistance (Fig. 2 b). Low-resistance areas were mainly in the lumbosacral region, predominating on the left side, where symptoms were most marked.

Case 3 Patient W.P., Male, 46 years (Fig. 3).

Complaint: This subject had his

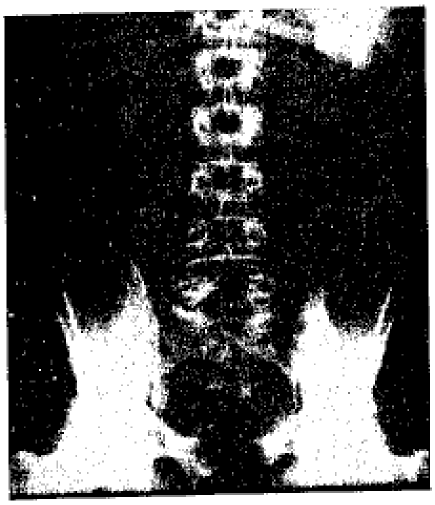


Fig. 2 a. Radiograph of patient H.M., standing (see text, Case 2).

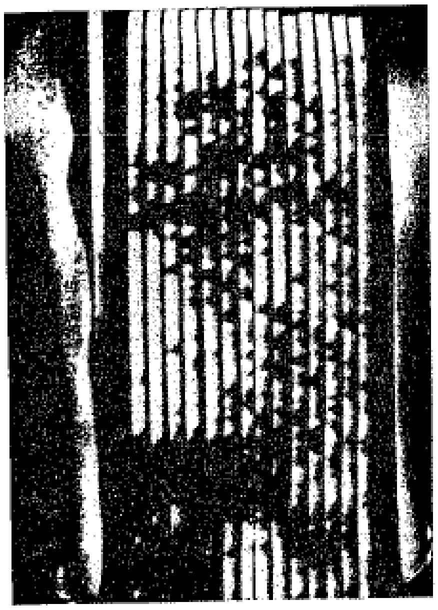


Fig. 2 b. The ESR pattern of patient H.M. shows most conspicuous low-resistance areas in the lumbosacral region, particularly on the left side, where symptoms were most marked. Recorded with photographic method.

left leg amputated more than 30 years prior to this study, because of osteomyelitis. He had no complaint (other than occasional, mild gastrointestinal distress), but was selected for study because of our interest in his musculoskeletal adaptations to the amputation.

Radiographic and physical examination. According to relative heights of his femur heads measured radiographically in the standing position, his artificial leg (attached to the mid-thigh stump) was almost one inch (approximately 2.5 cm.) too short. He had a long mild scoliotic curve, convex to the left, extending from the tilted sacrum to a sharp "breakover" point between the sixth and seventh thoracic vertebrae. Paraspinal musculature was thickened and tense on the left side throughout the length of the scoliosis and one or two segments above, as compared with the right side. Deep tenderness was especially marked on the left side in the lumbar region and in the midthoracic region.

Electrical skin resistance (Fig. 3). The exploration revealed a virtually continuous area of low resistance on the left side, extending from the level corresponding to the top of the sacrum to the midthoracic region.

Case 4. Patient A.W., Female, 30 years (Fig. 4).

Complaint: About two weeks prior to this study the patient had slipped on an icy sidewalk and fallen heavily, the impact being mainly on the left buttock. In addition to painful bruise of the coccyx, she complained of persistent pain and muscular spasm along the lumbar spine on the left side. She had also observed areas of exquisite hyperesthesia of the low back, groin and thigh.

Radiographic examination revealed nothing significantly related to the complaint.

Electrical skin resistance. Fig. 4 shows areas of low resistance found on this patient. They corresponded very closely with the areas of hyperesthesia, even light movement of the exploring electrode over them causing considerable discomfort. Comparison of this chart with maps of the sympathetic dermatomes based on the boundaries between high and low resistance areas found on patients following ganglionectomies at various segmental levels (*Richter* and *Woodruff*[13]), indicate an irritative injury of spinal roots L-1 and L-2 on the left side, as a consequence of the fall.

Case 5. Patient M.S., Male, 42 years (Fig. 5).

Complaint: This man, a farmer, was brought to the hospital unable to bear his weight on the right leg because of severe lumbosacral pain on the right side, with sciatic radiation. Onset followed a series of severe "bumps" while driving a tractor on his farm. Similar attacks, though less severe, had occurred in previous months, especially following vigorous physical work and operation of motorized farm equipment on which he was seated. On the basis of symptoms and physical findings a diagnosis of

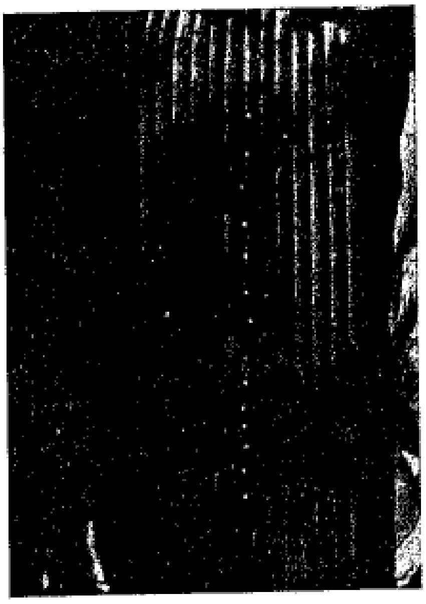
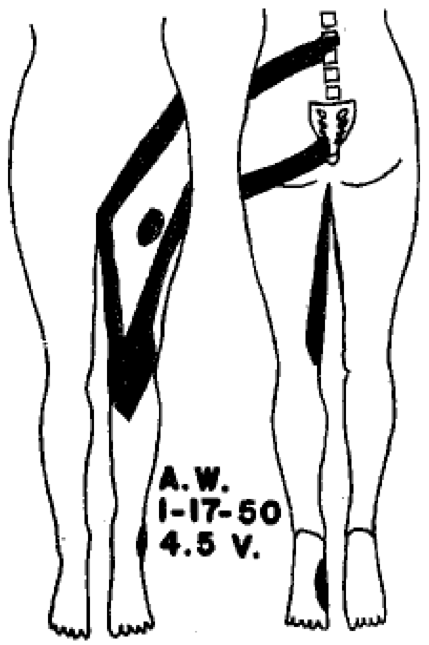


Fig. 3. The ESR pattern of patient W.P. shows a large area of low resistance on the left side, from the midthoracic region to the base of the sacrum. Photographic method (see text, Case 3).

Fig. 4. The ESR pattern of A.W. shows low resistance areas which correspond closely to the areas of hyperesthesia in this patient. Exploration with hand-held electrode (see text, Case 4).



EMG, SNS, reflexes, etc.

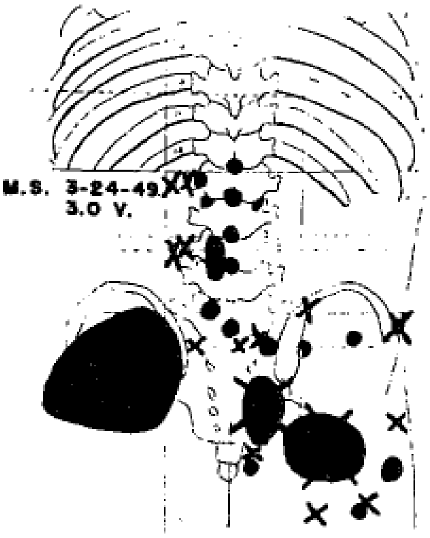


Fig. 5. The ESR pattern of patient M.S. The areas of low resistance are shown as black spots: the areas of tenderness are indicated by X marks. Exploration with hand-held electrode (see text. Case 5).

rupture of the intervertebral disc between L-5 and the sacrum, with herniation on the right side was made. This diagnosis was confirmed at surgery.

Electrical skin resistance. The lower part of the trunk of this patient was explored with hand-held electrode about one hour following admission to the hospital. The areas of markedly lowered resistance are shown as black spots of various sizes in Fig. 5. According to the system described in a previous paper[1] the resistance in the areas marked in black is $1/_{30}$ or less that of the background resistance, in this case 150,000 ohms or less as compared with a general resistance of at least 3,000,000 ohms (1 μa of current flow or less at 3 volts). The area shown over the left ilium was intermediate (about 750,000 ohms) and was shown in gray on the original chart: the difference in density from the other areas was, however, lost in photographic reproduction of the chart.

Areas of tenderness. At our request, the attending physician independently conducted a palpatory examination of the patient in which he elicited areas of most severe deep tenderness by digital pressure and recorded them on a chart similar to that used for the ESR patterns. His chart was then superimposed on ours and, in the composite chart shown in Fig. 5, the areas of tenderness are indicated by X marks. Vigorous digital pressure to the areas caused not only local pain but, in most of the areas, also radiation and even remote reference of pain similar to that described by *Travell*[14] and others.

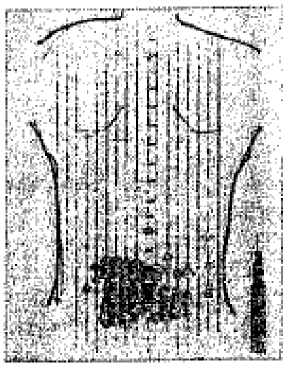



Fig. 6 a. Radiographs of patient I.M., standing (see text, Case 6).

Fig. 6 b. The ESR pattern of patient I.M. The areas of low resistance in the lumbosacral region developed after applying heat to the ventral surface of the patient. Recorded with pantographic method (see text, Case 6).

Case 6. Patient I.M., Male, 28 years (Fig. 6).

Complaint: Severe pain over the lumbosacral area.

Radiographic examination (Fig. 6 a) revealed bone change in the articulation of L-4 and L-5, including erosion of the lamina of L-5 on right side, probably due to pressure of inferior articular process of L-4. The inferior facets of L-4 and L-5 are frontal, rather than sagittal, in orientation.

Electrical skin resistance. The patient's ESR pattern, obtained with the pantographic method, is shown in Fig. 6 b. The apparently facilitated area shown in the lumbosacral area was elicited in this subject by applying heat to the body. Though explored in mid-spring (April 30) at room temperature 25.6°C, the skin of his back had a uniformly high resistance. Electric heating pads were applied to the ventral surface and the area shown in the figure had appeared after 30 minutes. An additional 20-minute period of heating produced only slight upward spread of this area.

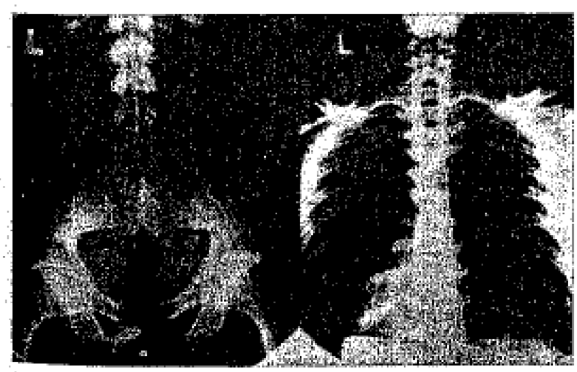
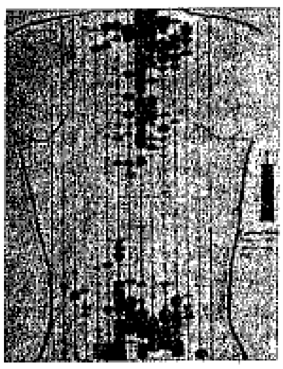



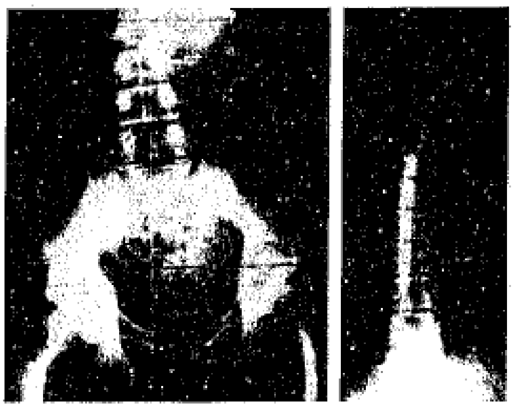
Fig. 7 a. Radiograph of patient G.C., standing (see text, Case 7).

Fig. 7 b. The ESR pattern of patient G.C. shows areas of low resistance in the lumbosacral and cervicodorsal regions which were related to the areas of musculoskeletal stress. Pantographic method.

Case 7. Patient G.C., Male, 21 years (Fig. 7).

Complaint: Lumbosacral pain; discomfort and restricted motion at the cervicodorsal junction and occasional torticollis.

Radiographic and physical examination. Stress at the lumbrosacral junction is evident in the apparent loss of cartilage and the thickening of the articular plates between L-5 and



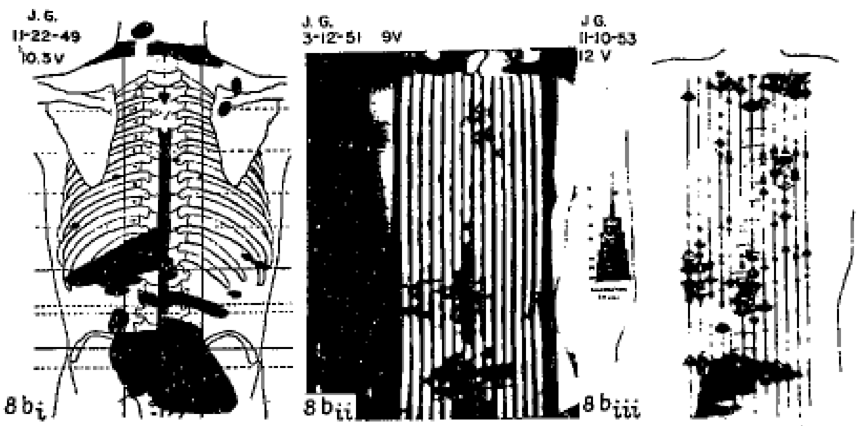


Fig. 8 a. Radiographs of patient J.G., standing (see text, Case 8).

Fig. 8 b. The ESR patterns of patient J.G. taken over a period of 4 years consistently showed areas of low resistance at the lumbosacral, the dorso-lumbar and the cervico-dorsal junctions and in the midthoracic region. The relation of the patterns to clinical findings is discussed in the text. — 8 bi. November 1949; pattern recorded with hand-held electrode. — 8 bii. March 1951; photographic method. — 8 biii. November 1953; pantographic method.

Fig. 8 c. Electromyographic record of the posterior vertebral muscles during quiet standing, in patient J.G. — The cardiac artifact is evident on each record, but is easily distinguished from electromyographic activity which was consistently most marked, in this subject, at the upper thoracic levels (especially on the right side) and at lumbar levels on the left side. Slight or moderate activity, as shown here, was also usually evident at lower thoracic levels.

Activity of the paravertebral muscles at various segmental levels during standing was sampled in the following manner. Silver surface electrodes were tightly affixed to the skin at selected sites (resistance lowered with electrode paste) over the spinal extensors. Electrodes were placed at levels corresponding to the tips of spinous processes of alternate vertebrae T 1, T 3, T 5 . . . L 5, on left and right sides. Electrodes were led through a switchbox to four differential amplifiers (Offner) *for recording with penwriters (and for monitoring with cathode ray oscilloscope and loudspeaker).*

Two consecutive electrodes on each side T1 — T3, T3 — T5 . . . L3 — L5) served as electrode pairs, thus sampling activity in the intervening musculature. Four such areas (electrode pairs) were sampled simultaneously, the switchbox making possible a survey of the entire length of thoracic and lumbar spine (16 electrode pairs) within 30 seconds. Subjects were asked to stand at rest and relaxed, serial records being taken until activity had subsided to a minimum.

S-1 on the left side (Fig. 7 a). Asymmetry with respect to planes of the articular surfaces (sagittal on the left, more nearly frontal on the right) between L-4 and L-5 and between L-5 and S-1 may have contributed to the stress. A lateral tilt of the cervical spine to the right is also evident in the film.

Examination of the patient disclosed considerable muscular splinting in the lumbar area, particularly on the left side, and fixity of the thoracic spine with some loss of the normal posterior convexity. The patient's head was carried in a forward position. This was associated with considerable thickening of tissue over the cervicodorsal junction and much muscular tension in this area.

Electrical skin resistance (Fig. 7 b). Pantographic exploration showed that the areas of low resistance predominated in areas of skin which are regionally related to areas of musculoskeletal stress.

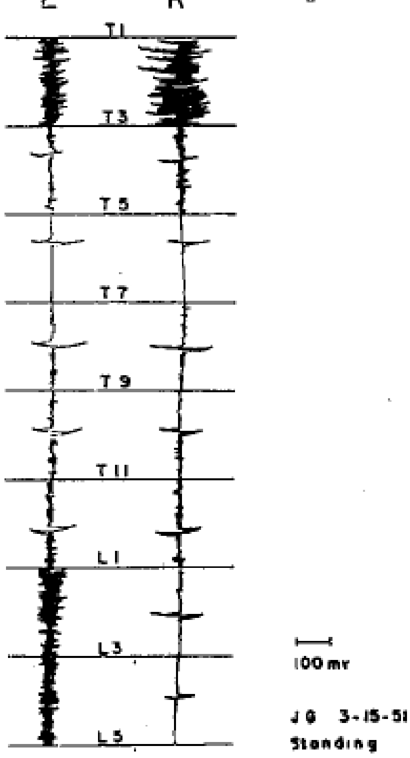
Case 8. Patient J.G., Male, 25 years (Fig. 8).

Complaint: Pain in low back; pain and stiffness at cervicodorsal junction; occipital and suboccipital headaches.

Radiographic examination. Multiple lateral curves of the spinal column are evident in Fig. 8 a, possibly related to the discrepancy in leg length, the left femur head being approximately one inch (2.5 cm.) lower than the right. One scoliotic curve, convex to the left, involves the entire lumbar spine. The planes of the articular surfaces between L-3 and L-4, L-4 and L-5, L-5 and S-1 appear to be factors in the lumbosacral stresses contributing to the symptoms in this area. Another lateral curve, also convex to the left, involves the lower half of the thoracic spine, with relatively sharp angulations at the extremes of the curve, T-12—L-1 and T-5—T-6. The cervical spine (not shown) leaned considerably to the left, there also being a lateral curvature, convex to the right, and a sharp inflection at the cervicodorsal junction. This patient carried his head well over the left shoulder, with considerable tension in the posterior cervical musculature on the right side.

Electrical skin resistance. The major areas of low resistance (Fig. 8 b)

Fig. 8 c



appeared over a period of several years (November, 1949 — November, 1953) to be consistently associated with the regions of sharpest angulation of the vertebral column: the vicinity of the lumbosacral junction, the dorsolumbar junction, the midthoracic region and at the cervicodorsal junction.

Electromyographic observations. An electromyographic sampling of the activity of the posterior vertebral muscles during quiet standing (Fig. 8 c) indicated that considerable activity of the spinal extensors, much stronger on one side than the other, was required in these same regions for the maintenance of the erect posture in this patient. Thus, there was conspicuous activity of the lumbar musculature, extending somewhat to the lower thoracic levels, on the convex (left) side of the scoliosis, and of the upper thoracic segments, especially on the right side, possibly because of the lateral displacement of the head and neck. (Activity of the cervical musculature was not sampled.)

This electromyographic study was part of a series done on a large number of subjects, many of them observed repeatedly over long periods of time *(Korr* and *Thomas*[15], *Wright* — unpublished observations[16]). As has been shown by *Floyd* and *Silver*[17], *Portnoy* and *Morin*[18], *Joseph* and *McColl*,[19, 20] and others, we too found that some subjects were able to achieve a standing posture in which there was very little activity of the posterior vertebral muscles. However, in our experience, some degree of localized, often asymmetrical, activity was found in every subject. The patterns of such activity — location, extent, relative amount, etc., varied from subject to subject, according to body build, posture, weight distribution, spinal and pelvic configuration and other, unidentified factors. As we have found to be true for sudomotor and vasomotor activity[1, 2] the patterns are remarkably constant and characteristic for each subject.

Discussion

In the preceding report from this series of investigations[8], we showed that we were able to modify the ESR patterns of human subjects by experimentally induced irritations and stresses in the musculoskeletal tissues. Intramuscular injection of small quantities of hypertonic saline, for example, caused the appearance of new areas of low ESR in those individuals in whom referred pain was induced, the new areas of low resistance appearing in the reference zone. Postural stresses caused exaggeration of existing patterns of low-resistance areas (further lowering of resistance and spreading of areas) and the appearance of new areas of low resistance according to the nature and location of the applied stress, the individual's vertebral adaptation to the stress and the areas of discomfort. On the basis of studies by *Thomas* and others in our laboratories previously cited[3–5], the induced changes in ESR (and accompanying vasomotor changes) would seem to represent sympathetic responses to the experimental musculoskeletal insults.

In discussing our findings in the foregoing paper, we proposed that the sympathetic changes were not anomalous reflexes, invoked *de novo* by the noxious myofascial stimulation, but that they were modifications of normally operating patterns of somato-autonomic coordination. Examples of these patterns are those of centrally ordered adjustment of visceral, cardiovascular and thermoregulatory functions which continually take place according to changing muscular activity, heat production of muscular work and posture. Although the efferent components of these reflex patterns (motoneurons and preganglionic neurons, largely spinal in origin) are multisegmental and under control of higher centers, their activity is also under the continual influence of afferent impulses arising in peripheral receptors and nerve endings, conveyed over dorsal root fibers. Indeed, the local and segmental sensory inputs are essential to the proper execution of the patterns with appropriate adjustment to local circumstances and demand. It was our conclusion that the sympathetic responses (indicated by altered ESR patterns) to the experimental myofascial insults reported in the preceding paper were exaggerated versions of the local components.

The studies reported in this paper on subjects with musculoskeletal stresses and irritations of traumatic, congenital, postural or pathological origin revealed similar regional exaggerations of sympathetic activity. Although the changes produced in the affected musculoskeletal tissues in a few minutes or even a few hours, by saline injection or by experimental postural stresses, may be expected to bear only superficial resemblances to those associated with clinical conditions of much longer duration such as are reported in this paper, it is likely that the neural and reflex mechanisms are fundamentally the same. As we stated in the previous paper[8], we believe that the altered patterns of sympathetic activity (as well as associated alterations in muscular activity) are either reflex manifestations of changes in sensory input arising in nerve endings and receptors in the musculoskeletal tissues or the effects of direct insults to nerve fibers (or ganglion cells) or a combination of both.

Nevertheless, the question arises as to how the processes that are involved are modified with time. Our experimental studies certainly indicate that the altered sudomotor and vasomotor activities in the aberrant areas at least *begin* as parts of reflex responses to centripetal streams of impulses originating in somatic structures or, possibly, as the effects of direct mechanical or chemical irritation of nerve fibers. But one wonders whether the same mechanisms would continue to operate in essentially the same way for periods of weeks to years. Clinical and pathological evidence indicates that in the face of chronic stress or irriation and of sustained reflex activity, adaptive changes would take place either in the stressed or irritated tissue (e.g., fibrosis of muscle), in the participating neurons (e.g., altered excitability), in the responding organs or tissues (e.g., altered contractility of blood vessels, altered secretory activity of sweat glands) or in combinations thereof.

In studies to be reported more fully in a subsequent publication[3,21,22] we investigated the functional alterations in the apparently aberrant segments by comparing the simultaneous responses of these areas with those of apparently normal adjacent or corresponding contralateral areas to such generalized stimuli as alteration in environmental temperature, change in posture from recumbent to standing, pain, threat of pain, startling, etc. We found that the segments represented by aberrant dermatomes (with respect to sudomotor and vasomotor activity) *are* profoundly altered functionally. The responses of these segments to thermoregulatory, postural or emotional demand were, relative to the adjacent or contralateral control segments, so altered quantitatively, in terms of threshold, latency, magnitude and duration of response, as to be inappropriate to the demand. The direction of the alteration in the segments represented by low-resistance areas have been consistently in such a direction as to indicate facilitation of the sympathetic pathways to the skin. Whether this reflects an alteration in those neurons themselves or sustained afferent (or pre-ganglionic) bombardment has not been determined. The recent studies of *Thomas* and *Kawahata*[5] clearly indicate that in our subjects the altered sudomotor responses in the low-resistance areas were due to changes in impulse traffic in the sudomotor pathways rather than in the sweat glands themselves. Whether changes in the sweat glands would eventually occur in such situations has not yet been determined, although the occasional finding of extremely high-resistance, nearly anhidrotic, areas, similar in size, shape and distribution to low-resistance areas reported in these studies, suggests that such changes may occur.

The reader is referred to our preceding paper[8] on experimental insults and stresses for a more detailed discussion of the theoretical and clinical implications of the segmentally and regionally patterned autonomic concomitants of myofascial stresses and abnormalities, and of the relevant work of other investigators. The present study confirms that local changes in sympathetic function may be not only acutely and temporarily induced by relatively brief experimental results, but that enduring changes in patterns of sympathetic activity may become associated with musculoskeletal disturbances of clinical origin. This study also strengthens our suggestion that the patterns of aberrant areas of sudomotor and vasomotor activity previously described in apparently healthy subjects[1, 2] may reflect subclinical and asymptomatic disturbances of afferent bombardment, over selected dorsal roots, or of direct irritation of nerve fibers or ganglion cells. The patterns associated with visceral disturbances as such sources of afferent bombardment and neural irritation will be presented in the succeeding paper.

Summary

1. These studies on 130 patients have been concerned with topographical patterns of sudomotor activity associated with known musculoskeletal disturbances, myofascial stresses and pain syndromes.

2. The method employed for measuring sudomotor activity, as an indicator of regional variations in sympathetic activity, was that of recording the electrical resistance of the skin (ESR). Radiographic, electromyographic and palpatory examinations, as well as other conventional clinical methods, were used in the evaluation of the musculoskeletal disturbances.

3. The observations frequently showed the presence of regional and segmental patterns of low electrical skin resistance (LRA) in areas of referred pain and dermatomes segmentally related to the musculoskeletal disturbances or myofascial stresses.

4. These patterns of altered electrical skin resistance appear to reflect enduring changes in the patterns of sympathetic activity associated with musculoskeletal disturbances of clinical origin.

5. These studies suggest that the patterns of aberrant areas of sudomotor and vasomotor activity, which we have previously described in apparently normal subjects, may reflect subclinical and asymptomatic sources of afferent bombardment, over selected dorsal roots, or of direct irritation of nerve fibers or ganglion cells. That is, the altered patterns of sympathetic activity appear to be either reflex manifestations of changes in sensory input arising in nerve endings and receptors in the musculoskeletal tissues or the effects of direct insults to nerve fibers (or ganglion cells) or a combination of both.

References

1. *Korr, I.M., P.E. Thomas* and *H.M. Wright*, Patterns of electrical skin resistance in man. Acta neuroveget., Wien, *17* (1958), 77-96.

2. *Wright, H.M., I.M. Korr* and *P.E. Thomas*, Local and regional variations in cutaneous vasomotor tone of the human trunk. Acta neuroveget., Wein, *22* (1960), 33—52.

3. *Thomas, P.E.*, and *I.M. Korr*, The relationship between sweat gland activity and electrical resistance of the skin. J. Appl. Physiol., Wash., *10* (1957), 505—510.

4. *Kawahata, A.*, and *P.E. Thomas*, Further studies on the neural basis for regional differences in ESR. Fed. Proc. *18* (1959), 80.

5. *Thomas, P.E.*, and *A. Kawahata*, Neural factors underlying variations in electrical skin resistance of apparently non-sweating skin. J. Appl. Physiol., Wash., *1962, 17.*

6. *Korr, I.M.*, Experimental alterations in segmental sympathetic (sweat gland) activity through myofascial and postural disturbances. Fed. Proc. *8* (1949), 88.

7. *Korr, I.M.*, Skin resistance patterns associated with visceral disease. Fed. Proc. *8* (1949), 87.

8. *Korr, I.M., H.M. Wright* and *P.E. Thomas*, Effects of experimental myofascial insults on cutaneous patterns of sympathetic activity in man. Acta neuroveget., Wien, *23* (1926), 329—355.

9. *Thomas, P.E.*, and *I.M. Korr*, The automatic recording of electrical skin resistance patterns on the human trunk. Electroencephalogr. *3* (1951), 361—368.

10. *Thomas, P.E., I.M. Korr* and *H.M. Wright*, A mobile instrument for recording electrical skin resistance patterns of the human trunk. Acta neuroveget., Wein, *17* (1958), 97—106.

11. *Jasper, H.*, An improved clinical dermometer. J. Neurosurg., Springfield. *2* (1945), 257—260.

12. *Denslow, J.S., J.A. Chace, O.R. Gutensohn* and *M.G. Kumm*, Methods in taking and interpreting weight-bearing X-ray films. J. Amer. Osteopath. Ass. *54* (1955), 663—670.

13. *Richter, C.P.*, and *B.G. Woodruff*, Lumbar sympathetic dermatomes in man determined by the electrical skin resistance method. J. Neurophysiol., Springfield, *8* (1945), 323—338.

14. *Travell, J.*, Pain mechanisms in connective tissues in C. Ragan. Ed. Second Conference on Connective Tissues. Josiah Macy Jr. Foundation (1952), 86—125.

15. *Korr, I.M.*, and *P.E. Thomas*, Segmental patterns in man. Fed. Proc. *10* (1951), 75.

16. *Wright, H.M.*, Unpublished observations.

17. *Floyd, W.F.*, and *P.H.S. Silver*, The functions of the erectores spinae muscles in certain movements and postures in man. J. Physiol. *129* (1955), 184-203.

18. *Portnoy, H.*, and *F. Morin*, Electromyographic study of postural muscles in various positions and movements. Amer. J. Physiol. *186* (1956), 122—126.

19. *Joseph, J.*, Man's posture; electromyographic studies. p. 1—88, Thomas, Springfield, 1960.

20. *Joseph J.*, and *I. McColl*, Electromyography of muscles of posture: posterior vertebral muscles in males. J. Physiol. *157* (1961), 33—37.

21. *Thomas, P.E., H.M. Wright* and *C.W. Hart, Jr.*, Relation of sweat gland recruitment to ESR. Fed. Proc. *12* (1953), 143.

22. *Korr, I.M., P.E. Thomas* and *H.M. Wright*, Symposium on the functional implication of segmental facilitation. J. Amer. Osteopath. Ass. *54* (1955), 265—282.

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