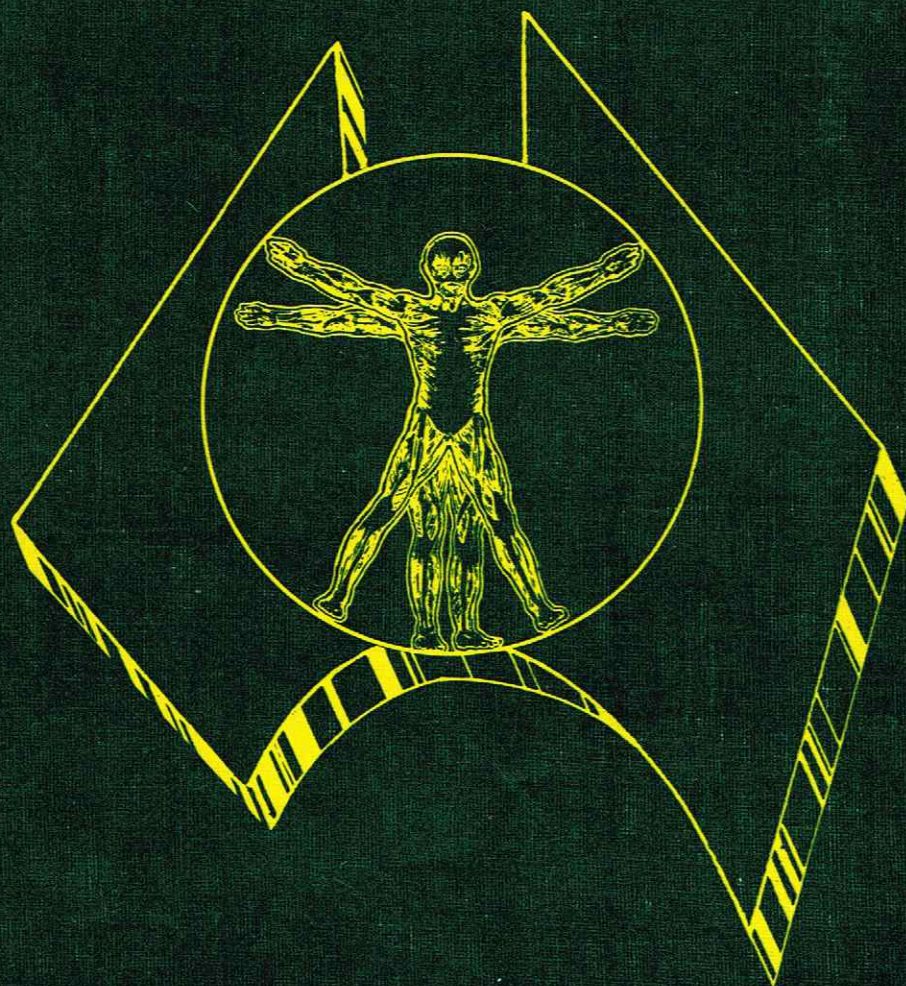


**Australian
Association of
Musculoskeletal
Medicine**

Bulletin



Intervertebral Disc Biology

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AUSTRALIAN ASSOCIATION OF MUSCULOSKELETAL MEDICINE

OFFICE-BEARERS 1988

The following members were elected to office at the annual general meeting in Brisbane on 23rd October, 1987.

PRESIDENT:

Dr. Nikolai Bogduk BSc (Med) (Hons), MB, BS (Hons), PhD,
Dip Anat, Hon MMTAA.

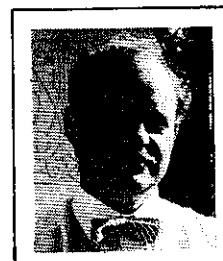
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Dr. Roger Watson	Townsville, Qld.	(077) 71 3084

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Editorial

The physical and biological sciences have been regarded as fundamental elements of medical knowledge ever since medicine began to develop as a scientific discipline. This is acknowledged by their designation as "basic sciences". However, their place in medical thought and discussion is often underrated and they tend to be overshadowed by clinical subjects, which possibly seem more relevant to the problems encountered by practising clinicians.

When thought and discussion relate to conditions which can be treated effectively by a number of modalities, it seems natural for the emphasis to be on therapeutic methods and techniques. Such an approach involves a fundamental imbalance between theoretical and practical aspects but this is generally accepted on the grounds that the basic scientific considerations will have little bearing on the clinical outcome. This may or may not be the case, and the attitude of imbalance is a basic weakness of many medical meetings and publications.

When conditions that do not respond readily to common management strategies are under consideration, this imbalance of thought is of particular importance. Refinements of therapeutic technique, although valuable in their own way, are often of no relevance to such problems and discussion of them may actually be counterproductive by obscuring the real issues. This type of obfuscation is frequently seen in articles on back pain which assume a clinical entity such as "non-specific back pain" and go on to discuss its treatment by various modalities; clearly the real problems concern pathogenesis and diagnosis, not treatment.

The essence of any problem is that its solution is not readily apparent. Those who seek to solve a problem need to increase their understanding of the nature of its elements. It behoves all of us, who deal regularly with the practical problems of musculoskeletal medicine, to make ourselves familiar with the physical and chemical mechanisms operating in the structures and functions involved and to relate them to the clinical phenomena which we observe. In this way we increase our knowledge in both breadth and depth, and the significance and relevance of our observations are made clearer.

The A.A.M.M. Committee gave a great deal of thought to the place of the basic sciences in its preparation of the syllabus published last year. It was felt that considerable emphasis should be given to increasing members' knowledge in these areas as a means of advancing the discipline as a whole. Hence the predominantly "theoretical" nature of the last Annual Scientific Meeting, a theme which has been continued in this issue of the Bulletin.

On later pages will be found a report of the 1987 meeting and papers setting out details of the embryology, functional anatomy and biochemistry of the intervertebral disc, together with considerations of factors which influence them, particularly the changes that develop through life with the ageing process. There is also a paper on biomechanical principles, exemplified by reference to the known behaviour of disc tissues under various conditions.

The abstracts section of this issue is again of considerable length and is devoted mainly to considerations of biomechanics, ergonomics and factors which influence epidemiology.

To some these topics may appear "dry" and "academic". Some may even feel they are the province of the undergraduate rather than of the experienced practitioner in the field. In fact, they are none of these things: they are the very essence of the science on which effective clinical practice is based. Application of their principles will ultimately provide the keys not only to problems of clinical assessment and diagnosis but also to the matters of therapeutic efficacy with which clinicians are most concerned.

From The Hon. Secretary's Desk



At the Back Pain Seminar held in Melbourne on Saturday, March 12th, 1988 a number of interesting and contentious points were discussed. By the way, the day appeared to be fairly successful, with most of the participants spending an extra hour pontificating over a number of issues.

I think it was Brendan Pitts who raised the issue of why aging is accompanied by loss of stature and spinal length. An assertion was made from the floor that this was due to natural thinning of the intervertebral discs. However, this assertion is incorrect, according to the paper of Lance Twomey and James Taylor "Age Changes In Lumbar Intervertebral Discs" (*Acta Orthop Scand* 1985; 56:496-499). This paper's abstract and first paragraph is as follows:

"Measurements of disc thickness, shape and degeneration using the criteria described by Rolander (1966) were recorded from 204 post-mortem lumbar spines. The 'true average disc height' increased with age as the discs 'sink' into the vertebrae. These results add information to previous studies which indicate that the loss of transverse trabeculae of lumbar vertebrae is primarily responsible for the change in shape of both vertebrae and discs in the elderly. While the incidence of disc degeneration does increase in old age, the majority of the discs examined did not show evidence of any such change.

Old age is accompanied by decline in stature and spinal length, which has been attributed largely to a reduction in the height of the intervertebral discs. However, quantitative studies of age changes in the vertebral column indicate that there is a loss in the height of vertebrae and a change in the shape of the vertebral end-plate in old age, and that this is the major factor leading to the decline in stature. There are no studies showing a reduction in intervertebral disc height in old age in 'normal' populations. Indeed, Nachemson et al (1979), reporting on a relatively small number of lumbar discs, showed that old age and disc degeneration are not necessarily linked, and also that disc degeneration is not synonymous with disc thinning. In their study, the five most grossly degenerated discs showed no evidence of disc thinning.

In fact, the mid disc height increases considerably as the end-plate collapses, and the anterior and posterior heights thin".

The use of bed rest also came into question. This issue has been excellently presented in one of the 1987 Volvo Awards for Research in Low-Back Pain. The paper was written by Gordon Waddell, is in *Spine* 1987; 12,7:632-644, and is entitled "Treatment of Low-Back Pain".

Studies have shown that two days of rest are better than seven, but are two days better than no days. I have certainly witnessed the vicious cycle of rest, where attempts at mobilisation become increasingly complicated by pain exacerbation, leading to more rest and radical therapeutics. I commend all those practitioners who are immersed in rest and total pain avoidance to read this article, and to consider changing their ways.

I quote one of this paper's paragraphs:

"The evidence is clear. There is a fundamental antithesis between the passive and active approaches of rest or activity. There is no evidence that rest has any beneficial effect on the natural history of low-back pain. On the contrary, there is strongly suggestive evidence that rest, particularly prolonged bed rest, may be the most harmful treatment ever devised, and a potent cause of iatrogenic disability. There is clear evidence that, despite general belief, activity is not harmful, and active rehabilitation not only restores function but also reduces pain. It remains to be proved whether a policy of active mobilisation and early return to work can be put into widespread clinical practice but the following questions can no longer be avoided: rest or mobilisation? rest or restoration of function? rest or recovery?"

See you at the track.

David Vivian



NEWS

"heard on the bush telegraph"

At a recent meeting of the Committee the decision was taken to publish the Bulletin three times a year, in January, May and September. There were several reasons for the change, including rising costs, but the most important ones were logistic: the production of the Bulletin is truly a team effort these days.

* * *

The annual conference will be held in Newcastle this year, from 25th to 27th November, 1983. The Committee discussed several alternatives involving combined meetings with other associations, as has been done previously, but decided instead to have a conference just for the A.A.M.M. membership. It was also decided to have an essentially practical theme for the meeting, "Injections in Musculoskeletal Medicine", to round off a year in which theoretical scientific concepts have already received considerable attention. Further details will be found on the Meetings pages.

* * *

The main thrust of the Association's current educational programme, which began with the development of the syllabus last year, is now being directed towards the establishment of formal courses in musculoskeletal medicine leading to registerable qualifications in the discipline. It is envisaged that courses will be conducted at two levels, one leading to a diploma and the other to a master's degree. Obviously it would not be appropriate for the Association to run such courses itself and negotiations are in progress with tertiary educational institutions with suitable interests and facilities.

* * *

Meantime, our colleagues across the Tasman have been developing similar ideas and their diploma course, through the University of Otago, is expected to commence in 1989. The New Zealanders have had considerable help in the setting up of their course from Dr. Jiri Dvůřák, an internationally recognised authority whose publications will be familiar to most members.

* * *

Members interested in skiing will be patching up their thermal underwear and digging out their snowproof parkas in preparation for the Winter Meeting to be held at Mount Buller again this year, in the last week of July. Winter Meetings are one of the Association's lesser known but more enjoyable activities and all members and their families are welcome to attend. Details will be found on the Meetings pages. Those who would like to go but have not yet signified their intention are asked to do so as soon as possible, as arrangements must be finalised in the near future.

* * *

Following his protracted study tour of Europe last year, committee member **Clive Kenna** of Melbourne is involved in organising a ten day workshop course in orthopaedic medicine with Dr. Robert Maigne in Paris in September, 1988. Anyone interested can contact him on (03) 598 4095.

* * *

The publishers of the English language edition of the F.I.M.M. journal "Manual Medicine" are reviewing their commitment and are believed to be formulating a new editorial policy to be administered by a new editorial board. Opportunities exist for greater Australian input for this journal (after all, we do lead the English-speaking world in this field) and all A.A.M.M. members are encouraged both to subscribe and to contribute to it.

* * *

The President will be away for most of May attending international conferences in several parts of the world, including New Orleans, USA, and Montreux, Switzerland. Whilst international travel can be enjoyable under some circumstances, few would envy his busy schedule. The rest of us can be very grateful that he is prepared to put so much effort into maintaining such a high international profile, which is reflected onto us all.

* * *

W.A. State Representative **Marius Loeffler** is continuing to develop a more active branch in that state despite difficulties which have arisen in his path. He is obviously determined to succeed and great things are expected to be heard from the State of Excitement in the near future.

* * *

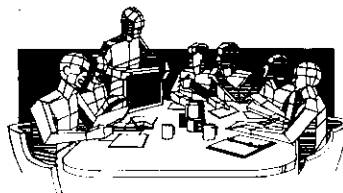
Some minor changes were made to the Association's constitution at the last Annual General Meeting. The full text of the current constitution is published on pages 58 and 59 of this issue of the Bulletin for the information of all members.

* * *



A cheerio call to someone selected at random from the membership barrel

The call goes out this time to **David McGrath** who is very busy this month moving from Queensland to Victoria. It will be a major change in more ways than one, as it marks the end of David's long period of service in the R.A.A.F. He and his wife Aleysha will be leaving Amberley, his last service posting, to make their home in Shepparton, where David will be going into private practice. No doubt his interests in musculoskeletal medicine and occupational medicine will be appreciated by the community there and the Air Force's loss will be Shepparton's gain.



MEETINGS, CONFERENCES AND COURSES

LOCAL AAMM MEETINGS

Regular meetings, practical sessions and courses are conducted in numerous centres around Australia by state branches, local groups and individual members of the Association. These activities are mainly for the benefit of members living in a particular area and they will generally be advised by letter or by local notices of dates, times and venues. Anyone who is not receiving information about local activities, or who would like more details about what is going on, should contact one of the local organisers listed below.

In **Adelaide**, Dr. Norm Broadhurst, telephone (08) 295 1890.

In **Ballarat**, Dr. Jim Rose on (053) 35 7366.

In **Brisbane**, Dr. Carl Rotkirch on (07) 344 1022.

In **Canberra**, Dr. Goff Nelson on (062) 95 6773.

In **Hobart**, Dr. Ron Heddle on (002) 34 5990.

In **Melbourne** and **Geelong**, Dr. Bruce Kinloch on (03) 420 5313 and Dr. David Vivian on (03) 596 7211.

In **Newcastle**, Dr. Nik Bogduk on (049) 68 5699.

In **Perth**, Dr. Marius Loeffler on (097) 33 5220.

In **Sydney**, Dr. Conrad Winer on (02) 27 8926.

In **Taree**, Dr. Wade King on (065) 50 5167.

In **Toowoomba**, Dr. Jeff Phillips on (076) 38 4800.

In **Townsville**, Dr. Roger Watson on (077) 71 3084.

In **Wollongong**, Dr. Alex Ganora on (042) 67 2811.

Those who live in other areas and who would like to organise or participate in local meetings should contact one of their state representatives, who can arrange publicity and other assistance from the resources of the Association.

CERVICAL SPINE SEMINAR

The **Melbourne** seminar on Cervical Spine Disorders has been changed to Saturday, July 2nd, 1988.

The venue is 302 Malvern Road, Prahran. The speakers will include Mr Rossi, Dr Holland and Dr Vivian. Contact is via Dr D Vivian, 302 Malvern Road, Prahran, 3181. Phone (03) 529 1988.

WINTER MEETING

The Winter Meeting will be held at **Mount Buller**, Victoria, again this year, from Sunday 24th until Friday 29th July, 1988. This meeting is designed to bring together members and their families in a more relaxed atmosphere than is usual at the formal scientific meetings conducted by the Association. Plenty of time is available for discussions and demonstrations, both on and off the ski slopes.

Mount Buller offers a wide variety of runs for all grades of skiers, including children and beginners who are especially well catered for. At a cost of \$150 per person for the six days this is too good an opportunity to miss. Those who would like to attend should contact Dr. Wade King, P.O. Box 1044, Taree, NSW, 2430, telephone (065) 50 5167, as soon as possible.

ORTHOPAEDIC MEDICINE WORKSHOP COURSE

A ten day practical workshop course will be conducted in English by the internationally recognised Dr. Robert Maigne at the Department of Orthopaedic Medicine, **Paris**, France, from 12th to 23rd September, 1988.

This is a unique opportunity for doctors either to be introduced to orthopaedic medicine and spinal manipulation, or to update their skills.

Numbers will be strictly limited.

For further details, contact Dr. Clive Kenna, P.O. Box 116, Chadstone Centre, Melbourne, Victoria, 3148, telephone (03) 598 4095.

ANNUAL CONFERENCE

The eighteenth Annual Scientific Meeting of the Australian Association of Musculoskeletal Medicine will be held in **Newcastle**, NSW, on **25th to 27th November, 1988**.

The main theme of the meeting will be "**Injections in Musculoskeletal Medicine**" and both theoretical and practical aspects of the uses of injections will be addressed. Programme details and registration forms will be sent to members in due course.

Further information can be obtained from Dr. Nik Bogduk, Faculty of Medicine, University of Newcastle, Newcastle, NSW, 2308, telephone (049) 68 5699 or from Dr. Wade King, P.O. Box 1044, Taree, NSW, 2430, telephone (065) 50 5167.

OTHER AUSTRALIAN MEETINGS

Numerous meetings on topics of relevance to musculoskeletal medicine are held throughout Australia by groups allied to the A.A.M.M. Members are specifically invited to attend many of these and they are advertised in the Bulletin on a reciprocal basis. Some of those coming up include the following.

May 11-14 1988. The Australian Pain Society will be conducting its 10th Annual Meeting in **Canberra**. For information, contact Raymond Newcombe, telephone (062) 85 1977.

June 1-3 1988. The 8th Annual Scientific Meeting of the ACRM will be held in **Brisbane** and entitled "Expo Rehab 88". Contact Mrs Anne Worden, 55 Charles Street, Ryde NSW, 2112.

July 16 1988. M.T.A.A. Symposium on "Current Concepts in the Management of Shoulder Region Dysfunction" at Stephen Roberts Lecture Theatre, Sydney University, **Sydney**. A registration form is enclosed with this Bulletin.

August 27 - September 2, 1988. **Cairns**. "Australian Bicentennial Medical Congress". Contact Ms J Myers, PO Box 20, Glebe, NSW, 2037.

October 8-9, 1988, **Sydney**. "The Spine & Low Back Pain Symposium". Speakers include W Kirkaldy-Willis, H Farfan, N Bogduk, G Bedbrook. Contact: Conference Secretariat, Science Foundation Centre, 35-43 Clarence Street, Sydney, 2000.

MEETINGS OVERSEAS

June 8-10, 1988. Industrial Ergonomics and Safety Conference '88 will be held in **New Orleans, Louisiana, USA**. Contact Dr F Aghazadeh, Conference Chairman, Industrial Engineer Department, Louisiana State University, Baton Rouge, LA 708 03, USA.

June 26 - July 1, 1988. Spine Disorders 1988: Current Solutions, **Gothenburg, Sweden**. Contact Alf Nachemson, MD, Dept. of Orthopaedics, Sahlgren Hospital S-413 45 Gothenburg, Sweden.

September 4-9, 1988. The International Federation of Orthopaedic Manipulative Therapists 1988 Congress in **Cambridge, UK**. For further information contact: IFOMT 88 Congress, Conference Services Ltd., Aldine House, 9-15 Aldine Street, London, UK, W12 8AW.

September 7-9, 1988, **Salford, UK**. 28th AGM Biological Engineering Society.

September 12-23, 1988, **Paris, France**. Ten Day Workshop in Orthopaedic Medicine by Dr R Maigne. Contact: Dr Clive Kenna, PO Box 116, Chadstone Centre, Vic. 3148.

September 22-23, 1988, **Newcastle-on-Tyne, UK**. The Biomechanics and Orthotic Management of the Foot-2.

October 24-28, 1988, **Beijing, China**. International Conference on Ergonomics, Occupational Safety & Health & The Environment.

November 4-6, 1988, **Rotorua, New Zealand** - Annual Conference of the New Zealand Association of Musculo Skeletal Medicine. Contact: Dr P Watson, 36 Ensign Street, Christchurch 3, NZ.

November 7-12, 1988, **Bangkok, Thailand**. 3rd International Conference on Musculoskeletal Accidents in the Workplace.

The International Society for the Study of the Lumbar Spine Traveling Fellowship Award. Information for applications can be obtained from Dr Henry LaRocca, Chairman, Committee for Spine Fellowships, The International Society for the Study of the Lumbar Spine, 4938 Prytania Street, **New Orleans, LA 70115, USA**.

September 18-22, 1989. The FIMM 9th International Congress will be held in **London, UK**, with plenary sessions at the Kensington Town Hall. A.A.M.M. members will be sent registration brochures nearer the time. Enquiries at this stage should be directed to Conference Associates FIMM, 27A Medway Street, London SW1P 2BD, United Kingdom.

1987 ANNUAL SCIENTIFIC MEETING REPORT

In October 1987, the Annual Scientific Meeting of the AAMM was held in conjunction with the NZAMM and the Australian Spinal Research Society. The highlight of the meeting was a symposium on "The Biology of the Lumbar Disc". This symposium was designed as a comprehensive and detailed teaching session on this topic. The lectures were designed to review all current knowledge on the lumbar disc, and ordered to provide a description of how normal structure is affected by age and injury, leading to an explanation of how discs can become a source of pain, and how this pain might be managed.

In the first session on the Saturday morning, three lectures were given which outlined the structure and development of the disc, and to outline basic principles of biochemistry and biomechanics. The latter two lectures were designed to provide definitions of terms and concepts that would be used and developed in later lectures. In the second morning session, the normal movements and biomechanics of the lumbar spine were described in order to set the context for interpreting abnormal and damaging movements which were to be addressed later.

In the first afternoon session on Saturday, the lectures still addressed the normal, uninjured disc, but focussed on how the disc changes with age. The object was to clarify that certain changes that occur in discs are due simply to age, and should not be construed as pathological. The final afternoon session addressed the pathology of disc pain. In this session, all the concepts that had been introduced previously in the context of normal discs were marshalled to explain how discs could be injured and become painful; how excessive ranges of movement could damage the anulus fibrosus, and how alterations in the biochemistry of the disc could result in pain. The object was to explain how the disc itself could become a source of pain, in the absence of disc herniation. In fact, the session specifically avoided any consideration of disc herniation; the intention being to withdraw attention to this over-emphasised condition, and to focus on new data on the putatively more common intrinsic disc lesions as sources of back pain.

Having established a model of the pathology of painful discs on the Saturday, the Sunday session turned to clinical issues: how the painful disc might be detected and how it might be treated. The first Sunday session addressed the radiological diagnosis of intrinsic disc lesions, and the concluding session addressed their surgical and conservative management.

In forthcoming issues of the Bulletin, full papers will be published of all the lectures delivered at the Symposium. In this issue, we present the first three papers, addressing the basic structure of the disc and the biochemical and biomechanical principles pertinent to understanding how the structure, chemistry and behaviour of the disc changes with age and following injury.

The first paper is by Dr Jim Taylor, Associate Professor of Anatomy at the University of Western Australia. Jim has had a long-standing interest in the structure of the disc, having undertaken studies on the development of the vertebral column for his Ph.D. at the University of Edinburgh, and having later studied age changes in the disc before recently turning his attention to the lumbar zygapophyseal joints.

The second paper is by Dr Peter Ghosh, who is a biochemist, Director of the Raymond Purves Laboratories at Royal North Shore Hospital, Sydney, and Associate Professor in the Department of Orthopaedic Surgery in the University of Sydney. He is an internationally respected researcher in the field of connective tissue biochemistry, and apart from interests in cartilage biochemistry he has published extensively on biochemistry of the disc and the chemistry of scoliosis. He is the editor of a book on "The Biology of the Disc", published by CRC Press and released in March 1988.

The third paper is by Janet Macintosh who is concluding a Ph.D. under my supervision. She is currently a Lecturer in Science (Anatomy and Physiology) at the Newcastle College of Advanced Education (renamed the Hunter Institute), and in 1987 received the Volvo Award for Back Pain Research, for her studies of the lumbar back muscles.

Nik Bogduk
President, AAMM and ASRS

THE DEVELOPMENT AND ADULT STRUCTURE OF LUMBAR INTERVERTEBRAL DISCS

James R Taylor

University of Western Australia

DEVELOPMENT

In the human embryo, the notochord and the neural tube induce formation of the primitive vertebral column around them. The notochord has the greatest influence on development of the vertebral bodies and intervertebral discs; the neural tube controls development of the vertebral arches (Taylor & Twomey, 1986).

The original vertebral column is simply a continuous, unsegmented condensation of mesenchyme around the notochord. This column is surrounded, at regular intervals, by small paired branches of the primitive aorta. The first sign of segmentation in this column is its differentiation into alternate light and dark bands. The light bands, or primitive vertebral bodies, form at the level of the paired parietal branches of the aorta. The dark bands become intervertebral discs. The unsegmented notochord runs from head to tail through the centre of this column (Taylor & Twomey, 1986).

Fig 1

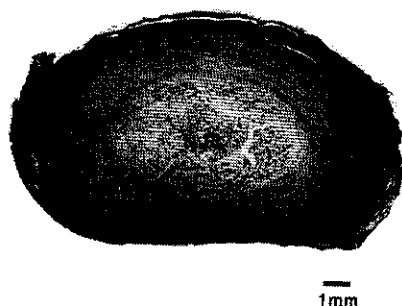


Figure 1. Horizontal section of a foetal lumbar intervertebral disc, showing the notochordal nucleus pulposus (N.P.) enclosed by the lamellar anulus fibrosus (A.F.)

The light bands grow rapidly and differentiate into cartilage. The embryonic dark bands grow more slowly; their peripheral cells differentiate into fibroblasts, align themselves in an outwardly convex lamellar pattern and begin to form collagen (Peacock, 1951). Soon, primary centres of ossification appear in the cartilage models of the vertebral bodies, while the notochord segments by the aggregation of its cells in the primitive intervertebral

discs, leaving only a "mucoid streak" in the vertebrae (Walmsley, 1953). The mucoid streak usually disappears from the centrum in the "mid-term" foetus, persisting after this, only in the cartilage plates.

Meantime, the notochordal cells multiply and expand in the centre of the developing disc, forming the foetal nucleus pulposus. Around this, the anulus fibrosus is built by fibroblasts, in the form of concentric lamellae of fibrous tissue and fibrocartilage. Between the notochordal tissue and the anulus (fig 1), some primitive "fibrocartilage" remains undifferentiated. During foetal life and infancy, the notochordal nucleus pulposus and its enveloping anulus grow rapidly (Taylor, 1973).

Fig 2

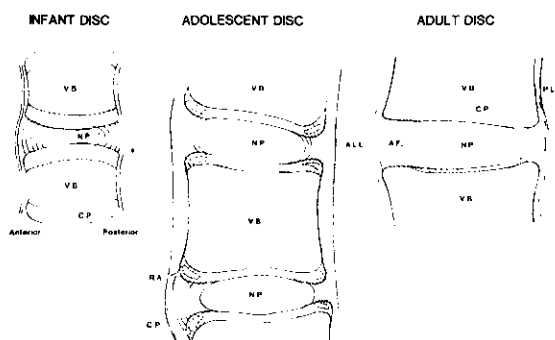


Figure 2. Diagrams of three developmental stages of a lumbar intervertebral disc - infant, adolescent and adult, showing their three parts: the nucleus pulposus (NP) anulus fibrosus (AF) and cartilage plates (CP). The AF and CPs together form an elliptical envelope for the NP. A ring apophysis (RA) develops in the peripheral region of each CP during adolescence. This ring fuses with the vertebral body (VB) at skeletal maturity and helps to anchor the peripheral part of the anulus to each vertebra. The longitudinal ligaments (ALL and PLL) are usually fused to the outer AF of each disc.

Notochordal cells were erroneously described by Keyes and Compere (1932) and by Bradford and Spurling (1945) as degenerating in foetal life; unfortunately these descriptions have been perpetuated in many texts. In fact, notochordal cells are among the most "active" cells of the rapidly growing foetus and infant. This is evidenced, not only by their rapid multiplication during this period, but also by their

production of proteoglycans and by their liquefaction and digestion of the inner margins of the surrounding anulus and cartilage plates (Taylor, 1987).

Histological examination of the disc in the infant shows it to consist of three elements: the central notochordal nucleus pulposus, encapsulated by the anulus fibrosus and the cartilage plates (fig 2). The cartilage plates are legitimately described as "unossified epiphyses" of the vertebral bodies, but they are also integral parts of the disc. Polarised light studies demonstrate the continuity of the "vertical" lamellar structure of the anulus with the "horizontal" lamellar structure of the cartilage plates; the anulus and cartilage plates form an elliptical envelope containing the fluid nucleus (Taylor, 1987).

In the foetus and infant, this envelope is highly vascular (fig 3); the many vascular canals of the cartilage plates end in multiple capillary loops or "glomeruli" which approach very close to the anulus and nucleus, without ever penetrating the nucleus, since the nucleus is at all stages of its development, completely avascular. The vascularity of the disc gradually decreases in the growing child, resulting in a change in the cell population of the nucleus. Apparently the notochordal cells cannot survive in the relatively avascular disc of the older child; the fibroblasts and chondrocytes of the "envelope", which were formerly incorporated into the nucleus by the liquefactive activities of the notochordal cells, now "colonise" the nucleus, since these cells can survive and work in conditions of lower oxygen tension. The new cell population continues to produce proteoglycans but it also produces collagen, which progressively increases in the nucleus making it less "fluid" and compliant and progressively more "viscous".

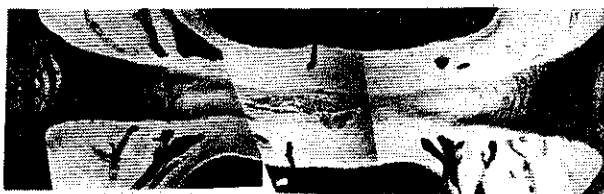


Fig 3

Figure 3. A photographic montage of a coronal section of a full term foetal lumbar disc showing numerous vascular canals, with their capillary plexuses approaching close to the anulus and nucleus of the growing disc.

Schmorl's nodes and other "end-plate lesions"

The proteoglycans of the nucleus have a strong affinity for water. This gives the nucleus a swelling pressure or "turgor" which is resisted by the incapacity of the fibrous and fibrocartilaginous envelope to expand significantly. The continual outward "pressure" of the nucleus will seek out any weak points in the envelope, particularly while the nucleus remains soft and fluid, in

active young individuals.

While the blood vessels of the cartilage plates atrophy during childhood, the connective tissue sheaths of the canals persist into adolescence. These canals begin under the periosteum around the waist of each vertebra and arch around the vertebral end-plates, running radially in the cartilage plates towards the centre of each disc. In this situation the canals are tangential to the growth plates on the cephalic and caudal aspects of each centrum and they locally inhibit the advance of ossification, making radial grooves in the vertebral end-plates. When the ring apophyses of each vertebra appear in early adolescence, the canals run between the apophysis and the centrum (fig 4A). They form channels through which herniations of nuclear material may occur through the cartilage plates towards the vertebral spongiosa or out under the anterior longitudinal ligament.

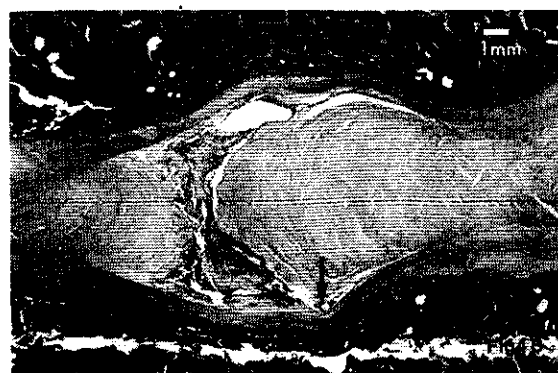
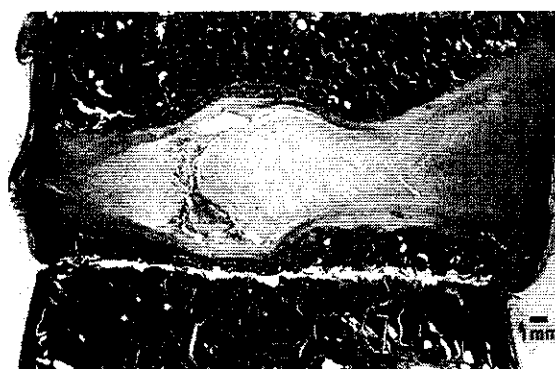


Figure 4. A: a median sagittal section of a 13 year old female lumbar disc. Part of the ring apophysis (RA) is visible anteriorly. There are no viable notochordal cells visible in this section on microscopy but the hour-glass shaped central region of the nucleus appears to consist of the debris of dead notochordal cells in a mucoid matrix.

B: a higher power view of the central area of the same section shows an indentation (arrowed) in the concave CP, where the notochordal track originally penetrated it. This forms a weak point where prolapse of nuclear material into the vertebral spongiosa may occur. The connective tissue parts of a former vascular canal (VC), from which the vessel has disappeared, are seen in the anterior CP. The cartilage columns of the vertebral growth plate are seen as translucent linear areas between the CP and the vertebral body.

A triangular depression from the nucleus into each

cartilage plate, a little behind the centre of each plate in the median plane, also forms a weak point through which a Schmorl's node may pass into the postero-central spongiosa. This depression is situated where the mucoid streak originally passed through the cartilage plate to join the nucleus. The most common type of Schmorl's node passes through a fracture in the cartilage plate at this point (Taylor & Twomey, 1985). Such nodes are usually multiple, aligned with each other in the median plane and are seen in 38% of hemisectioned adolescent and adult spines, most commonly in lower thoracic or upper lumbar vertebrae. Schmorl's nodes are as common in adolescents as in adults (Taylor & Twomey, 1986).

With the appearance of the ring apophyses in adolescence and their fusion to the centre at skeletal maturity (16-19 years) the peripheral half of the anulus fibrosus becomes directly attached to the vertebral bony rim. The inner half of the anulus remains directly continuous with the lamellar structure of the cartilage plates.

Effects of erect posture activity on lumbar spinal growth.

Lumbar spinal posture changes during later infancy (about one year of age) from a primary curve, concave forwards, to a physiological lordosis. This change in lumbar spinal posture is its response to the hip joint and pelvic extension of erect posture. At the same time, the fluid nucleus pulposus changes shape and appears to move forwards within the disc, displacing the softer fibrocartilage which formerly separated it from the anterior anulus. In a child of three to five years the large, viscous, soft nucleus lies centrally within the disc. The forces on the vertebral end-plate, accompanying erect posture weightbearing change its shape from a convex or flat shape to a central concavity. This concavity lies opposite the maximum bulge of the nucleus pulposus; it is best seen in lower lumbar vertebrae and it is well developed by about seven years. The shape change may reflect central compression by the nucleus, or peripheral traction by the anulus, or both. In the childhood years, following assumption of the erect posture, the shape of lumbar vertebrae and discs changes in other ways. The disc not only increases in thickness and assumes the biconvex shape characteristic of lower lumbar adult discs, but with the lumbar vertebrae it also grows dramatically in its horizontal dimensions. The dependence of these changes on walking in the erect posture can be seen by comparing the shapes of vertebrae in ambulant and non-ambulant children of about the same age (fig 5).

In juveniles and adolescents, a sex difference develops in lumbar discs and vertebrae, due to the more rapid growth in height of the female spine and the more rapid growth in girth of the male spine. The more

slender female spine is thus less "stable", more mobile and less resistant to bending forces than the male spine (Taylor & Twomey, 1984).

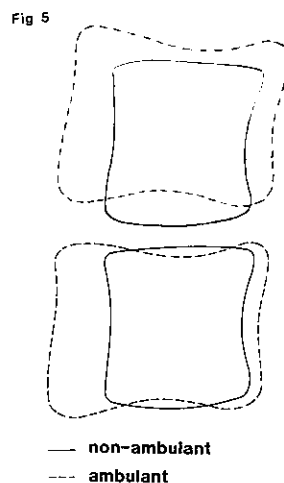


Figure 5. Diagrammatic outlines of two lumbar vertebrae and a disc space from each of two 14 year old female subjects, based on tracings of lateral radiographs. Note the lack of both horizontal and vertical disc growth in the non-ambulant female compared to the ambulant female and the failure of the non-ambulant vertebral end-plates to change from a convex shape to the concave shape characteristic of this age.

ADULT STRUCTURE

Adult discs have a similar structure to those of children, with a relatively soft nucleus, rich in proteoglycans, contained by a strong fibrocartilaginous envelope. The outer lamellae of the anulus are anchored in the bony rim and the inner lamellae are continuous with the cartilage plates. The outer lamellae of the anulus are almost indistinguishable from the longitudinal ligaments. Inner fibres of the longitudinal ligaments may attach to the vertebral rims.

Transverse sections of fresh young adult discs show a white glistening appearance with regular concentric anular lamellae. The anterior and lateral parts of the anulus are thicker than the posterior part. The nucleus swells on sectioning.

The Nucleus Pulposus

The principal changes in the disc on maturation are in the nucleus pulposus. The progressive increase of collagen, begun in childhood and related to the change

in its cell population, continues in the adult nucleus. The more sparse cell population of the adult nucleus, associated with its reduced vascularity, continues to produce proteoglycans; spaces in the bony end-plates permit 10% of the vascular spaces of the vertebral marrow to come in contact with the cartilage plates (Maroudas et al, 1975) and the peripheral anulus contains a few small blood vessels. According to Puschel (1930) there is a reduced water content in the young adult nucleus (76%) compared to the newborn disc (88%).

However, normal adult discs still have a high level of hydration, and can absorb more water readily, particularly into the nucleus. Recently cut sections of normal discs buckle due to this rapid absorption of water by the nucleus. Conversely, dehydration of the discs during histological processing, inevitably produces some contraction artefact in the nucleus. This artefact, characteristically shows horizontal splits near the upper and lower margins of the nucleus, parallel to the adjacent cartilage plates, joined by a vertical split through the centre of the nucleus (fig 6).

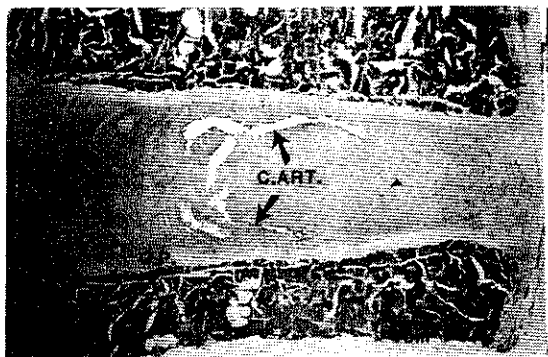


Figure 6. An adult intervertebral disc in median sagittal section shows contraction artefact (C.Art.) in the nucleus, reminiscent of the appearance of a normal discogram. The CPs are the clear linear areas separating the NP and AF from the vertebral spongiosa. The structure of the adult anulus and cartilage plates resemble earlier stages, but the nucleus is now entirely fibrocartilaginous and the vertebral end-plates are flatter than in the adolescent. There may be a small fissure in the anterior anulus (AAF).

This appearance recalls the shape of normal discograms (McCormick, 1987); it may be explained by the distribution of collagen bundles in the nucleus. On "high power" microscopic examination, collagen fibres appear to form random network, but "lower power" examination shows that in different parts of the "nucleus", bundles of collagen fibres are oriented in preferred directions; in the upper and lower areas of the nucleus, bundles are parallel to the cartilage plates; in the area where the anulus and nucleus merge, loosely lamellar bundles are convex inwards towards the centre of the nucleus; here, loosely arranged vertical bundles are seen in the area previously occupied by the

"notochordal debris" (fig 4). The bilocular "hamburger" shape of normal discograms is related to the pathways of spread of contrast injected into the nucleus, which may be determined by the orientation of the collagen bundles described.

The Anulus Fibrosus

The histology of the adult anulus is similar to that of the child. There are differences between the anterior and posterior parts of the anulus in lumbar discs, related to the lumbar lordosis.

Anteriorly, there are more than 20 fairly thick lamellae. The outer lamellae appear entirely fibrous with thick coarse bundles of fibres which run vertically between the vertebral bony rims. The outer lamellae are loosely fused to the strong anterior longitudinal ligament. The inner lamellae have finer fibres embedded in a densely stained basophilic matrix and they are gently curved with an outward convexity, becoming continuous with the lamellar structure of the "hyaline" cartilage plates above and below. The lateral anulus resembles the anterior anulus.

The posterior and postero-lateral parts of the anulus are much thinner (figs 2 & 7), with 12-15 more closely packed thinner lamellae which are more sharply curved in an outwardly convex U-shaped course. The outer fibres are fused with the thin posterior longitudinal ligament. The outer anular fibres attach to the thinner posterior vertebral rims and the inner fibres are continuous with the cartilage plates.

Fig 7



Figure 7. A thick (2mm) horizontal section of a lumbo-sacral mobile segment showing the relationship of three pairs of spinal nerves to the disc. The small S2 nerves (without connective tissue coverings) lie within the dural sac; the S1 nerve roots within their dural and connective tissue coverings lie in the lateral recesses of the spinal canal closely applied to the posterior surface of the disc and the L5 spinal nerves lie closely applied to the lateral surface of the disc outside the intervertebral foramina.

Blood vessels are frequently seen between the longitudinal ligaments and the anulus, and a few small vessels are usually found within the outer layers of the

adult anulus. The inner anulus is not clearly demarcated from the nucleus in the adult disc, and some loose inwardly convex lamellae are usually seen in the transitional area. These are also present in the discs of older children. They cannot be entirely explained on the basis of dehydration contraction artefact. They probably represent an alignment of the collagen bundles in the outer nucleus in response to the mechanical compressive and dynamic forces to which the disc is subjected in weightbearing and movement.

Thick parasagittal sections of the outer lateral anulus clearly show the alternating direction of the collagen fibres in adjacent lamellae; they are arranged such that first, third, and successive layers have parallel fibres while the second, fourth and successive layers have parallel bundles in a direction virtually opposite to that of the fibres in lamellae 1 and 3. The angle between the crossing fibres of adjacent lamellae (the interstriation angle) is about 50-55° in the lateral anulus of lumbar discs. The angle is less than this in the posterior anulus and may be more than this in the anterior anulus. The complexity of the spiralling concentric lamellae, with the outer layers exchanging fibres with the longitudinal ligaments and some apparent interweaving of fibres in inner lamellae, was said by Walmsley (1953) to "almost defy description". However, the elliptical encapsulation of the nucleus by the inner anulus and cartilage plates with the direct bony attachment of the outer anular fibres are essential structural features; the alternating spiral arrangement of the fibres in successive lamellae gives great strength and helps to limit movements, especially rotation.

Cartilage Plates

At the periphery of each cartilage plate, a ring apophysis appears, fuses with the centrum and forms the hard bony rim of the vertebral end-plate, but the

larger central part of each hyaline cartilage plate persists in the adult as part of the envelope of the nucleus. In the cartilage plate, the lamellae of the anulus intimately interlock with a persisting part of the cartilage model of the foetal vertebral body. The cartilage plates have a horizontal lamellar arrangement when viewed by polarised light. They are about 1mm thick and they contribute to the resilience of the mobile segment. They are also important pathways for diffusion of nutrients from the vascular spongiosa into the central parts of the disc, since 10% of each bony vertebral end-plate is perforated by small vascular buds which make contact with the cartilage plate. These vascular contacts are more plentiful centrally than peripherally (Maroudas et al, 1975).

Direct Neural Relations of the Disc

The posterior and postero-lateral surfaces of each lumbar disc are directly related to two pairs of spinal nerves (fig 7). The spinal nerves emerging from the intervertebral foramina (canals) are in direct contact with the postero-lateral disc surfaces. Within the intervertebral canals, these nerves descended obliquely above the level of the disc. Within the lateral recesses of the spinal canal, the posterior surface of the same disc is in direct contact with the next pair of spinal nerves, which have just pierced the spinal arachnoid and dura. On the antero-lateral surface of the disc, the sympathetic chain descends, in direct contact with vertebrae and discs; rami communicantes connecting it to each spinal nerve, pass across the lateral surfaces of vertebral bodies and intervertebral discs supplying the periosteum and outer anulus. Other small nerves, arising from the spinal nerves or their ventral rami close to the intervertebral foramen, supply the postero-lateral and posterior surfaces of the disc (Taylor & Twomey, 1980; Bogduk et al, 1981).

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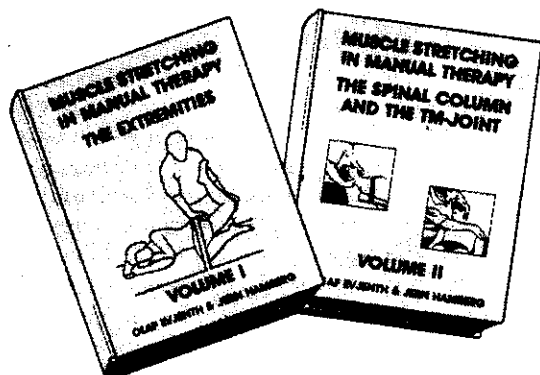
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BASIC BIOCHEMISTRY OF THE INTERVERTEBRAL DISC AND ITS VARIATION WITH AGEING AND DEGENERATION

Peter Ghosh

Director, Raymond Purves Research Laboratories,
and
Associate Professor, University of Sydney

Introduction

Although the intervertebral disc is composed of three distinct regions - the nucleus pulposus (NP), annulus fibrosis (AF) and the cartilage end-plate (CEP) see Figure 1), they are all connective tissues. Connective tissue for the most part perform a mechanical role and unlike soft tissues contain a low density of cells and a high content of extracellular matrix per unit volume. A more detailed description of the various anatomical regions of disc, their function and morphology is given by Associate Professor James Taylor (see accompanying paper in this volume). This short review will be confined to the biochemistry of the components of the disc extracellular matrix and their variation with ageing and degeneration.

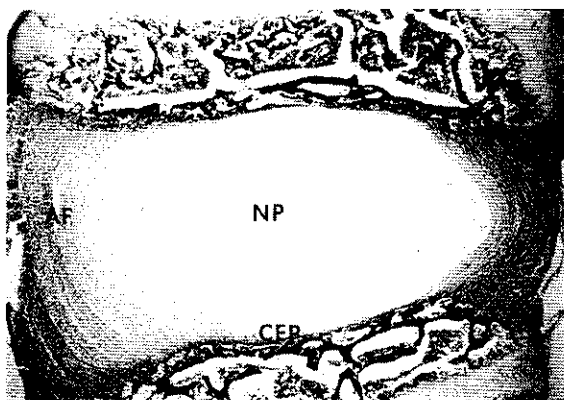


Figure 1. Photomicrograph of a sagittal section of an immature rabbit intervertebral disc stained by the Masson trichrome procedure showing the three principle regions: NP, nucleus pulposus; AF, annulus fibrosis and CEP, cartilaginous end-plate.

The extracellular matrix of all connective tissues consist essentially of a network of collagen fibres which are embedded in a hydrated gel of proteoglycans (PGs). The collagen provides the tensile strength of the tissue and maintains its overall shape. The PGs because of their high charge density attract and bind water molecules within the collagen network and literally "inflate" it. The entrapment of proteoglycans and water within the collagenous framework thus provide the

resilience of the tissue, i.e. enabling it to recover after mechanical deformation. This is particularly relevant to the disc where the NP is very rich in proteoglycans and water, thereby providing the hydroelastic qualities important for disc function.

The basic building-block of collagen is the tropocollagen molecule which when processed by the connective cells is released into the pericellular environment where it undergoes aggregation to form microfibrils, fibrils and fibres (figure 2). Although the processes which determine the extent of tropocollagen aggregation are unknown they are undoubtedly under tight control since only fine collagen fibres are laid down in the proteoglycan rich NP region of the disc while the AF consists of thick well aligned fibres assembled in the form of concentric lamellae. Several genetically distinct collagens have been identified in the disc and other connective tissues. These different collagen species arise by combining different polypeptide a-chain to form the tropocollagen triple helix. The biochemistry of the collagens of the intervertebral disc have been recently reviewed (Eyre 1988) but it should be noted that the principal types which reside in the disc are Types I and II. The NP contains predominantly Type II collagen, the AF Type I.

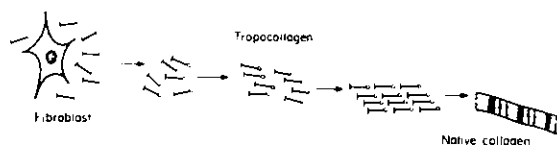


Figure 2. Tropocollagen molecules processed and released by disc cells spontaneously aggregate into fibrils and fibres in the extracellular environment. The mechanisms which determine the extent of aggregation are presently unknown.

The other major non-aqueous component of the disc extracellular matrix are the PGs. They exist in the tissue largely as huge macromolecule aggregates. These aggregates are formed from PG sub-units which

interacts electrostatically with another polymer — hyaluronic acid (HA). A diagrammatic representation of the PG sub-unit is shown in Figure 3, where it can be seen that many glycosaminoglycan (GAG) chains are attached to a central PG core protein to give a “bottle-brush” appearance. In the disc the GAGs attached to the core protein are the chondroitin sulphates (CS) and keratan sulphate (KS).

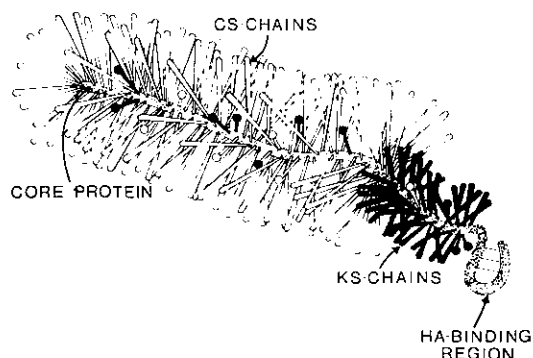


Figure 3. Diagrammatic representation of the proteoglycan sub-unit showing arrangement of chondroitin (CS) and keratan sulphate (KS) glycosaminoglycan attached to the core protein. (Taken from “Antirheumatic Drugs and Cartilage” by Ghosh P In; Clinics in Rheumatic Disease, Ed. Brooks P, Balliere, Tindall, WB Sanders and Co., London, Oxford, 1988, with permission of the author).

These GAGs consist of polymeric sugar chains which bear sulphate esters on the 4 or 6 hydroxy groups of the hexosamine rings which constitute the GAG chains. The chemical structures of the various polymer repeating units for the GAGs in the disc are shown in Figure 4. While the structures of these GAGs look unduly complex it should be remembered that they are really only providing a backbone on which the strongly anionic sulphate groups are distributed in particular conformation. It is these highly charged, hydrophilic sulphate groups which keep the polymer chains stiff and bind water molecules and interact with proteins and cell receptors. At one end of the PG core protein is a special region which because of its amino acid sequence can interact electrostatically with HA. The structure of HA is shown in Figure 4 and it can be seen that HA is a linear GAG devoid of sulphate groups. The interaction between HA and PG subunits is further strengthened by a third component, the link proteins to give the ternary complex shown in Figure 5.

As already mentioned the entrapment of the highly negatively charged PGs within the collagenous network is essential for the functionality of the disc. The synthesis and turnover of these molecules is thus of considerable importance for the “health” of the disc and this has been recently reviewed by McDevitt (1988).

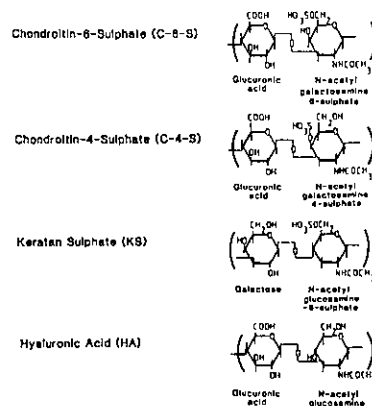


Figure 4. Polymer repeating sub-units for the glycosaminoglycan (GAGs) present within the intervertebral disc.

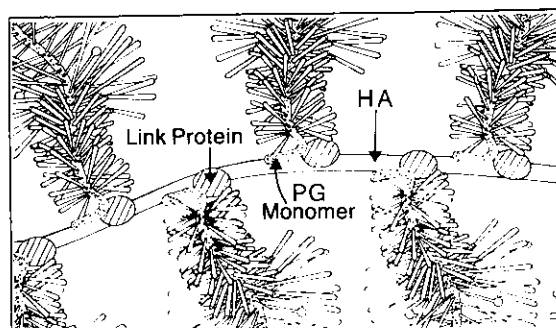


Figure 5. Proteoglycan sub-units (PGs) aggregate with hyaluronic acid (HA) by electrostatic interaction. This interaction is stabilised by link proteins. (Taken from “Antirheumatic Drugs and Cartilage” by Ghosh P In; Clinics in Rheumatic Disease, Ed. Brooks P, Balliere, Tindall, WB Sanders and Co., London, Oxford, 1988, with permission of the author).

Changes in the Disc Matrix as a Function of Ageing and Degeneration

The major biochemical changes observed in the disc matrix with ageing are similar to those described in other connective tissues. The most noticeable in the disc, however, is dehydration of the NP and the loss of sulphated GAGs accompanied by a large increase of non-collagenous proteins. The water content of the NP of the human disc falls from 88% of dry weight at birth to 69% at 77 years. In the AF, water content declines from 78% at birth to 70% at 30 years, thereafter remaining relatively constant (Gower & Pedrini 1969). The absolute amount of collagen may also increase with ageing but only slightly as a fraction of dry weight (Mitchell et al, 1961). Thereafter the age-related drying of the NP is not simply caused by an increased deposition of collagen, though it may be due in part to an increased crystallinity of the collagen. In the aged NP, collagen fibrils are commonly observed to gather together to form thicker fibre bundles (Naylor et al, 1954, Happey et al 1964). However, whether the

change is due to the re-organisation of existing collagen or is because new collagen has replaced the old has not been determined. The ratio of Type II to Type I collagen in the AF was observed to increase between infancy and maturity (Eyre & Muir 1977). This loss of Type I collagen could be associated with a reduction of the tensile strength of the annulus.

There is no doubt that the loss of GAGs from the disc NP with ageing is responsible for the dehydration of this tissue (Adams and Muir 1976). The GAGs lost are highly sulphated and are derived from the CS-rich PGs (Gower & Pedrini 1969).

Other biochemical parameters relating to the PG molecules of the disc which change with age are a progressive replacement of the chondroitin-4-sulphate by the chondroitin-6-sulphate isomer and an overall decrease of CS content accompanied by an increase of KS content. These age-related changes have been observed in canine (Ghosh et al, 1977 a,b), rabbit (Davidson & Small 1963) and human (Gower & Pedrini 1969, Adam & Muir 1976) discs.

Since canine discs of known age and genetic origin are readily available they have been the most extensively studied by Australian researchers. Furthermore, since the chondrodystrophoid canine breeds show a high incidence of disc disorders they have been used as a model system for human disc degeneration. In the non-chondrodystrophoid (non-ChD) canine annulus, the major GAGs present from birth to middle-age (4-5 years) is CS (Ghosh et al 1977, a,b) but with ageing this is gradually replaced by KS. KS eventually becomes the major GAG in the old disc tissues. These age-related biochemical changes take place in discs of both the chondrodystrophoid (ChD) and non-ChD canine breeds. However the rate of changes occur much earlier in discs of the ChD breeds than those of non-ChD breeds. The most marked variation in all the biochemical parameters cited above occurred during the first two and a half to three years of birth in the discs of the ChD breeds, whereas, such changes spanned the entire life of the non-ChD breeds. Previous studies in these laboratories (Chosh et al 1976 b) found that the beagle NP contained an average collagen NP content of 25% dry weight within one year of birth, whereas the greyhound NP collagen content remained at 5% or less for most of its adult life. In addition, the GAG content of the young greyhound's discs were found to be higher than that of the beagle of corresponding age. These differences were most pronounced in the NP region of the disc (Ghosh et al 1976 a,b; 1977 a,b). From these studies it was suggested that the variation in composition of the canine disc with ageing may be related to the prevalence of disc protrusions and spinal disorders in the chondrodystrophoid canine breeds.

Detailed studies on the variation in structure of the beagle disc PGs with ageing have recently been described (Cole et al 1986). Briefly, it was shown that the average hydrodynamic size of the non-aggregating PGs species isolated from the AF of old beagles were larger than the corresponding population of the younger animals. The rate of biosynthesis of PGs was found to be higher in the old animals and it was concluded that with ageing and degeneration, the PGs of the beagle disc undergo increased turnover. As a consequence of this enhanced turnover the PG population which is of larger hydrodynamic size and richer in KS, accumulates in disc of older animals.

Increased PG degradation, particularly at the HA binding region of the PG core protein (Figure 3) has been reported to occur in hemiated and aged human disc specimens (Lyons et al 1966, 1981). The observation (Lyons et al 1981) that the PGs isolated from degenerative human IVD were of larger hydrodynamic size and lower galactosamine/glucosamine ratio than similar preparations obtained from younger discs was in accord with the studies on the canine chondrodystrophoid disc (Cole et al 1986). These findings thus support the use of the chondrodystrophoid canine breeds as models for human disc studies and that the upright stance is not the only determinant of disc degeneration as proposed by many.

Several independent studies on hemiated or severely degenerated discs have shown similar biochemical changes to the ageing process, i.e. a loss of water and PGs from the extracellular matrix (Davidson & Woodhall 1959, Mitchell et al 1961, Lyons et al 1966, 1981, Adams & Muir 1976). In recent reports from Canada (Pearce 1985, Pearce et al 1987), a good correlation was demonstrated between the morphological grade of disc degeneration and its PG content. This group also suggested that morphologically recognisable disc degeneration occurs only if a low PG concentration is present in all discs of the lumbar spine. This strongly indicates that loss of PGs from the disc precede its degeneration.

Numerous histopathological studies of human discs at autopsy (Vernon-Roberts and Pirie 1977, Vernon-Roberts 1976) have confirmed that a high incidence of primary degenerative changes are present in individuals over the age of 30, and this increases with age. However, retrospective investigations of the medical records of these individuals failed to reveal a history of back complaints in all cases. This indicates that disc degeneration does not invariably lead to clinical symptoms of back pain.

From these findings we may conclude that with ageing biochemical changes take place within the

matrix of the disc which can reduce its ability to efficiently dissipate the mechanical stresses imposed on the spine during everyday activities. This reduction in functionality itself can then lead to an acceleration of the degenerative process which takes place within the tissue and by mid-life, discs of many individuals would show morphological evidence of microtrauma or even frank prolapse (including Schmorl's nodes). While in many instances these disc derangements become symptomatic, this is not always the case. The reasons for this are presently unknown but implicate factors not readily identifiable by present techniques. Notwithstanding this limitation in our knowledge, it is clear that clinical symptoms can arise initially from degenerative changes which take place within the disc which lead to a decline in its biomechanical performance (functionality). With time these disc changes can then result in the imposition of abnormal mechanical stresses on adjacent spinal structures (e.g. nerve roots, ligaments, facet joints, etc.) leading to symptoms. (This is summarised in Figure 6).

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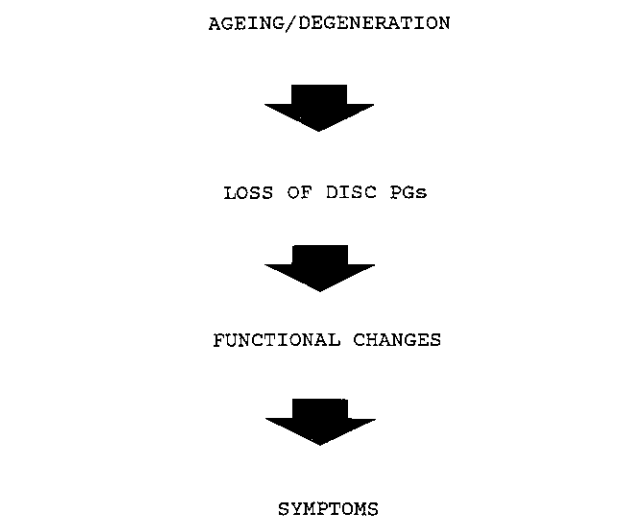


Figure 6. Summary of pathway thought to be implicated in back pain.

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BASIC BIOMECHANICS PERTINENT TO THE STUDY OF THE LUMBAR DISC

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Because of its jargon and mathematical flavour, biomechanics is a subject that is often daunting and overwhelming to students of anatomy. However, certain biomechanical concepts are indispensable for the description and interpretation of the movements and age-changes of the lumbar spine. It is, therefore, appropriate as a prelude to later lectures in this Symposium, to review and summarise these concepts. In this regard, this paper represents a summary of the chapter on basic biomechanics in Bogduk and Twomey's text on the lumbar spine (Bogduk and Twomey, 1987).

Movements

There are two types of motion that a bone may undergo: **translation** and **rotation**. The essence of translation is that every point on the bone moves in the same direction and to the same extent (Fig. 1). Translation occurs whenever a single force or a net single force acts on a bone, and any force that tends to cause translation is called a **shear** force.

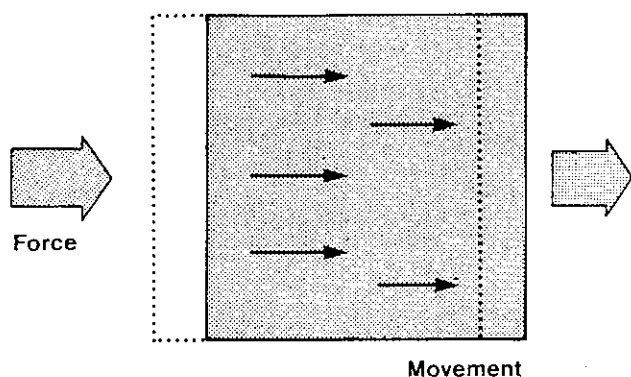


Figure 1. Translation. A single net force causes all points in a body to move in parallel, in the same direction, to the same extent. Reproduced from Bogduk and Twomey (1987).

Rotation is characterised by all the points on a bone moving in parallel around a curved path centred on some fixed point. The points move in a similar direction but to different extents depending on their radial distance from the fixed point which is known as the

centre of rotation (Fig. 2). Rotation occurs when two unaligned forces act in opposing directions on different parts of the bone, forming what is known as a **force couple** (Fig. 2), and the net force tending to cause rotation is referred to as the **torque**.

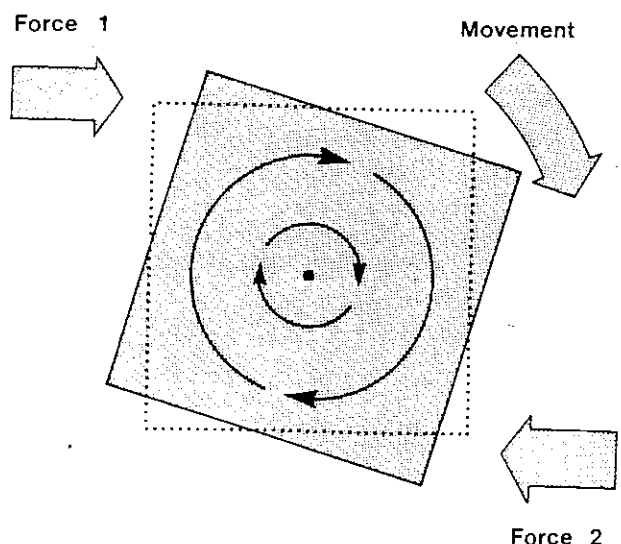


Figure 2. Rotation. Two unaligned, opposite forces (a *force couple*) cause the points in a body to move around a stationary centre. Reproduced from Bogduk and Twomey (1987).

In three-dimensional space, translation and rotation can occur in any of three fundamental planes. By convention, biomechanics define movements in relation to three imaginary axes drawn through the body, which are labelled X, Y and Z (White and Panjabi, 1978). The X axis passes sideways through the body; the Y axis passes through it vertically; and the Z axis passes through it from back to front (Fig. 3). Movements can then be described as along or around any particular axis. Thus, sagittal translation is translation along the Z axis; sideways gliding movements are translations along the X axis; and up and down movements are along the Y axis. Forward bending is rotation around the X axis; side-bending is rotation about the Z axis; and twisting movements are rotations around the Y axis.

Formally, the direction of movement is defined by

convention as (+) or (-), as illustrated in Figure 3, but adjectives such as "upward", "downward", "left" and "right" can be used, and are somewhat less prone to ambiguity.

When any movement is analysed, it can be shown to consist of a combination of translations and/or rotations around one or more of the three axes. In particular, it can be shown that lumbar flexion consists of + X axis rotation and + Z axis translation of the lumbar vertebrae. On the other hand, axial rotation of a lumbar vertebra is purely left or right (+ or -) Y axis rotation.

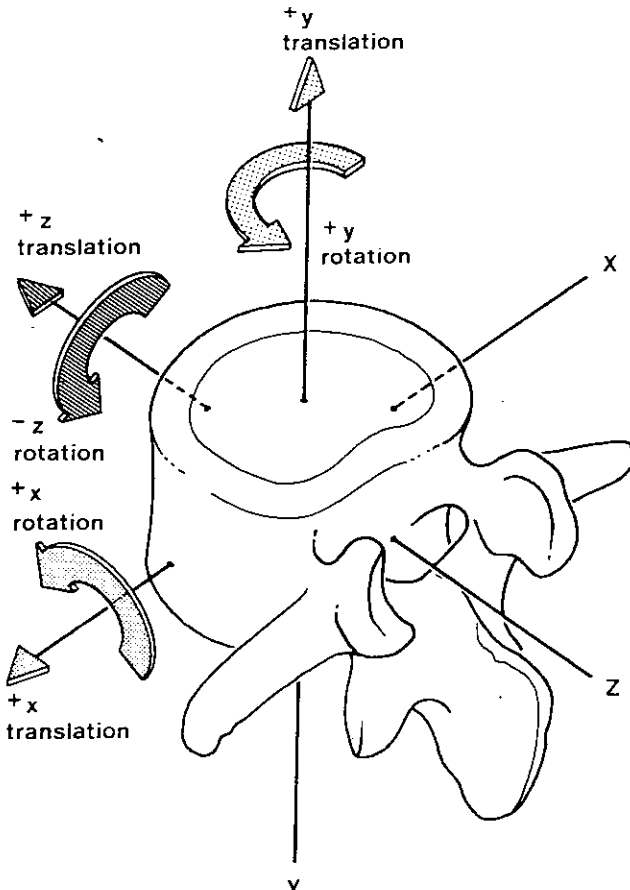


Figure 3. Axes and directions of motion: biomechanical system. Reproduced from Bogduk and Twomey (1987).

Stress-Strain

To stretch a collagen fibre, a force must be applied to it. Once it starts to stretch, the fibre resists elongation by developing a resisting force generated by the chemical bonds between collagen fibrils, between tropocollagen molecules, between collagen fibres, and between collagen fibres and proteoglycans (Bogduk and Twomey, 1987). By convention the applied or elongating force is known as the applied stress, and the extent to which the fibre is elongated is known as the strain. Stress is measured in units of force (newtons) and strain is usually measured in terms of the fractional increase of the initial length of the fibre. The same convention applies when a deformable structure is

compressed; the compressing force is the stress, and the strain is the decrease in height or length of the structure. When a structure is twisted, the stress is referred to as torque, and the strain, known as torsion, is measured in terms of the angular deformation of the structure.

At rest, single collagen fibres are usually buckled, and the wavy shape they assume is referred to as **crimp** (Shah et al, 1977). When stress is applied to a collagen fibre, the first effect is to straighten this crimp. Little energy is required to do this as there are no major chemical bonds that maintain the crimp. Thus, a crimped collagen fibre will elongate in response to little applied force. However, once crimp has been removed, the collagen fibres starts to resist strongly any further elongation. The stress attempts to break the bonds between the collagen fibrils and tropocollagen molecules. Energy is required to oppose, strain and perhaps eventually break these bonds. Consequently, more force is required to produce further elongation of the collagen fibre. If sufficient force is applied, the bonds may break and when this occurs in a substantial number of bonds, the collagen fibre ceases to resist elongation and is said to 'fail'. Once the collagen fibre has failed, only small forces are required to tear apart its now unbonded component fibrils and molecules.

The mechanical behaviour of collagen fibres subject to stress can be depicted graphically (Abrahams, 1967) as in Figure 4. Such graphs are known as stress-strain curves.

STRESS

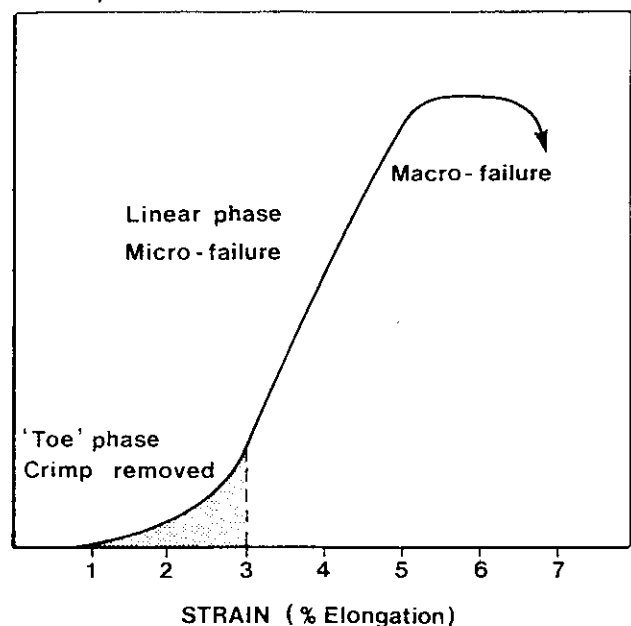


Figure 4. Stress-strain curve of collagen. Reproduced from Bogduk and Twomey (1987).

The curve exhibits three main regions. The first

region, known as the 'toe' phase, reflects the phase when crimp is being removed from the collagen fibre. The second, or linear, region is the steep slope along the middle of the curve. Mathematical calculations reveal that the junction of the toe phase and the linear region represents the point where crimp has been maximally removed from the fibre, and the stress starts to stretch the collagen fibre longitudinally (Abrahams, 1967; Shah et al, 1977). The linear region represents the phase when bonds within and between collagen fibrils are being strained and some are being broken. The peak of the curve represents the phase of failure of the collagen fibre, when substantial numbers of bonds are irreversibly broken. As depicted by the last part of the curve, once failure has occurred, elongation can continue with ever decreasing amounts of stress being required.

A key feature of the mechanical properties of collagen is that bonds within and between collagen fibrils start to be strained and broken somewhere after 3-4% elongation of the fibre has occurred. Consequently, about 4% elongation is the maximum a fibre can sustain without risking microscopic damage.

Collagenous tissues, like ligaments and joint capsules, behave in a similar manner to isolated collagen fibres, and exhibit similar stress-strain curve (Nordin and Frankel, 1980; Noyes, 1977; Shah et al, 1977), but certain additional mechanical events are involved (Fig. 5). In addition to the removal of crimp, the toe phase may represent the removal of any macroscopic slack in the ligament.

STRESS

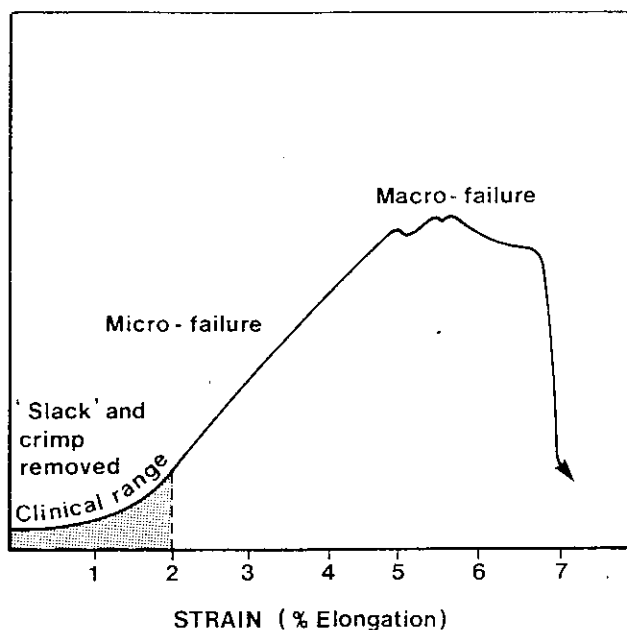


Figure 5. Stress-strain curve for a ligament. Reproduced from Bogduk and Twomey (1987).

During the second phase, collagen fibres are being re-arranged in the stressed structure. Fibres that, at rest, are curved or run obliquely in the three dimensional lattice of the ligament or capsule, are straightened to line up with the applied force. Thus, when the three-dimensional lattice is stressed, any bonds between separate collagen fibres and between collagen fibres and their surrounding proteoglycan matrix are strained. Furthermore, to make way for the re-arrangement of collagen fibres, water and proteoglycans may need to be displaced from between the collagen fibres.

All of these processes require energy: energy to strain the bonds, to move the collagen fibres and proteoglycans, and to squeeze out water. Thus, to achieve continued elongation more force must be applied, and this creates the steep slope of the second phase (Fig. 5). Eventually, after the collagen fibres, proteoglycans and water have been re-arranged, the bonds within individual collagen fibres are strained. In the face of increasing stress, these bonds and those between collagen fibres will fail and the entire structure fails.

What proportion of collagen fibres need to fail before macroscopic failure of a ligament or capsule occurs is not known, and it is not possible to predict the stress-strain curves for different structures on the basis of the number or nature of their constituent collagen fibres. Therefore, the mechanical behaviour of different structures has to be derived empirically by subjecting several samples of the same structure to known stresses and obtaining average stress-strain curves representative of the particular structure.

The value of stress-strain curves is that they graphically depict the mechanical properties of collagenous (and other) structures; notably their strength and the way in which they resist elongation. In turn, the mechanical behaviour reflects the biochemical properties of the structure, for alterations in the proteoglycan content and the bonding within and between collagen fibres will affect the way a ligament or a capsule can resist applied forces.

To a certain extent, physical examination involves obtaining a stress-strain curve for a joint, and its capsule or ligaments. When passive movement is induced, a stress is applied, and strain is reflected both in terms of the range of movement observed and in the form of the palpated resistance to movement. It is important to realise, however, that clinical examination studies only the early part of the stress-strain curve, no further than just beyond the toe phase (Nordin and Frankel, 1980). The limit is well within the 4% elongation at which microscopic injury occurs. Physical examination rarely (and shouldn't) enter into the second phase, for then it is actually inducing micro-failure of the structure, and

risks macro-failure. Physical examination, therefore, gains access to only a part of the total stress-strain curve possible. Nevertheless, it does detect some of the physical properties of the structure examined, which can be interpreted in the light of knowledge of the microstructure and biochemistry of the structure examined, and knowledge of its total mechanical behaviour as determined in cadaveric and post-mortem material.

Stiffness

The stiffness of a given structure is its resistance to deformation, and can be measured by the force required to produce a unit elongation or deformation (Twomey and Taylor, 1982). In mathematical terms, it is the slope of the stress-strain curve of a structure. Stiffer structures resist deformation and the slope of their stress-strain curve will be steeper. In biochemical terms, stiffness implies a greater degree of bonding between collagen fibres, or between collagen fibres and their surrounding matrix.

Initial Range of Movement

If a joint is moved passively or actively by a constant force, a point is reached where no further movement appears possible. The resistance in the capsule and ligaments of the joint balances exactly the force attempting to move the joint. The distance moved by the joint up to this point is known as the **initial range of movement**. If a stress-strain curve were constructed for the joint, the initial range of movement would be found to occur somewhere early in the second phase of the curve, just after the toe phase, when collagen bonding is starting to resist the movement.

Application of a greater force would strain the resisting structures further and a new, greater initial range of movement would be perceived. The amount of increased range would be dependent both on the increase in force and on the stiffness of the joint and its ligaments. However, to obtain a substantially greater initial range of movement, considerably larger forces would need to be applied to most joints and ligaments. Such larger forces are not usually possible during normal clinical examination.

With the forces used in clinical examination, the initial range of movement remains early in the second phase of the stress-strain curve, and even if the applied force varies somewhat with the strength of the examiner, the resistance of the joint is such that the differences in perceived range of movement are not great. Consequently, the initial range of movement as perceived from clinical examination falls in a narrow range and can be called the normal range of movement.

Creep

Initial ranges of movement are usually measured on

the basis of a brief application of force. The force is applied until range of movement is maximal, and once the range is measured, the force is released. However, if a constant force is left applied to a collagenous structure for a more prolonged period, further movement is detectable. This movement is small in amplitude, occurs slowly, almost imperceptibly, and is consequently known as **creep**.

Graphically, creep is seen as continued displacement when a constant force is maintained at some point on a stress-strain curve (Fig. 6). The time over which creep can be measured is optional, and various studies have employed times varying from minutes to hours (Kazarian, 1972, 1975; Koreska et al, 1977).

STRESS

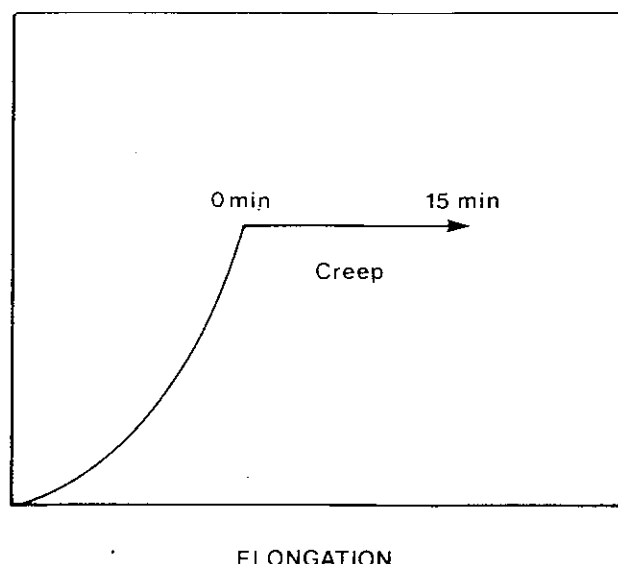


Figure 6. Stress-strain curve illustrating creep. Despite maintenance of a constant load, elongation occurs with the passage of time. Reproduced from Bogduk and Twomey (1987).

The biochemical and structural basis of creep is not known for certain, but it appears to be due to the gradual re-arrangement of collagen fibres, proteoglycans and water in the ligament or capsule being stressed. Forces of short duration may not act long enough to squeeze water out of a ligament or to allow all the re-arrangement of collagen that could possibly occur. The force is removed before maximal displacement has had a chance to occur. In contrast, sustained forces allow for these displacements to occur, whereupon the ligament or capsule can elongate slightly as a result of the internal re-adjustment of its constituents.

The academic relevance of creep is that it provides an indirect, though readily obtainable, measure of the interactions of collagen, proteoglycans and water in a ligament or capsule. By studying the creep of structures one can determine how these interactions vary with age or in the face of disease processes or injury. However, creep is not just a laboratory phenomenon, for it occurs regularly in activities of daily living.

Many occupational groups, e.g. stonemasons, bricklayers, roofing carpenters and the like, regularly submit their lumbar spines to prolonged load-bearing in flexion. Once they achieve such a posture there is often little movement away from it, and their lumbar joints will creep. The possible significance of this phenomenon is discussed below.

Hysteresis

Most structures, and certainly all biological tissues, exhibit differences in mechanical behaviour during loading versus unloading. Loading produces a characteristic stress-strain curve, but gradual release of the load produces a different stress-strain curve. Restoration of the initial length of a ligament occurs at a lesser rate and to a lesser extent than did deformation (Fig. 7). This difference in behaviour is referred to as **hysteresis**, and reflects the amount of energy lost when the structure was initially stressed.

STRESS

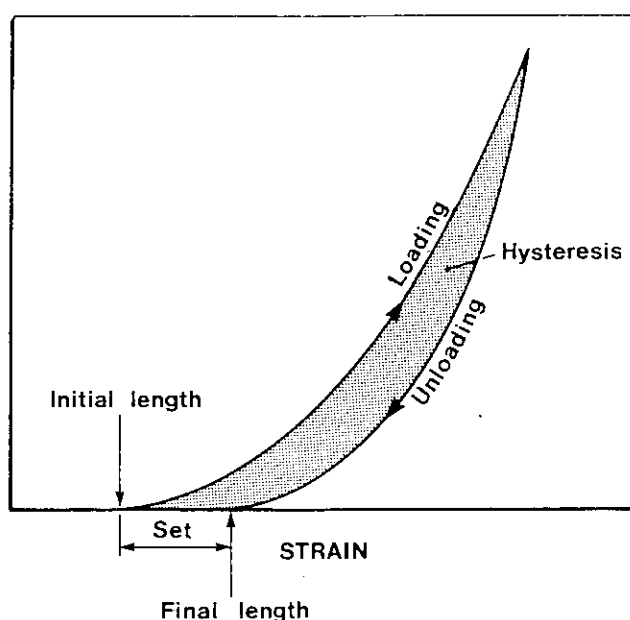


Figure 7. Stress-strain curve illustrating hysteresis. When unloaded, a structure regains shape at a rate different to that at which it deformed. Any difference between the initial and final shape is the 'set'. Reproduced from Bogduk and Twomey (1987).

When a structure is deformed the energy applied to it goes into deforming the structure and into straining the bonds within it. For collagenous tissues, some of the energy goes into displacing proteoglycans and water, re-arranging the collagen fibres, and perhaps even into breaking some of the bonds between collagen fibres. Once used in this way, this energy is not immediately available to restore the structure to its original shape. Displaced water, for example, does not remain in the structure exerting some sort of back-pressure attempting to restore its original form. It is squeezed out of the structure, and the energy used to displace the water is no longer available to the system. If chemical

bonds are broken, they cannot act to restore the form of the structure.

Thus, with less energy available to restore the structure, the rate and extent of its restoration is reduced. When all applied forces are completely removed, the final length of the ligament or capsule may remain greater than its original length (or less in the case of compressed structures). This difference between initial and final length is referred to as a **set**.

In general, hysteresis and a residual set do not occur if a structure is stressed only in the toe phase of its stress-strain curve for bonds within and between the collagen fibres are not broken. However, the further a structure is stressed beyond its toe phase, more bonds are broken and the greater the hysteresis and set (Abrahams M, 1967).

In time, collagen fibres and proteoglycans in a structure may be re-arranged into their usual configuration, and any displaced water is eventually reabsorbed, restoring the structure to its original form. Under these circumstances any set disappears, and the structure regains its original size.

A set often occurs after creep. When the applied force is released the structure does not immediately spring back to its original shape, although it may do so in time. However, if bonds between or within collagen fibres have been broken, the set may not disappear until and unless the bonds are exactly reconstituted. If the original bonds are not reformed, or if new bonds are formed in the set position, the set may persist indefinitely.

This phenomenon has implications in the interpretation of trauma to ligaments or capsules. The energy lost in breaking the tissue may not be recoverable, and the original structure is not fully reformed. Healing may occur in a set position, and this may compromise the mechanical function of the structure. Healing in a set position effectively lengthens the ligament, and it will therefore accommodate greater than normal initial ranges of movement, which may not be desirable.

The phenomena of creep and hysteresis are also of particular relevance to the interpretation of sustained insults to ligaments and capsules. A ligament may be subjected to forces well within its load-bearing capacity. However, if these forces are sustained for prolonged periods, the ligament will creep, and because of hysteresis, eventual release of the load does not result in the immediate restoration of the form and microstructure of the ligament. The ligament requires time to reform fully. In the meantime, the mechanical properties of the ligament have been altered. Its stress-

strain capacity is different from normal, and until the structure is fully reformed it cannot be expected to sustain re-applied loads in the normal, or accustomed, way. Therefore, the structure may be liable to injury during this vulnerable period of restoration.

Such processes may underlie what might otherwise be called 'fatigue' in a ligament or capsule. After prolonged strain, ligaments, capsules and intervertebral discs of the lumbar spine may creep, and they may be liable to injury if sudden forces are unexpectedly applied

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during their vulnerable recovery phase.

Conclusion

This lecture provides a synopsis of some of the concepts and definitions pertinent to the biomechanics of the lumbar spine. Later lectures in this symposium will draw on this foundation to deal with specific issues such as the biomechanics of the normal lumbar disc; the way this changes with age; and the biomechanics of mechanical injury to the disc.

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VOLTAREN. Diclofenac Sodium. Diclofenac sodium, as a non-steroid compound, exhibits marked antirheumatic, anti-inflammatory, analgesic and antipyretic activity.

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Cross-sensitivity has been demonstrated between diclofenac sodium and aspirin. Therefore, VOLTAREN must not be given to patients in whom attacks of asthma, urticaria or acute rhinitis are precipitated by aspirin or by other drugs which inhibit prostaglandin synthesis.

PRECAUTIONS: Patients with a history of dyspepsia or other gastro-intestinal disorders such as Crohn's disease and ulcerative colitis or with pre-existing dyshaemopoiesis or disorders of blood coagulation, as well as those with severe hepatic or renal disease, should be kept under close surveillance during treatment with VOLTAREN.

In elderly patients, who are generally more prone to side-effects, particular caution should be exercised. If peptic ulcer or gastro-intestinal bleeding occurs during treatment with VOLTAREN, administration of the drug must cease immediately.

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Use in Pregnancy: Safety of diclofenac sodium in pregnancy has not been established; therefore VOLTAREN should not be used in pregnant women or those likely to become pregnant unless the expected benefits outweigh any potential risk.

Use in Lactation: Following oral administration of VOLTAREN to six lactating women, in doses of 50 mg twice daily for the first week after parturition, no unchanged drug could be identified in the milk. The detection limit was 10 ng/ml.

Interactions with Other Drugs: Concurrent treatment with acetylsalicylic acid lowers the plasma concentration of VOLTAREN by about one-third, but the clinical significance of this effect has not been determined. The concomitant administration of VOLTAREN with preparations containing lithium or digoxin, may raise the plasma concentrations of these drugs, however, no clinical signs of overdosage in such cases have yet been encountered. The addition of glucocorticoids to non-steroidal anti-inflammatory agents, though sometimes necessary for therapeutic reasons, may aggravate gastrointestinal side effects. The concurrent oral treatment with two or more non-steroidal antirheumatic drugs may promote the occurrence of side effects.

ADVERSE REACTIONS: VOLTAREN is generally well tolerated. At the start of treatment, however, some patients may complain of gastro-intestinal symptoms (e.g. eructation, nausea, epigastric pain or discomfort). These effects are usually mild and transient, and need not interfere with continuation of medication. Peptic ulcer or gastro-intestinal haemorrhage, has been reported during therapy with VOLTAREN. Usually these episodes occurred in patients with a history of such disorders, or who were receiving concomitant therapy with other drugs. Occasionally, skin reactions such as drug rash and eczema, peripheral oedema or slightly raised serum transaminase levels have been observed. There have been isolated reports of anaphylactoid reactions. Central nervous system reactions in the form of headache and dizziness, tiredness, insomnia, or irritability may be experienced by some patients, but these are usually mild and transient. The occurrence of myoclonic encephalopathy has been described in two patients.

Blood dyscrasias (aplastic anaemia, agranulocytosis, leucopenia) have been encountered very rarely in association with the use of VOLTAREN.

A few cases of haemolytic anaemia, thrombocytopenia, reduction in haemoglobin levels and positive Coombs' test have also been reported. Some further unwanted effects which have rarely been observed are jaundice, hepatitis, renal failure and nephrotic syndrome. Isolated cases of erythema multiforme have been reported.

DOSAGE AND ADMINISTRATION: Initial dosage is 75 to 150 mg daily depending on the severity of the condition, given in 2 or 3 divided doses. For long-term therapy, 75 or 100 mg daily, in divided doses, is usually sufficient.

The tablets, being enteric-coated, should be swallowed whole.

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BIOMECHANICS

MITAL A, WANG LW, FARD HF. **BOUNDARY LINE BETWEEN THE STRENGTH AND ENDURANCE REGIONS IN MANUAL LIFTING.** *Clinical Biomechanics* 1987; 2: 220-222.

Abstract: Previous work by Mital et al showed that repetitive dynamic strength (RDS) of individuals is a better predictor of psychophysically acceptable weight (PAW) than either the maximal dynamic strength (MDS) or maximal static strengths (MSSs). It was also pointed out that somewhere between a frequency of one lift per minute and a frequency of three lifts per minute, the orientation of lifting tasks changes and muscular strengths no longer remain the limiting factor. This paper reports the results of a follow-up study conducted to pinpoint the lifting frequency just beyond which this transition takes place. The results indicated that a significant correlation existed between RDS and PAW for lifting frequencies up to 1.5 lifts per minute. Beyond 1.5 lifts per minute, no significant correlation between the two measures was found. We therefore concluded that lifting tasks performed every 40 seconds, or less frequently, are strength oriented. For those tasks which require lifting more frequently than once every 40 seconds, individual's strengths are not a limiting factor.

Relevance: We have identified the frequency which determines whether a manual lifting task belongs to the strength category or the endurance category. The identification of this border line frequency should assist practitioners in determining when to use strengths and when to use endurance measures for pre-employment screening.

PEARCY MJ, GILL JM, JOHNSON GR. **MEASUREMENT OF HUMAN BACK MOVEMENTS IN THREE DIMENSIONS BY OPTO-ELECTRONIC DEVICES.** *Clinical Biomechanics* 1987; 2: 199-204.

Abstract: Two systems for the measurement of the movement of retro-reflective markers in three-dimensional space have been used to measure rotations of the human back. Both the CODA-3 and the VICON devices used are available commercially. Both devices were shown to be capable of producing reproducible data on three-dimensional rotations. However, neither system was shown to be ideal due to the difficulty of maintaining the markers in the field of view. In particular, the CODA-3 system was found to be severely limited in this application due to the problem of cross-over conflict between the retro-reflective prisms that results in the loss of data. The VICON system was found to be more flexible but data analysis requires an interactive input from the operator and so can be very time consuming.

Relevance: The non-invasive measurement of dynamic back movement will provide clinicians with objective data to assess whether alterations to patterns of movement are of assistance in the diagnosis of back pain. The assessment of techniques to provide these data is the first stage in the development of a tool for clinical use.

NACHEMSON AL, ANDERSSON GBJ, SCHULTZ AB. **VALSALVA MANEUVER BIOMECHANICS. EFFECTS ON LUMBAR TRUNK LOADS OF ELEVATED INTRAABDOMINAL PRESSURES.** *Spine* 1986; 11: 476-9.

Abstract: The ability of a partial or full Valsalva maneuver (voluntary pressurization of the intraabdominal cavity) to unload the spine was investigated in four subjects. During the performance of five isometric tasks, intraabdominal and intradiscal pressures and surface myoelectric activities in three lumbar trunk muscle groups were measured. The tasks were carried out without voluntary pressurization of the intraabdominal cavity and then when the subjects performed partial and full Valsalva maneuvers. A biomechanical model analysis of each task was made to help interpret the experimental measurements. Intraabdominal pressure was found not to be an indicator of spine load in these experiments. The Valsalva maneuvers did raise intraabdominal pressure, but in four of the five tasks increased rather than decreased lumbar spine compressions occurred.

ANDERSON CK, CHAFFIN DB, HERRIN GD. **A STUDY OF LUMBOSACRAL ORIENTATION UNDER VARIED STATIC LOADS.** Spine 1986; 11:456-62.

Abstract: This paper describes a study of lumbar and sacrum orientations in select standing postures with the patient holding different loads in the hands. Vertebral rotation data were gathered from two young, healthy men and two young, healthy women while they performed static lifts at two load levels and in postures ranging from erect standing to deep squatting. The results disclosed a predictable reorientation of the sacrum and lumbar spine for both men and women as a function of torso and knee angles. Nonlinear second-order regression models of torso angles and knee angle versus reorientation angle were fit to the data with resulting r^2 values of about 0.89. Load was not found systematically to affect the sacrum/lumbar reorientation.

SCHOLTEN PJM, VELDHUIZEN AG. **THE BENDING STIFFNESS OF THE TRUNK.** Spine 1986; 11:463-7.

Abstract: Much research is done on the physical properties of the isolated human spine. However, little knowledge exists about the relationship between the physical properties of an isolated spine and the physical properties of the whole trunk *in vivo*. The first part of this article is a literature review. The next part is a description of experiments performed to study the bending stiffness in flexion of the whole trunk *in vivo*. One hundred fifty measurements were made in unanaesthetised subjects and 150 in anaesthetised ones. The bending stiffness of the whole trunk *in vivo* was found to be about 10 times larger than the mean bending stiffness of an isolated spine.

WRIGHT V. **THE RHEOLOGY OF JOINTS. HEBERDEN ORATION 1985.** Br J Rheumatol 1986;25:243-52.

Abstract: The value of rheological studies of joint tissues has been illustrated by studies from our department. These have included studies of the stiffness of joints which suggest that subjective stiffness is more likely to be related to limitation of movement of a joint than to increased physical stiffness (either elastic or dissipative torques). A review of goniometry suggests that the diminution of joint movement with advancing age varies with the frequency of use of the joint. A simple goniometer for the hip has been described, and in contrast a sophisticated telemeterized system has been devised. Instruments to measure passive movement of joints, and their application for hypermobility, have been discussed. A knee analyser has been constructed to measure ligamentous and meniscal damage. Ligament replacement has been successfully achieved in the pig and in man by using a woven polyester tube. The load-bearing function of the menisci has been clearly demonstrated, explaining the relationship found in studies of parachutists and physical education teachers between meniscectomy and osteoarthritis of the knee. Support for the Leeds biomechanical hypothesis for the development of osteoarthritis has been described from rheological studies of cartilage at the patellofemoral joint and at the ankle. The intervertebral joint does not appear to be a shock absorber in compression. The spine must bend to function in this way. The relevance to rigid segments of the spondylitic spine and surgical fusion of vertebrae is discussed.

KOFOED H, LINDENBERG S. **EFFECT OF SIMULATED JOINT EFFUSION ON SUBCHONDRAL HAEMODYNAMICS AND METABOLISM.** Injury 1986; 17:274-6.

Abstract: The purpose of the present study was to investigate the effect of simulated joint effusion on po_2 , pco_2 , the regional blood flow and intraosseous bone marrow pressure in the subchondral bone of rabbit.

Mass spectrometry was used for simultaneous and continuous registration of subchondral po_2 and pco_2 while the relative argon signal was used for qualitative estimation of regional bone blood flow. The bone marrow pressure was recorded continuously by pressure transducers. Isotonic sodium chloride infusion at a constant pressure of 75 mmHg into the knee joint cavity constituted the basis for joint effusion.

An instant increase in the subchondral bone marrow pressure followed the joint effusion ($P < 0.001$). This resulted in a significant ($P < 0.01$) decrease in the qualitative bone blood flow, significant ($P < 0.01$) hypoxia and significant ($P < 0.01$) hypercapnia in the subchondral bone. Joint effusion always lasted 30 minutes. Following its release all changes were reversed to normal values within 15 minutes. Within the period of observation no nervous or humoral factors seem to be brought into action. It was concluded that regional venous stasis was responsible for all changes, and that joint effusion should not be left untreated for long periods.

LEATT P, REILLY T, TROUP JDG. **SPINAL LOADING DURING CIRCUIT WEIGHT-TRAINING AND RUNNING.** Br J Sports Med 1986; 20:119-24.

Abstract: Spinal shrinkage was used as an indicant of loading on the spine in circuit weight-training and running regimes. The loss of stature during two sets of a circuit of weight-training ($n=10$), a 6km run by novices ($n=9$) and a 25km run by trained runners ($n=7$) was assessed in male subjects. Shrinkage was not significantly different between the weight-training regime and the 6km run by novices, mean losses being 5.4 and 3.25mm respectively. The rate of height loss in the experienced runners was 2.35mm over 6km run at $12.2\text{km}\cdot\text{h}^{-1}$, representing $0.4\text{mm}\cdot\text{km}^{-1}$ over the 6km run, this shrinkage rate being continued over the last 19km run at $14.7\text{km}\cdot\text{h}^{-1}$. The loss of height could not be predicted from a set of covariates. The magnitude of the circadian variation, mean 14.4mm, exceeded the change in height during the 25km run. The diurnal variation conformed to a cosine function, though a better fit was obtained with a power function equation. A marked diurnal pattern was also observed in lumbar extension. Though reversal of spinal shrinkage was observed during a night's sleep, no significant recovery occurred during a 20 min resting period immediately following the exercise regimes. These results have implications for the warm-up and timing of exercise regimes that impose significant loading on the spine.

MARRAS WS, WONGSAM PE. **FLEXIBILITY AND VELOCITY OF THE NORMAL AND IMPAIRED LUMBAR SPINE.** Arch Phys Med Rehabil 1986; 67:213-7.

Abstract: Trunk mobility, as defined by trunk angle, has long been considered an acceptable means to evaluate the degree of impairment in patients with low back pain (LBP). However, biomechanically, there is reason to believe that patients with LBP may exhibit significant sensitivity to trunk velocity of motion as well as angular mobility factors. An experiment was performed to study the trunk action of patients with LBP and of a normal control group. A lumbar monitor was used to monitor both trunk angle range and trunk velocity. The results indicate significant differences between the two groups for both angle and velocity measures. However, the velocity measure revealed more dramatic difference between groups and was the only parameter that was capable of distinguishing between the particular experimental tasks for both LBP and normal groups. Thus, it is suggested that trunk velocity be used as a quantitative measure of low back disorder and that it be used as a means to monitor the rehabilitative progress of patients with LBP.

LANTZ SA, SCHULTZ AB. **LUMBAR SPINE ORTHOSIS WEARING. I. Restriction of gross body motions.** Spine 1986; 11:834-7.

Abstract: The effects of wearing commonly prescribed low-back braces and corsets on restriction of gross body motions were investigated. A lumbosacral corset, a chairback brace, and moulded plastic thoracolumbosacral orthosis (TLSO) were studied. Four trunk movements (flexion, extension, lateral bending, and twisting) were examined in five healthy adult men when standing and sitting. All three orthoses restricted at least some gross body motion to approximately two thirds to one half of no-orthosis values. All three orthoses failed to provide restrictions of at least 10% in at least one motion. Mean motion restrictions across all eight movements studied in all five subjects were largest when wearing the TLSO and least when wearing the corset. Gross body motion restrictions relieve lumbar trunk muscle and spine loads.

LANTZ SA, SCHULTZ AB. **LUMBAR SPINE ORTHOSIS WEARING. II. Effect on trunk muscle myoelectric activity.** Spine 1986; 11:838-42

Abstract: The effects of wearing commonly prescribed low-back braces and corsets on myoelectric signal levels in the erector spinae and oblique abdominal muscles were investigated. A lumbosacral corset, a chairback brace, and a moulded thoracolumbosacral orthosis (TLSO) were studied. Nineteen tasks involving sitting and standing were performed by five healthy adult men. Myoelectric signal levels measured when wearing each orthosis were compared with those measured when performing the same tasks while wearing no orthosis. The changes in mean myoelectric signal levels ranged from a 9% reduction to a 44% increase when the lumbosacral corset was worn, from a 27% reduction to a 25% increase when the chairback brace was worn, and from a 38% reduction to a 19% increase when the TLSO was worn.

ERICSON MG, NISELL R, EKHOLM J. **QUANTIFIED ELECTROMYOGRAPHY OF LOWER-LIMB MUSCLES DURING LEVEL WALKING.** Scand J Rehabil Med 1986; 159-63.

Abstract: The electromyography (EMG) of eleven different lower limb muscles of ten healthy subjects was quantified during normal level walking. The surface EMGs obtained were normalised, in percentage, to the activity obtained during an isometric maximum voluntary test contraction of each subject. The mean peak activities of the gluteus maximus, gluteus medius, rectus femoris, vastus medialis, vastus lateralis, biceps femoris and medial hamstring muscles occurred at heel-strike and were between 5 and 15% of max isometric EMG. The magnitudes of tibialis anterior and triceps surae muscular activity were higher than those of the other muscles investigated. Mean peak activity in tibialis anterior was 27%, in gastrocnemius medialis 42%, in gastrocnemius lateralis 19% and in soleus 40%. The important role of the triceps surae during walking was reflected in comparatively high muscular activity at push-off.

KUROWSKI P, KUBO A. **THE RELATIONSHIP OF DEGENERATION OF THE INTERVERTEBRAL DISC TO MECHANICAL LOADING CONDITIONS ON LUMBAR VERTEBRAE.** Spine 1986; 11:726-31.

Abstract: Degeneration of lumbar intervertebral discs is typical for the aging process and contributes to common low-back problems. It is likely to influence vertebrae by changing the mechanical interaction within each motion segment. This study focuses on the influence of disc degeneration on the mechanism of load transmission through the lumbar vertebral body. Effective stresses, ways of load transmission and failure modes of vertebral body were examined in cases of healthy and degenerated discs. The stress analysis was performed using the Finite Element Method. For healthy discs, the highest effective stresses were found in the centre of bony end-plates. For degenerated discs, they were found in the lateral aspects of the end-plates, in the cortical wall, and also in the vertebral body rims. However, regardless of the disc condition, the highest effective stresses do not occupy the whole thickness of the end-plate and/or the cortical wall, but are concentrated near the spongy core. Ways of load transmission through the lumbar vertebral body and modes of eventual damage to it are also strongly influenced by the disc condition.

MCGILL SM, NORMAN RW. **PARTITIONING OF THE L4-L5 DYNAMIC MOMENT INTO DISC, LIGAMENTOUS, AND MUSCULAR COMPONENTS DURING LIFTING. 1986 VOLVO AWARD IN BIOMECHANICS.** Spine 1986; 11:666-78.

Abstract: This work describes a dynamic model of the low back that incorporates extensive anatomical detail of a three-dimensional musculo-ligamentous-skeletal system. The reactive moment about L4-L5, determined from sagittal plane lifts, was partitioned into restorative components provided by the disc in bending, ligament strain, and active muscle contraction. Skeletal kinematics were obtained from the cine analysis of markers on the rib cage and pelvis. The musculature was driven from surface EMG collected from six sites. When compared with past models, features of this model included (1) improved anatomical modelling, (2) improved monitoring of vertebral motion unit kinematics, (3) improved estimation of neural activation of the musculature, and (4) consideration of the effects of muscle length, velocity, cross-sectional area and passive elasticity in force estimation. Estimations of L4-L5 disc compression and shear were, on average, 16.2% and 42.5% lower, respectively, than those calculated from a simple 5cm erector tissue moment arm length. There was no need to invoke intra-abdominal pressure or other contentious compression-reducing mechanisms. Muscle activity, particularly that of the sacrospinalis, dominated the generation of the restorative moment. Ligaments played a very minor role in the lifts studied. High muscle loads are consistent with the common clinical observation of muscle strain often produced by load handling.

BOHANNON RW. **UPPER EXTREMITY STRENGTH AND STRENGTH RELATIONSHIPS AMONG YOUNG WOMEN.** J Orthop Sports Phys Ther 1986; 8:128-33

Abstract: The static strength of 10 upper extremity muscle groups of 31 young women was tested bilaterally to gain a preliminary estimate of the strength of the muscle groups and the relationship between the strength of muscle groups. Strength was measured using a hand-held dynamometer. Descriptive statistics were calculated for the measurements obtained. Inferential statistics revealed a significant difference in strength between the left and right side for only three muscle groups. The only antagonistic muscle groups that differed significantly on both the left and right side were the elbow flexor and extensor muscles. The strength of each muscle group was significantly related to the strength of every other muscle group on each side. The strength values and strength relationships reported herein should prove useful to clinicians testing the upper extremity strength of young women.



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OGSTON NG, KING J, GERTZBEIN SD, TILE M, KAPASOURI A, RUBENSTEIN JD. **CENTRODE PATTERNS IN THE LUMBAR SPINE. BASELINE STUDIES IN NORMAL SUBJECTS.** Spine 1986; 11:591-95.

Abstract: Segmental spinal instability is a known cause of back pain, but no method of accurately quantifying instability exists. The movement of complex joints with rotational and translational components (such as the lumbar motion segment) is tracked by a pathway of instantaneous centres of rotation, or a centrode. Instability, ie, excessive and/or erratic movement, is reflected by increased centrode length in cadaver studies. This study describes an *in vivo* method that precisely determines the centrode pattern and reports the results for 21 normal male volunteers who were studied at the L4-5 and L5-S1 levels. Each volunteer underwent lateral radiographs of the lumbar spine. High speed films were used and six positions, from full extension to full flexion, were recorded. Acetate tracings and contour matching techniques recorded the relative positions of the vertebral bodies on each film. Multiple tracings of each radiograph, combined with a digitizer and computer, were used to improve precision in the calculated centrode patterns. Centrode lengths measured 43.7mm and 55.9mm, respectively, for the L4-5 and L5-S1 levels. This study demonstrates that precise centrode pattern analysis for sagittal plane motion of the lumbar spine is possible *in vivo*. Studies are under way to determine whether this technique will be useful as a clinical test in diagnosing early segmental instability of the lumbar spine in patients with low-back pain.

HARMS-RINGDAHL K, EKHOLM J. **INTENSITY AND CHARACTER OF PAIN AND MUSCULAR ACTIVITY LEVELS ELICITED BY MAINTAINED EXTREME FLEXION POSITION OF THE LOWER-CERVICAL-UPPER-THORACIC SPINE.** Scand J Rehabil Med 1986; 18: 117-26

Abstract: The aim of this study was to find out whether maintained extreme flexion position of the lower-cervical-upper-thoracic spine in a sitting posture could induce pain, and thus possibly play a role in work related disorders with cervico-brachial pain. Ten healthy subjects assessed pain intensity of experimentally-induced pain on a Visual Analogue Scale (VAS). The quality and location of the pain was indicated on a drawing of the body. The load moment induced by the weight of the head-and-neck was calculated. The EMG activity levels were recorded from the splenius, thoracic erector spinae-rhomboid, and descending part of trapezius muscles. This posture, which resembles the posture in some common work, caused pain in all subjects. This pain was experienced within 15 min, increased with time, disappeared within 15 min after the end of provocation, but was again experienced by nine subjects the same evening or next morning and lasted up to four days. The primary location was in the dorsal part of the lower cervical and upper thoracic spine; three subjects also reported pain in the arms and one in the head. The recorded EMG levels were very low, but they increased somewhat during provocation. It is suggested that thorough recordings of work postures should be included in ergonomic analyses to provide a basis for the avoidance of such positions which might provoke pain.

NITZ AJ, PECK D. **COMPARISON OF MUSCLE SPINDLE CONCENTRATIONS IN LARGE AND SMALL HUMAN EPAXIAL MUSCLES ACTING IN PARALLEL COMBINATIONS.** American Surgeon 1986; 52:273-7.

Abstract: A small short muscle acting across a joint in parallel with vastly larger and longer muscles is clearly unable to play more than a minimal mechanical role in such a "parallel muscle combination" (PMC). This research investigates a feed back role for the small muscles of PMCs, proposing a significantly higher muscle spindle concentration therein to be consistent with this role. Epaxial PMCs (semispinalis and multifidus *versus* rotatores brevis) from the C5-C6, T6-T7, and L4-L5 regions of three 36-week-old male fetuses and two adult cadavers were removed and fixed in Carnoy's fluid. Tissue samples were embedded in paraffin, cut into 10µm thick sections perpendicular to the muscle's longitudinal axis and stained by Harris's hematoxylin and eosin. Representative tissue sections were projected onto a stereological grid and the percentage volume of spindles determined. Data were analysed with Student's unpaired t test. In all PMCs, rotatores brevis spindle percentage volumes ranged from 4.58 to 7.30 times higher than those of multifidus and semispinalis. Differences in mean spindle percentage volumes between large and small members of all PMCs were significant ($P < 0.001$). Our findings are consistent with the notion of a "kinesiological monitor" or feedback role for rotatores brevis.

SHIRAZI-ADL A, AHMED AM, SHRIVASTAVA SC. **MECHANICAL RESPONSE OF A LUMBAR MOTION SEGMENT IN AXIAL TORQUE ALONE AND COMBINED WITH COMPRESSION.** Spine 1986; 11:914-27.

Abstract: In the current study, a nonlinear three-dimensional finite element program has been used to analyse the response of a lumbar L2-3 motion segment subjected to axial torque alone and combined with compression. The analysis accounts both for material and geometric nonlinearities and treats the facet articulation as a general moving-contact problem. The disc nucleus has been considered as an incompressible inviscid fluid and the annulus as a composite of collagenous fibres embedded in a matrix of ground substance. The spinal ligaments have been modeled as a collection of nonlinear axial elements. Effects of loss of intradiscal pressure and removal of the facets on the joint response have been analysed as well. Torsion is primarily resisted by the articular facets that are in contact and the disc annulus. The ligaments play an insignificant role in this respect. For the intact segment, with an increase in torque, the axis of rotation shifts posteriorly in the disc so that under maximum torque it is located posterior to the disc itself. Loss of disc pressure increases this posterior shift whereas removal of the facets decreases it. Torque, by itself, cannot cause the failure of disc fibres, but can enhance the vulnerability of those fibres located at the posterolateral and posterior locations when the torque acts in combination with other types of loading, such as flexion. The most vulnerable element of the segment in torque is the posterior bony structure.

SEROUSSI RE, POPE MH. **THE RELATIONSHIP BETWEEN TRUNK MUSCLE ELECTROMYOGRAPHY AND LIFTING MOMENTS IN THE SAGITTAL AND FRONTAL PLANES.** J Biomech 1987; 20:135-46.

Abstract: In this study, we explore the relationship between moments in the frontal and sagittal planes, generated by a lifting task, vs the electromyographic (EMG) activity of right and left trunk muscle groups.

In particular, we postulate that the functional dependence between erector spinae muscle activity and the applied lifting moments about the spine is as follows: (1) the sum of left and right erector spinae processed EMG depends on the sagittal plane moment, and (2) the difference of left and right erector spinae processed EMG depends on the frontal plane moment. A simple out-of-sagittal plane physical model, treating the lumbar spine as a two degree-of-freedom pivot point is discussed to justify these hypotheses. To validate this model, we collected surface EMG and lifting moment data for ten males performing a grid of frontal and sagittal plane lifting tasks. A digital RMS-to-DC algorithm was developed for processing raw EMG. For these tests, we measured EMG for the left and right erector spinae and for the left and right external oblique muscles. The processed EMG signals of the left and right erector spinae muscles are summed and differenced for comparison to the measured sagittal and frontal plane moments. A linear correlation (r^2) of 0.96 was obtained for the sum of erector spinae EMG vs the sagittal plane moment; a corresponding value of $r^2=0.95$ was obtained for the difference vs the frontal plane moment. No correlations ($r^2<0.004$) was found for (1) the sagittal plane moment and the difference of the left and right erector spinae EMG, and (2) the frontal plane moment and the sum of the left and right erector spinae EMG.

PROSKE U, MORGAN DL. **TENDON STIFFNESS: METHODS OF MEASUREMENT AND SIGNIFICANCE FOR THE CONTROL OF MOVEMENT. A Review.** J Biomech 1987; 20:75-82.

Abstract: An appraisal of the role of tendons in transmitting muscle tension to skeletal parts during posture and movement requires accurate knowledge of the mechanical characteristics of the tendon. Here the most important property is tendon stiffness. While it is relatively easy to measure the stiffness of an isolated segment of tendon, more sophisticated methods must be sought to take into account the whole length of tendon, including its intramuscular portion. Two methods are currently available for measurement of whole tendon stiffness: each has a limited range of muscle tensions over which it appears to provide reliable values, one method being better at low tensions, the other at high tensions. Some controversy remains about the precise values obtained in the mid-tension range covered by both methods. Nevertheless it is now possible to achieve reasonable estimates of tendon stiffness over the whole working range of the muscle. An important consideration which has emerged from the discussion is that at low tensions the tendon is much less stiff than at higher tensions.

GOLDSTEIN SA, ARMSTRONG TJ, CHAFFIN DB, MATTHEWS LS. **ANALYSIS OF CUMULATIVE STRAIN IN TENDONS AND TENDON SHEATHS.** Biomech 1987; 20:1-6

Abstract: Twenty-five fresh frozen flexor digitorum profundus tendons stratified by sex were subjected to uniaxial step stress and cyclic loads in twelve intact human cadaver hands. By attaching specially designed clip strain gage transducers on tendons just proximal and distal to an undisrupted carpal tunnel, the interactions of the tendons, tendon sheath and retinacula were measured.

The elastic and viscous response of the tendon composites to step stresses were found to fit fractional power functions of stress and time respectively. A significant and quantifiable decrease in strain from the proximal to the distal tendon segment was found to be a function of wrist deviation.

The results indicate that an accumulation of strain does occur in tendinous tissues during physiologic loading.

ADAMS MA, HUTTON WC. **GRADUAL DISC PROLAPSE.** Spine 1985; 10:524-31.

Abstract: Fifty-two cadaveric lumbar motion segments were subjected to fatigue loading in compression and bending to determine if the intervertebral discs could prolapse in a gradual manner. Prior to testing, the nucleus pulposus of each disc was stained with a small quantity of blue dye and radiopaque solution. This enabled the progress of any gradual prolapse to be monitored by direct observation and by discogram. Six discs developed a gradual prolapse during the testing period. The injury starts with the lamellae of the annulus being distorted to form radial fissures and then nuclear pulp is extruded from the disc and leaks into the spinal canal. Discs most commonly affected were from the lower lumbar spine of young cadavers. Tests on ten older discs with pre-existing ruptures showed that such discs are stable and do not leak nuclear pulp.

ANDERSON CK, CHAFFIN DB, HERRIN GD, MATTHEWS LS. **A BIOMECHANICAL MODEL OF THE LUMBOSACRAL JOINT DURING LIFTING ACTIVITIES.** J Biomechanics 1985; 18:571-584.

Abstract: A biomechanical model of the lumbosacral region was constructed for the purpose of systematically studying the combined stresses and strains on the local ligaments, muscles and disc tissue during sagittal plane two-handed lifting.

The model was validated in two ways. The first validation was a comparison of experimental study results with model predictions. In general, predictions compared very reasonably with observed values of several authors with the exception of strain predictions on the articular ligaments. Second, a sensitivity analysis was performed over a wide range of lifting tasks. The predicted stress/strain values followed anticipated patterns and were of reasonable magnitudes.

On the basis of the results of the sensitivity analysis, it was concluded that typical lifting tasks can lead to excessive disc compressive forces, muscle moment generation requirements and, possibly, lumbodorsal fascia strains. Conversely, annulus rupture of a healthy disc due to overstrain appears very unlikely.

DIETRICH M, KUROWSKI P. **THE IMPORTANCE OF MECHANICAL FACTORS IN THE ETIOLOGY OF SPONDYLOLYSIS: A MODEL ANALYSIS OF LOADS AND STRESSES IN HUMAN LUMBAR SPINE.** Spine 1985; 10:532-42.

Abstract: Because the etiology of spondylolysis is not well understood, the authors performed an analysis of loads and stresses in human lumbar vertebrae to determine whether purely mechanical factors are likely to cause spondylolytic fractures in a normal spine. To perform these studies, modeling methods were applied. A mechanical system was developed to study muscle forces and reactions in joints of the lumbar spine. Next, an optimization approach was applied to find loads on vertebrae and muscle forces. Finally, photoelastic experiments were performed to find effective stresses and stress concentrations in low lumbar vertebrae. The analysis showed that the highest stresses appear in pars interarticularis. The results prove that factors of a purely mechanical nature are of fundamental importance in the etiology of spondylolysis.

GOEL VK, FROMKNECHT SJ, NISHIYAMA K, WEINSTEIN J, LIU YK. **THE ROLE OF LUMBAR SPINAL ELEMENTS IN FLEXION.** Spine 1985; 10:516-24.

Abstract: The forces induced in the disc and ligaments of a lumbar motion segment in resisting a quasistatic external load, using a semiexperimental approach, are presented. The lines of action of ligaments (direction cosines) and disc centre for the initial position of the specimen were determined using a morphometer. The changes in these lines of action for a known external load were computed by using the three-dimensional load-deformation characteristics of an intact motion segment. The load-deformation behaviour were obtained by applying a known load to the motion segment's superior vertebra and recording the motion produced. A seven-dial gauge motion-measuring system was used for this purpose. The six equations of equilibrium yielded a statically indeterminate model. A linear optimization technique in conjunction with a cost function enabled the computation of forces in the ligaments as well as forces and moments in the disc. This approach made it possible to determine the component forces without a prior knowledge of the structural properties of ligaments. Typically, for an external flexion moment of 6.9 nm, the supraspinous ligament experienced the most force (60 N), followed by capsular ligaments (25 N), and transverse ligaments (15 N). A compressive force of 100 N within the disc was predicted. The load-deformation curve, obtained from this study, for the supraspinous ligament was nonlinear and is in agreement with published experimental results.

MAHAR RK, KIRBY RL, MACLEOD DA. **SIMULATED LEG-LENGTH DISCREPANCY: ITS EFFECT ON MEAN CENTRE-OF-PRESSURE POSITION AND POSTURAL SWAY.** Arch Phys Med Rehabil 1985; 66:822-4.

Abstract: We hypothesized that leg-length discrepancies of as little as 1 cm would induce a significant postural shift and increase the extent of postural sway. We had 14 normal volunteers stand on a force platform with their feet in a standard position. Centre-of-pressure data were recorded at 100 Hz for 20 sec while the subjects stood barefoot with no lifts or (in random order) with lifts of 1, 2, 3 and 4 cm under their left and right feet. From these data we derived the mean centre-of-pressure position and the extent of postural sway. Lifts of as little as 1 cm shifted the mean centre of pressure toward the longer leg to a statistically significant extent ($p < 0.001$), the mean difference compared with the barefoot condition being 6.1% of the distance between the feet; increasing the discrepancy did not proportionately increase the effect. The postural sway (total travel of the centre of pressure) in a mediolateral direction increased significantly with a 1-cm discrepancy ($p < 0.01$) and continued to increase in proportion to the magnitude of the discrepancy. There were no effects on anteroposterior position or sway and no influence of left-right dominance. These results support our hypothesis that a leg-length discrepancy of as little as 1 cm may be biomechanically important.

PATWARDHAN AG, BUNCH WH. **A BIOMECHANICAL ANALOG OF CURVE PROGRESSION AND ORTHOTIC STABILIZATION IN IDIOPATHIC SCOLIOSIS.** J Biomech 1986; 19:103-17.

Abstract: A biomechanical analog of curve progression and orthotic stabilization in idiopathic scoliosis has been developed using the classical theory of curved beam-columns. The interaction of the spinal musculature and other supporting structures is incorporated in the model using an equivalent flexural rigidity. The stability of a given scoliotic curve relative to a normal spine is described in terms of the so-called critical load ratio (P_c/P_e). This dimensionless quantity appears in the exact solution of the governing differential equation and boundary conditions. It is defined as the ratio of the load-bearing capacity of the scoliotic spine (P_c) to that of a normal spine where the load-bearing capacity of a normal spine is defined as Euler's buckling load (P_e). The computation of P_c/P_e is based on a maximum allowable moment criterion. This model is used to study the effect of the degree of initial curvature and curve pattern in the frontal plane on the stability of untreated idiopathic scoliosis. Although restricted to two-dimensions, the model appears to demonstrate the synergistic effects of end support, transverse loading, and curve correction on improvement in relative stability of an orthotically supported scoliotic curve. The results of this study are in qualitative agreement with clinical findings that are based on long-term studies of natural history of idiopathic scoliosis and of patients undergoing orthotic management for scoliosis.

SKIPOR AF, MILLER JAA, SPENCER DA, SCHULTZ AB. **STIFFNESS PROPERTIES AND GEOMETRY OF LUMBAR SPINE POSTERIOR ELEMENTS.** J Biomechanics 1985; 18:821-30.

Abstract: This paper reports measurements made in five fresh cadaver lumbar spine motion segments of the load-deformation properties of the posterior elements soft tissues. These properties were measured and the stiffnesses corresponding to them were calculated for loading in anterior, posterior and lateral shear; in longitudinal tension and compression; and in flexion, extension, lateral bending and axial torsion.

In addition, measurements were made in six motion segments of the positions of the inferior facet joint centres relative to the vertebral body centres, and of the orientations of the facet joint surfaces.

TWOMEYL, TAYLOR J. **AGE CHANGES IN LUMBAR INTERVERTEBRAL DISCS.** Acta Orthop Scand 1985; 56:496-9.

Abstract: Measurements of disc thickness, shape and degeneration, using the criteria described by Rolander (1966), were recorded from 204 post mortem lumbar spines. The "true average disc height" increased with age as the discs "sink" into the vertebrae. These results add information to previous studies which indicate that the loss of transverse trabeculae of lumbar vertebrae is primarily responsible for the change in shape of both vertebrae and discs in the elderly. While the incidence of disc degeneration does increase in old age, the majority of the discs examined did not show evidence of any such change.

SHIRAZI-ADL A, AHMED AM, SHRIVASTAVA SC. **A FINITE ELEMENT STUDY OF A LUMBAR MOTION SEGMENT SUBJECTED TO PURE SAGITTAL PLANE MOMENTS.** J Biomech 1986; 19:331-50.

Abstract: A nonlinear finite element program has been developed and applied to the analysis of a three-dimensional model of the lumbar L2-3 motion segment subjected to sagittal plane moments. The analysis accounts for both material and geometric nonlinearities and is based on the Updated Lagrangian approach. The disc nucleus has been considered as an incompressible inviscid fluid and the annulus as a composite of collagenous fibres embedded in a matrix of ground substance. Articulation at the facet joints has been treated as a general moving contact problem and the spinal ligaments have been modelled as a collection of nonlinear axial elements. Effects of the loss of intradiscal pressure in flexion and of facetectomy in extension have been analysed.

Comparison of the predicted gross response characteristics with available measurements indicates satisfactory agreement. In flexion relatively large intradiscal pressures are generated, while in extension negative pressures (i.e. suction) of low magnitude are predicted. The stress distribution results indicate that the load transfer path through the posterior elements of the joint in flexion is different from that in extension. In flexion the ligaments are the means of load transfer, while in extension the load is transmitted through the pedicles, laminae and articular processes. In flexion, the inner annulus fibres at the posterolateral location are subject to maximum tensile strain. It is suggested that large flexion moment in combination with other loads is a likely cause of disc prolapse commonly found at this location of the annulus.

FERNAND R, FOX DE. **EVALUATION OF LUMBAR LORDOSIS. A PROSPECTIVE AND RETROSPECTIVE STUDY.** Spine 1985; 10:799-803.

Abstract: Two lordotic angles were measured on roentgenograms of 973 adults in a prospective and retrospective review. The majority of the films were taken because of lumbar complaints. The mean lumbosacral (LS) angle (L2-Sacrum) was $45.05 \pm .85^\circ$. The mean lumbolumbar (LL) angle (L2-L5) was $29.96 \pm .74^\circ$. Only minor differences were found between a standardized (prospective) and a nonstandardized (retrospective) group. There was a statistically significant difference between men and women with both LS and LL angles, but no racial differences were observed. A 'routine' supine lateral lumbar spine roentgenogram is a very accurate means of measuring lordotic angles. A lordotic angle of less than 23° defines hypolordosis and more than 68° hyperlordosis.

BRINKMANN, P. **INJURY OF THE ANNULUS FIBROSUS AND DISC PROTRUSIONS - AN IN VITRO INVESTIGATION ON HUMAN LUMBAR DISCS.** Spine (Eur Ed) 1986; 11:149-53.

Abstract: Discs of 25 specimens of human lumbar motion segments were subjected to an internal division of the annulus fibrosus, sparing only a peripheral layer 1 mm thick. Thus an attempt was made to simulate an internal disruption of the annulus caused by a traumatic episode or a degenerative process. The disc bulge that developed at the site of the injury was observed under axial loads in the physiologic load range, after axial compression fracture and after intradiscal injection. Under 1000-N load, the bulge amounted to less than 0.5 mm; typically it increased to less than 1.0 mm after fracture. An extrusion of disc material at the site of the annulus injury was never observed. The results suggest that a radial division of the annulus is not sufficient to produce a clinically relevant disc herniation; further prerequisites are a fragmentation of the disc material and a separation from the endplates.

HARMS-RINGDAHL K, EKHOLM J, SCHULDT K, NEMETH G, ARBORELIUS UP. **LOAD MOMENTS AND MYOELECTRIC ACTIVITY WHEN THE CERVICAL SPINE IS HELD IN FULL FLEXION AND EXTENSION.** Ergonomics 1986; 29:1539-52.

Abstract: Sustained joint load in extreme positions (namely maximally flexed or extended positions) has been described as causing pain. The aim of the present study is to analyse eight different sitting work postures with respect to expect to extreme positions, and to assess the mechanical load and the levels of muscular activity arising in defined extreme positions of the cervical spine. Ten healthy female workers from an electronics plant took part in laboratory experiments. For seven of these, levels of neck and shoulder muscular activity in sitting postures with the cervical spine in different manually-adjusted extreme positions were recorded using surface electrodes. Loading moments of force about the bilateral motion axis of the atlanto-occipital joint (Occ-C1) and the spinal cervico-thoracic motion segments (C7-T1) were calculated. Extreme or almost extreme positions occurred in sitting postures with the thoracolumbar back inclined slightly backwards or with the whole spine flexed. Electromyographic (EMG) activity levels were very low in the manually adjusted extreme positions. The load moment for the Occ-C1 joint when the whole neck was flexed was only 1-2 times the value for the neutral position of the head, but for C7-T1 it increased to 3-6 times. It is concluded that extreme positions of the cervical spine do occur in sitting work postures, and that the levels of muscular activity in such positions are low. Thus, recordings of muscle activity and calculations of load moment alone are not a sufficient basis for evaluating work postures: thorough recordings of spine positions should be included.

KOELLER W, MUEHLHAUS S, MEIER W, HARTMANN F. **BIOMECHANICAL PROPERTIES OF HUMAN INTERVERTEBRAL DISCS SUBJECTED TO AXIAL DYNAMIC COMPRESSION - INFLUENCE OF AGE AND DEGENERATION.** J Biomechanics 1986; 19:807-16.

Abstract: This investigation was performed to study biomechanical properties of human intervertebral discs as a function of age. One hundred seventy-eight specimens from 21 spinal sections (TH9-S1, 5-84 yr) were subjected to axial dynamic compression; the load being 950 ± 540 N. The results revealed three distinct age ranges: (1) From the first to the middle of the third decade: axial deformability decreases within the thoracic region, and remains almost constant within the lumbar spine; creep decreases in both parts. (2) From the middle of the third to the beginning of the sixth decade: the biomechanical behaviour scarcely alters. (3) Afterwards: axial deformability remains unchanged; creep, however, again increases within the lumbar spine. The results reveal the discs behave most efficiently within the age range where the incidence of back pain is maximal.

TESH KM, DUNN JS, EVANS JH. **THE ABDOMINAL MUSCLES AND VERTEBRAL STABILITY.** Spine 1987; 12:501.

Abstract: It has been suggested that the muscles of the anterolateral abdominal wall increase the stability of the lumbar region of the vertebral column by tensing the thoracolumbar fascia and by raising intra-abdominal pressure. In this report these new mechanisms are reviewed and their contribution to vertebral stability assessed. The thoracolumbar fascia consists of two principal layers of dense fibrous tissue that attach the abdominal muscles to the vertebral column. Each of these layers was dissected in fresh and fixed material and samples chosen for light and scanning electron microscopy to study the arrangement of the component fibres. Computed axial tomography in volunteers showed the changes in spatial organisation that occur during flexion of the back and during the Valsalva manoeuvre. The fascia was then tensed experimentally in isolated unfixed motion segments. The results suggested that the stabilising action

of the thoracolumbar fascia is less than had been thought previously but was consistent with calculations based on the more accurate structural and mechanical information that had been derived from the current study. Abdominal muscle contraction was simulated in whole cadavers in both the flexed and lateral bending positions to compare the stabilising effect of the thoracolumbar fascia and intra-abdominal pressure mechanisms. These definitive experiments showed that the resistance to bending in the sagittal plane offered by the abdominal muscles acting through fascial tension was of a similar magnitude to that offered by a raised intra-abdominal pressure, both being relatively small in the fully flexed position. The stabilising influence of the middle layer of the thoracolumbar fascia in lateral bending was clearly demonstrated and warrants further study *in vivo*.

Key words: thoracolumbar fascia, anatomy, microscopy, intra-abdominal pressure, biomechanics.

GRACOVETSKY SA, ZEMAN V, CARBONE AR. **RELATIONSHIP BETWEEN LORDOSIS AND THE POSITION OF THE CENTRE OF REACTION OF THE SPINAL DISC.** J Biomed Eng 1987; 9:237-48.

Abstract: Whenever we stand upright in apparent static equilibrium, we are, in fact, continuously making minor adjustments in order to maintain our balance. For each intervertebral joint, a point must exist at which all moments applied to the joint are continually and dynamically balanced. This point, known as the centre of reaction, is a mathematical invention necessary to perform analyses of spinal motion, but which need not be associated with any real anatomical structure.

As the spine flexes and extends, this centre is expected to move; where it moves and the rationale for its motion is worthy of enquiry. In this paper, we propose that the centre of reaction remains confined to the nucleus of the disc, but only if one simple but crucial assumption is made; that the motion of the spine and control of its musculature maintain a minimum and equal stress at each intervertebral joint. This is a simple hypothesis which imposes a very specific relationship between lordosis and the centre of reaction. We investigate this relationship and its consequences on the teaching of lifting.

The impossibility of designing experiments adequately to verify this hypothesis prevents *in vivo* verification, and, therefore, the model's verification must be made through the inferred consequences. For example, the capability of correctly predicting physiological responses of the musculoskeletal system is an indication of the validity of a model; however, this is not universally accepted. In this particular case, additional experimental data are available in the form of the locus of the centre of rotation of a vertebra *vis-à-vis* its lower neighbour as the spine flexes and extends.

It is instructive to compare the predicted locus of the centre of reaction to experimentally determined locus of the centre of rotation; more than just coincidental similarities are found.

SHIRAZI-ADL A, DROUIN G. **LOAD-BEARING ROLE OF FACETS IN A LUMBAR SEGMENT UNDER SAGITTAL PLANE LOADINGS.** J Biomech 1987; 20:601-13.

Abstract: In the present work, the load-bearing role of the facet joints in a lumbar $L_{2,3}$ segment is quantitatively determined by means of a three dimensional nonlinear finite element program. The analysis accounts for both material and geometric nonlinearities and treats the facet articulation as a nonlinear moving contact problem. The disc nucleus is considered as an inviscid incompressible fluid and the annulus as a composite of collagenous fibres embedded in a matrix of ground substance. The spinal-ligaments are modelled as a collection of nonlinear axial elements. The loadings consist of axial compression and sagittal plane shears and bending moments, acting alone or combined.

The results show that in pure compression, the external axial force is transmitted primarily by the intervertebral disc. The facet joints carry only a small percentage of the force.

However, the facet joints carry large forces in extension, whereas in small flexion they carry none. Addition of compression tends to increase these contact forces in extension while it has no effect on them in flexion. In extension, the forces on the facet joints are transmitted by both the articular surfaces and the capsular ligaments. Although in small flexion the facets carry no load, large contact forces are predicted to develop as the segment is flexed beyond 7-8°. These forces are of the same magnitude as those computed under large extension rotation and are oriented nearly in the horizontal plane with negligible component in the axial direction.

The horizontal components of the contact forces generated during articulation are often larger than the axial

components which directly resist the applied compressive force. The axial components of the contact forces, therefore, grossly underestimate the total forces acting on the facets.

The transfer of forces from one facet to the adjacent one occurs through distinct areas in flexion and in extension loadings. That is, on the superior articular surface, the contact area shifts from the upper tip in large flexion to the lower margin in extension. On the inferior articular surface, the contact area shifts from the upper and central region in large flexion to the lower tip in extension.

MCGILL SM, NORMAN RW. **EFFECTS OF AN ANATOMICALLY DETAILED ERECTOR SPINAE MODEL ON L4/L5 DISC COMPRESSION AND SHEAR.** J Biomech 1987; 20:591-600.

Abstract: Biomechanical models utilised for analysis of tasks that load the lumbar spine often predict the resultant moment, disc compression and sometimes shear. Usually the extensor muscular and ligament forces of the lumbar spine are assumed to act 5 cm posterior to a disc centre of rotation. This study has re-examined the generation and pathways of muscular force transmission within the extensor musculatures. The effects on L4/L5 disc compression and shear estimates of an anatomically and biomechanically justifiable range of tissue moment arms, lines of force and force generating capacity of muscle, input to a computer model, have been determined. Results indicated that L4/L5 compression estimates could be reduced by up to 35% when the output from a more realistic anatomical model of the erector spinae muscle group was compared with that from the frequently reported and simplified single muscle equivalent with a 5 cm moment arm. The shear force estimates could be altered from more than 500 N (L4 tending to shear anteriorly on L5) to less than 200 N with L4 tending to shear posteriorly on L5. Using the combination of input variables considered by the authors to be most feasible to estimate compression, a single 'equivalent' extensor soft tissue moment arm of 7.5 rather than 5 cm would be needed to equate the compression. This simplification of course, does not accommodate the shear force estimate problem.

DUMAS GA, BEAUDOIN L, DROUIN G. **IN SITU MECHANICAL BEHAVIOUR OF POSTERIOR SPINAL LIGAMENTS IN THE LUMBAR REGION. An *in vitro* study.** J Biomech 1987; 20:301-190.

Abstract: The posterior ligaments: ligamentum flavum, articular, interspinous and supraspinous ligaments of twenty five fresh cadaveric intervertebral segments, from T11-T12 to L4-L5, extracted from fourteen spines were tested in tension. A progressive dissection method was used, that is, each segment was tested after first resecting the disk with the ligaments intact and a force-elongation curve obtained. Then one ligament was cut and the test repeated, and so on. The most restrictive ligament was found to be the ligamentum flavum followed by the articular, interspinous, and supraspinous ligaments.

DAGALAKIS NG, MUEHLHOUSE C, WAKAMIYA S, YANG JCS. **LOSS OF CONTROL BIOMECHANICS OF THE HUMAN ARM-ELBOW SYSTEM.** Biomech 1987; 20:385-96.

Abstract: An experimental study was conducted to determine whether external disturbance oscillations, such as those that could be created by hand held tools, alter the dynamic response characteristics of the human arm-muscle system. A special arm-test frame was used to induce external sinusoidal torque oscillations of various amplitudes and frequencies, while the reaction force and angular displacement were monitored.

Two different output variable frequency responses were determined using input/output cross-spectrum analysis. The angular displacement of the test frame and a component of hand reaction force were the output variables used, while the test frame torque was the input.

Test results from one subject are presented in this paper. Changes in the magnitude and phase angle of the frequency responses were observed for different frequencies of the disturbance torque. These changes indicate that the stability margin and response amplitude of the human arm-muscle system do change as a function of the frequency and amplitude of external disturbance oscillations. This suggests that at certain operating frequencies hand held tools can induce large reaction amplitudes or even loss of control.

ADAMS MA, DOLAN P, HUTTON WC. **DIURNAL VARIATIONS IN THE STRESSES ON THE LUMBAR SPINE.** Spine 1987; 12:130-7.

Abstract: Two complementary experiments were performed, the first on living people and the second on cadaveric spines. In the first experiment, electronic inclinometers were used to measure the range of lumbar flexion of 21 volunteers in the early morning and in the afternoon. The results showed that the range of movement increased by 5° during the day. In the second experiment, cadaveric lumbar motion segments were creep loaded to simulate a day's activity and their bending properties were measured before and after creep. The results showed that creep loading reduces the spine's resistance to bending (the effect being particularly marked in the disc) and increases the range of lumbar flexion by 12.5°. The results of the two experiments were combined to show that in life, forward bending movements subject the lumbar spine to higher bending stresses in the early morning compared with later in the day. The increase is about 300% for the discs and 80% for the ligaments of the neural arch. It is concluded that lumbar discs and ligaments are at greater risk of injury in the early morning.

NORDIN M, KAHANOVITZ N, VERDERAME R, PARNIANPOUR M, YABUT S, VIOLA K, GREENIDGE N, MULVIHILL M. **NORMAL TRUNK MUSCLE STRENGTH AND ENDURANCE IN WOMEN AND THE EFFECT OF EXERCISES AND ELECTRICAL STIMULATION. Part 1: Normal endurance and trunk muscle strength in 101 women.** Spine 1987; 12:105-11.

Abstract: The lack of trunk muscle strength and endurance has frequently been cited as a suspected factor in the etiology of low-back pain. Several investigators have suggested that asymptomatic patients have stronger trunk muscles than patients with low-back pain. People who are physically fit appear to have a decreased incidence of low-back pain. Increased trunk muscle endurance also have been observed to decrease the incidence of low-back pain. The objective evaluation of the strength and endurance of trunk musculature may, therefore, be significant. Part 1 of this study was designed to develop a reproducible strength-endurance screening procedure and to establish normal isometric-isokinetic trunk muscle strength and endurance parameters for women. This study showed that isometric trunk flexion varied from 19-109 Nm and trunk extension from 38-168 Nm. Peak values for isokinetic trunk flexion at two speeds (30° per second and 60° per second) varied from 17-191 Nm and isokinetic trunk extension from 14-208 Nm. The average endurance time for trunk extensors tested with the Sorensen test was 196 seconds.

KAHANOVITZ N, NORDIN M, VERDERAME R, YABUT S, PARNIANPOUR M, VIOLA K, MULVIHILL M. **NORMAL TRUNK MUSCLE STRENGTH AND ENDURANCE IN WOMEN AND THE EFFECT OF EXERCISES AND ELECTRICAL STIMULATION. Part 2: Comparative analysis of electrical stimulation and exercises to increase trunk muscle strength and endurance.** Spine 1987; 12:112-8.

Abstract: Several studies have shown positive correlations between muscle strength, flexibility, and the frequency of low-back pain. Weak trunk musculature and decreased endurance have thereby come to be identified as significant risk factors in the development of occupational back problems. Because it is widely accepted that exercise plays an important role in the conservative treatment and prevention of low-back pain, the goals of most rehabilitative programs involves improving the strength and endurance of the low-back pain patient. Whereas electrical stimulation has been shown to increase the muscle strength of the lower extremities, this effect has not been demonstrated for the trunk muscles. Part 2 is a prospective controlled study designed to document and to compare objectively the effects of electrical stimulation and exercise on trunk muscle strength. A total of 117 healthy women were divided randomly into four groups. Two groups received electrical stimulation with electrical parameters, one group received exercises, and one group acted as a control group. The results showed that low-frequency electrical stimulation and exercises significantly ($P<.05$) increased isokinetic back-muscle strength compared to the control and medium-high-frequency electrical stimulation groups. Both types of electrical stimulation, however, significantly increased ($P<.05$) the endurance in the back muscles compared with the control and the exercise groups. The study showed that electrical stimulation may be a valuable treatment in the early care of low-back pain patients in maintaining and increasing strength and endurance of back muscles when a more active exercise program is too painful to perform.

GOEL VK, NISHIYAMA K, WEINSTEIN JN, LIU YK. **MECHANICAL PROPERTIES OF LUMBAR SPINAL MOTION SEGMENTS AS AFFECTED BY PARTIAL DISC REMOVAL.** Spine 1986; 11:1008-12.

Abstract: The changes in the three-dimensional motion behaviour of the lumbar motion segments, as affected by partial disectomy, are presented. The injured specimens, when subjected to flexion, extension, lateral bending, or axial torsional loads, showed significant increases in their major motions when compared with the corresponding intact specimen. No significant increases in the coupled motions were observed. These results suggest that it is better to excise as little of the nucleus as possible at surgery, since it may limit the increase in motion due to the injury.

HANSSON TH, KELLER TS, PANJABI MM. **A STUDY OF THE COMPRESSIVE PROPERTIES OF LUMBAR VERTEBRAL TRABECULAE: EFFECTS OF TISSUE CHARACTERISTICS.** Spine 1987; 12:56-62.

Abstract: The compressive material properties of human lumbar vertebral trabecular bone were examined and compared to in vivo and in vitro measures of bone density and to the degree of macroscopic disc degeneration. No significant differences in the material properties were found for segment level (L1-L4) or for degeneration grade (I-IV), although trabecular bone specimens from segments with slightly degenerated disks (I-II) were stronger (24%) and stiffer (16%) on the average than specimens from segments with severely degenerated discs. Significant positive logarithmic regressions were obtained, however, between the in vivo and in vitro measures of trabecular bone density and trabecular bone mechanical properties. The results indicate that in vivo mineral measurements can accurately estimate the compressive material properties of lumbar vertebral trabeculae.

MELLIN G. **METHOD AND INSTRUMENT FOR NONINVASIVE MEASUREMENTS OF THORACOLUMBAR ROTATION.** Spine 1987; 12:28-31.

Abstract: An objective method of measuring thoracolumbar vertebral rotation by using a suitable compass attached to an auxiliary tool is described. The jugular notch and xiphisternum are used ventrally and the spinous process on the same horizontal planes is used dorsally as reference points for spinal rotation. The method was tested on 39 adults. The mean of intratester and intertester correlation coefficients for the measurements was 0.79 (SD 0.11), with no essential difference between intratester and intertester reproducibility. The results also showed that the method is of considerable validity and, thus, is a supplement to noninvasive goniometric measurements of thoracolumbar mobility in the sagittal and frontal planes.

FORWOOD MR, PARKER AW. **EFFECTS OF EXERCISE ON BONE GROWTH: MECHANICAL AND PHYSICAL PROPERTIES STUDIED IN THE RAT.** Clinical Biomechanics 1987; 2:185-190.

Abstract: Thirty-four pubescent male rats were divided into exercise and control groups to examine the effects of a 1-month intensive exercise programme on the mechanical, physical (group 1) and histological properties (group 2) of the tibia and femur. At the completion of training, rats were sacrificed and the right hind-limbs dissected and stored at -60°C prior to torsional-testing at a speed of 180/s. Left tibiae and femora were measured for length and weight. Values for the width of the epiphyseal plate were also obtained from animals in group 2. Following the exercise programme the tibiae showed significant reductions in energy absorbed to failure, bone length and width of the proximal epiphyseal plate. No change was observed for the mechanical properties of the femora, but significant reductions occurred in bone length and weight.

Relevance: These results suggest that high intensity exercise in young animals may lead to fatigue micro-damage in lower-limb bones, the repair of which alters the rate of calcification and remodelling associated with normal maturation; and questions the notion that exercise in young animals is "always" beneficial.

GILL K, VIDEMAN T, SHIMIZU T, MOONEY V. **THE EFFECT OF REPEATED EXTENSIONS ON THE DISCOGRAPHIC DYE PATTERNS IN CADAVERIC LUMBAR MOTION SEGMENTS.** Clinical Biomechanics 1987; 2:205-210.

Abstract: Little is known about the effect of mechanical treatment on the intervertebral disc in the management of low back pain, even though good clinical results are often claimed for this treatment. In order to understand the possible

effects of this treatment cadaveric lumbar motion segments were studied with discography at 103 levels in 19 lumbar spine specimens. Fifty-four motion segments were tested with repeated extension/compression moments and evaluation of the changes in discogram dye pattern was made. In 43% increased dye leakage was observed, while 31% of those studied showed some degree of increased bulging, and in 2% there was evidence of decreased bulging. The major effect of repeated extensions moments on the cadaveric lumbar motion segment appears to lie in forcing dye from the nucleus pulposus into the spinal epidural space, or some peridiscal space in many abnormal discs.

Relevance: Repeated lumbar spine extension movements did force some radiopaque material out of the pathologic discs. The possible clinical importance of this phenomenon is unclear, and these results did not explain extension treatment methods.

FRIBERG O. THE STATICS OF POSTURAL PELVIC TILT SCLIOSIS; A RADIOGRAPHIC STUDY ON 288 CONSECUTIVE CHRONIC LBP PATIENTS. *Clinical Biomechanics* 1987; 2:211-219.

Abstract: Standing orthoradiography of the lumbar spine, the hip and knee joints revealed a lateral lumbar curve of 5-22° (mean=9.0°, s.d.=4.2°) secondary to leg length inequality in 186 or 64.6% of 288 consecutive patients with chronic low back pain (LBP). The incidence of leg length inequality in LBP patients (mean=10.6mm, s.d.=6.7mm) was significantly higher ($P<0.001$) than in 366 asymptomatic controls (mean=5.1mm s.d.=2.4mm). In 170 cases (91.4%), the lumbar curve was convex toward the short leg side, correlating significantly with the degree of lateral inclination of the sacrum ($r=+0.97$) and with the amount of leg length inequality ($r=-0.81$). The curvature was generally coupled with an axial rotation of the vertebrae moving the spinous processes toward the concavity, as well as with an opposite rotation of the pelvis ($r=+0.77$), which were calculated to result in a significant torsional stress on the L5-S1 segment.

Relevance: Weight-bearing orthoradiography in a standardised and repeatable bipedal standing position is a practical means for measuring structural and functional asymmetries of the spine and the lower extremities that in a clinical examination as well as in recumbent 'routine' radiography generally remain undiagnosed. Postural asymmetries compensating for leg length inequality mostly disappear following correction of the length discrepancy with a lift under the shorter leg.

ERGONOMICS/EPIDEMIOLOGY

HAGBERG M, SUNDELIN G. DISCOMFORT AND LOAD ON THE UPPER TRAPEZIUS MUSCLE WHEN OPERATING A WORDPROCESSOR. *Ergonomics* 1986; 29:1637-45.

Abstract: Surface electromyogram recordings from the descending part of the trapezius muscle and discomfort ratings were assessed for six female VDT wordprocessor operators during their work. Each operator was studied during three work periods of 3 to 5 hours on different days. During one of the work periods, short pauses (15s) were introduced every sixth minute. A static local muscular load of 3.2 and 3.0% of the maximal voluntary contraction was found on the right and the left side, respectively. The median and peak muscular loads during work were low. There was a significant negative correlation between pauses and static load on the right upper trapezius muscle. The rating of perceived discomfort was less after the work periods with short pauses than after the work periods without.

HARMS-RINGDAHL K, EKHOLM J, SCHULDT K, NEMETH G, ARBORELIUS UP. LOAD MOMENTS AND MYOELECTRIC ACTIVITY WHEN THE CERVICAL SPINE IS HELD IN FULL FLEXION AND EXTENSION. *Ergonomics* 1986; 29:1539-52.

Abstract: Sustained joint load in extreme positions (namely maximally flexed or extended positions) has been described as causing pain. The aim of the present study is to analyse eight different sitting work postures with respect to extreme positions, and to assess the mechanical load and the levels of muscular activity arising in defined extreme positions of the cervical spine. Ten healthy female workers from an electronics plant took part in laboratory experiments. For seven of these, levels of neck and shoulder muscular activity in sitting postures with the cervical spine in different manually-adjusted extreme positions were recorded using surface electrodes. Loading moments of force

about the bilateral motion axis of the atlanto-occipital joint (Occ-C1) and the spinal cervico-thoracic motion segments (C7-T1) were calculated. Extreme or almost extreme positions occurred in sitting postures with the thoraco-lumbar back inclined slightly backwards or with the whole spine flexed. Electromyographic (EMG) activity levels were very low in the manually-adjusted extreme positions. The load moment for the Occ-C1 joint when the whole neck was flexed was only 1-2 times the value for the neutral position of the head, but for C7-T1 it increased to 3.6 times. It is concluded that extreme positions of the cervical spine do occur in sitting work postures, and that the levels of muscular activity in such positions are low. Thus, recordings of muscle activity and calculations of load moment alone are not a sufficient basis for evaluating work postures: thorough recordings of spine positions should be included.

SCHULDT K, EKHOLM J, HARMS-RINGDAHL K, NEMETH G, ARBORELIUS UP. **EFFECTS OF CHANGES IN SITTING WORK POSTURE ON STATIC NECK AND SHOULDER MUSCLE ACTIVITY.** *Ergonomics* 1986; 29:1525-37.

Abstract: In order to analyse the effect of changing the sitting posture on the level of neck and shoulder muscular activity, an electromyographic (EMG) study of ten healthy experienced female workers from an electronics plant was undertaken. A standardised, simulated task was performed in eight different sitting work postures. Using surface electrodes, the level of muscular activity was recorded as normalised, full-wave rectified low-pass filtered EMG. The results showed that the whole spine flexed sitting posture gave higher levels of static activity in several neck and shoulder muscles than the posture with a straight and vertical spine, which in turn gave higher levels than the posture with slightly backward-inclined thoraco-lumbar spine.

MARTIN PE, NELSON RC. **THE EFFECT OF CARRIED LOADS ON THE WALKING PATTERNS OF MEN AND WOMEN.** *Ergonomics* 1986; 29:1191-1202.

Abstract: In order to determine the effect of loads worn or carried on walking mechanics, 11 men and 11 women were filmed using high speed cinematography as they performed overground walking at 1.78m/s under five load conditions. The loads included a baseline condition in which subjects carried no added load, and additional loads of approximately 9, 17, 29 and 36 kg consisting of standard military items. The latter two loads were added in the form of a framed rucksack system. Values for several variables frequently used to describe temporal and kinematic characteristics of walking were quantified for the film. These included stride length, stride rate, single leg support time, double-support time, swing time and the forward inclination of the trunk. The results of the study demonstrated that the males and females displayed significantly different gait patterns under all load conditions. Not unexpectedly, the females required a higher rate of stepping than the males because of their shorter stride lengths. The results also demonstrated that the walking patterns of both male and female subjects were affected by the increases in carried load. In general, stride length and swing time decreased while stride rate and double-support time increased with increases in load. There was also an increased forward inclination of the trunk but only for the two heaviest loads which were carried in a rucksack. While the changes in gait characteristics were relatively small for the male subjects, the females were affected to a greater extent thereby demonstrating a greater sensitivity to load magnitude. It was concluded that careful consideration must be given to the absolute loads carried by males and females. Not only is it important for load requirements to be lower for females because of the physiological implications but also because of biomechanical implications and the associated mechanical stresses which must be endured during locomotion. While this study was directed primarily towards military applications, the results should also have implications for load carrying in a variety of situations and environments, including industrial and recreational applications.

ROHMERT W, WANGENHEIM M, MAINZER J, ZIPP P, LESSER W. **A STUDY STRESSING THE NEED FOR A STATIC POSTURAL FORCE MODEL FOR WORK ANALYSIS.** *Ergonomics* 1986; 29:1235-49

Abstract: The maximum endurance time (MET) in static force exertions was used as a parameter for the assessment of five working postures. By applying the methodology of Rohmert to the construction of a general model for static muscular work and evaluating the measured MET results, the need for a new static posture model has been shown.

The aim of the present pilot study was to test MET in load situations that would indicate when the general model can be used or when a new static *postural* force model is needed.

Subjects exerted static postural forces at different load levels until exhaustion. In the first two postures, the strain was

concentrated on the upper limbs, where active forces (muscular) play a key-role and justify the use of the model. In the remaining postures, the strain affected mainly the back/trunk, where the mechanical equilibrium of the body is brought about by active (muscles) and passive (skeleton and ligaments) structures.

During the tests electromyographic (EMG) measurements of selected muscles (objective measurements) as well as rated perceived exertion (RPE; subjective measurements on Borg's CR-10 scale) were recorded.

The results show that the maximum endurance times in upper extremity postures are predicted by the general model whilst in the back/trunk postures the measured MET was longer than predicted by the model. New models are presented for static postural force on the back.

The EMG measurements supported the conclusion that the muscles studied play a key role in the chosen upper-extremity postures but gave no clear indication in the back-oriented postures. Ratings of perceived exertion coincided with the EMG measurements in upper extremity postures and proved to be a good substitute for measurement and calculation of the load levels studied. The initial RPE can therefore be used in models for predicting maximal endurance times in complex cases.

For the range of relative postural loads tested, an exponential function for predicting MET in static posture exertions produced the best fit curve.

OLNEY DB, MARSDEN AK. THE EFFECT OF HEAD RESTRAINTS AND SEAT BELTS ON THE INCIDENCE OF NECK INJURY IN CAR ACCIDENTS. Injury 1986; 17:365-7.

Abstract: During a 5-month period a study was made of motor vehicle occupants presenting at an Accident and Emergency department following an accident. Records were made of the incidence of neck injuries in relation to the presence of head restraints and the use of seat belts. There was a slight reduction in injuries when a head restraint was fitted but this difference did not achieve statistical significance. The incidence of neck injury was not increased if a seat belt was worn. It may be that the reason for the failure of head restraints to afford the expected protection is their inappropriate design and lack of adequate adjustability.

NAG PK, CHINTHARIA S, SAIYED S, NAG A. EMG ANALYSIS OF SITTING WORK POSTURES IN WOMEN. Appl Ergonom 1986; 17:195-7.

Abstract: Based on EMG analysis on six middle-aged women, seven sitting work postures were compared with reference to relaxed standing position. The muscles included in the investigation are pectoralis major, levator scapulae, deltoideus, latissimus dorsi, upper fibres of the trapezius, erector spinae, vastus medialis and lateralis, rectus femoris and gastrocnemius muscles. The commoner sitting postures examined were sitting on the floor with crossed legs, sitting on the floor with right leg bent at the knee, sitting on the floor with left leg bent at the knee, squatting with both legs bent at the knee without any back support, sitting on a plank of 10 cm height with both legs bent at the knee, sitting on the floor with legs extended, and sitting upright on a stool of 40 cm height. The relative load on the muscles was highest in the case of sitting on the floor with the right leg bent at the knee. However, less muscle activity was noted when sitting on the floor with the legs extended, a posture commonly adopted by women performing various domestic and other duties.

STALHAMMAR HR, LESKINEN TPJ, KUORINKA IAA, GAUTREAU MHJ, TROUP JDG. POSTURAL, EPIDEMIOLOGICAL AND BIOMECHANICAL ANALYSIS OF LUGGAGE HANDLING IN AN AIRCRAFT LUGGAGE COMPARTMENT. Appl Ergonom 1986; 17:177-83.

Abstract: Loading and unloading of luggage in an aircraft luggage compartment is carried out manually in uncomfortable working positions. In this study, the loading work was analysed by surveying musculoskeletal symptoms, by recording the working postures and techniques at work, and by simulating the loading work in a mock-up of a DC-9 aircraft compartment. Low back, knees and shoulders were exposed to mechanical load in luggage handling. Video recordings were used to analyse posture and work technique. In the simulated luggage compartment in the laboratory, ground reaction forces, intra-abdominal pressure (IAP) and electromyography (EMG) signals from back and shoulder muscles were recorded simultaneously. Loading in sitting, squatting and kneeling were the postures that were used

the most often. Unloading was generally less stressful than loading, involving less static work. Handling time was shortest when kneeling but knee symptoms were dominant. Lateral ground reaction forces and EMG activity from trapezius were highest when sitting, and IAP peaks were greatest when squatting. Thus each posture had major, though differing, disadvantages and a radical redesign of the DC-9 luggage compartment was clearly indicated.

BENDIX T, JESSEN F. **WRIST SUPPORT DURING TYPING - A CONTROLLED, ELECTROMYOGRAPHIC STUDY.** Appl Ergonom 1986; 17:162-8.

Abstract: The effects of wrist support on the trapezius and brachial extensor muscle loads during touch-typing were investigated with 12 secretaries, who were suffering pain in one or more of these muscles. They typed for 15 min at each of four experimental situations. The load on the trapezius was significantly greater with wrist support than without, and more marked the higher the support was adjusted. The radial extensor muscle load did not vary significantly. In spite of the higher trapezius load, most of the secretaries preferred a wrist support. Typing performance and body movements, estimated from the movements transferred to a tiltable chair-seat, were both unaffected by wrist support. Whether or not a wrist support should be used for typing cannot be concluded from the present investigation. However, it can be concluded that for touch-typing the keys should be positioned low - probably as low above the thighs as possible.

ANDERSSON GBJ, SCHULTZ AB, ORTENGREN R. **TRUNK MUSCLE FORCES DURING DESK WORK.** Ergonomics 1986; 29:1113-27.

Abstract: Myoelectric activities of several trunk muscles were measured when subjects performed several common table-work tasks. At the same time, the contraction forces of these muscles were calculated using a biomechanical model. The measured myoelectric activities were transformed from microvolt to force data by means of regression analysis using a set of calibration experiments over the force range of interest. We suggest that that technique is more meaningful than relating the myoelectric data to, for example, a maximum voluntary contraction.

Loading of the spine was generally low in office table work. Further, the load levels were only marginally influenced by such factors as table-chair adjustment, manuscript location, and work tasks. We believe that the type of table work studied here does not influence the spine by imposing high loads, but rather by its static nature.

COLOMBINI D, OCCHIPINTI E. **POSTURE ANALYSIS.** Ergonomics 1985; 28:275-84.

Abstract: The authors commence by reviewing the most recent literature on methods for analyzing postures and come to the conclusion that two factors are vital for a proper study of working postures. These are the description and the assessment of posture tolerability. The descriptive models most recently put forward in the literature enable the information required for subsequent assessment to be collected, and further efforts to improve the descriptive capacity of these would be of slight benefit.

The major difficulties in posture analysis arise during assessment. In the first place, there is still a need for further basic knowledge to throw light on the natural and clinical development of changes due to unsuitable postures and to isolate the most significant individual or workplace-related factors.

In the second place, the most widely used assessment methods (electromyography, study of discal pressures, biomechanical analysis, etc.) are capable of providing useful information on the individual apparatus considered, whereas a posture turns out to be tolerable only when all the apparatuses involved are comprehensively safeguarded.

Lastly, the above-mentioned assessment methods are not always capable of providing both information on the appearance of short-term postural discomfort and enabling predictions to be made of the appearance of damage in the long-term, while both requirements must be met for a working posture to be considered as tolerable. For these reasons, the authors are in favor of the combined use of several methods for the assessment of working posture tolerability.

Practical examples provide guidelines to the authors' approach and conclusions are given.

POPE MH, BEVINS T, WILDER DG, FRYMOYER JW. **THE RELATIONSHIP BETWEEN ANTHROPOMETRIC, POSTURAL, MUSCULAR AND MOBILITY CHARACTERISTICS OF MALES AGES 18-55.** Spine 1985; 10:644-9.

Abstract: Three hundred twenty-one males, ages 18-55, had standardized tests to determine height, weight, Davenport Index, leg length inequality, determination of flexion and extension torques, flexion/extension balance, range of motion, straight leg raising, and lumbar lordosis. A total of 106 (33.0%) had never experienced low-back symptoms; 144 (44.9%) had or were having moderate low-back pain (LBP); and 71 (22.1%) had or were having severe low-back symptoms. These three subgroups showed no significant differences in height, weight, Davenport Index, lumbar lordosis, or leg length inequalities. LBP patients had less flexor and extensor strength and were flexor overpowered, had diminished range of motion for spinal extension and axial rotation ($P = 0.003$, $P = 0.0005$), and diminished straight leg raising capacity ($P = 0.04$). A multivariate correlation matrix demonstrated no typical pattern of associated abnormalities, except a diminished spinal range of motion in one plane was associated with the anticipated diminishment in all other planes of motion, and often with greater restrictions of straight leg raising tests.

ANDERSSON GBJ, SCHULTZ AB, ORTENGREN R. **TRUNK MUSCLE FORCES DURING DESK WORK.** Ergonomics 1986; 29:1113-27.

Abstract: Myoelectric activities of several trunk muscles were measured when subjects performed several common table-work tasks. At the same time, the contraction forces of these muscles were calculated using a biomechanical model. The measured myoelectric activities were transformed from microvolt to force data by means of regression analysis using a set of calibration experiments over the force range of interest. We suggest that that technique is more meaningful than relating the myoelectric data to, for example, a maximum voluntary contraction.

Loading of the spine was generally low in office table work. Further, the load levels were only marginally influenced by such factors as table-chair adjustment, manuscript location, and work tasks. We believe that the type of table work studied here does not influence the spine by imposing high loads, but rather by its static nature.

HARMS-RINGDAHL K, EKHOLM J. **INTENSITY AND CHARACTER OF PAIN AND MUSCULAR ACTIVITY LEVELS ELICITED BY MAINTAINED EXTREME FLEXION POSITION OF THE LOWER-CERVICAL-UPPER-THORACIC SPINE.** Scand J Rehab Med 1986; 18:117-26.

Abstract: The aim of this study was to find out whether maintained extreme flexion position of the lower-cervical-upper-thoracic spine in a sitting posture could induce pain, and thus possibly play a role in work-related disorders with cervico-brachial pain. Ten healthy subjects assessed pain intensity of experimentally induced pain on a Visual Analogue Scale (VAS). The quality and location of the pain was indicated on a drawing of the body. The load moment induced by the weight of the head-and-neck was calculated. The EMG activity levels were recorded from the splenius, thoracic erector spinae-rhomboid, and descending part of trapezius muscles. This posture, which resembles the posture in some common work, caused pain in all subjects. The pain was experienced within 15 mins, increased with time, disappeared within 15 min after the end of provocation, but was again experienced by nine subjects the same evening or next morning and lasted up to 4 days. The primary location was in the dorsal part of the lower cervical and upper thoracic spine; three subjects also reported pain in the arms and one in the head. The recorded EMG levels were very low, but they increased somewhat during provocation. It is suggested that thorough recordings of work postures should be included in ergonomic analyses to provide a basis for the avoidance of such positions which might provoke pain.

KLABER MOFFETT JA, CHASE SM, PORTEK I, ENNIS JR. **A CONTROLLED, PROSPECTIVE STUDY TO EVALUATE THE EFFECTIVENESS OF A BACK SCHOOL IN THE RELIEF OF CHRONIC LOW BACK PAIN.** Spine (Eur Ed) 1986; 11:120-3.

Abstract: Ninety-two chronic low back pain patients were randomly allocated to two groups to evaluate the effectiveness of a back school compared with an exercise-only regimen according to specified outcome variables. The data from 78 patients with 7 years mean duration of symptoms was analyzed. Three assessments were made: before treatment and 6 and 16 weeks after treatment. Changes in patients' levels of pain, functional disability, and other related variables were compared in the two groups. Almost all variables showed an improvement at 6 weeks. At 16 weeks, functional disability and pain levels showed a significant difference. Back school patients continued to make

an improvement. This method of managing low back pain makes maximal use of limited resources and appears to be effective, especially in the longer term.

SAKAKIBARA H, MIYAO M, KONDO T, YAMADA S, NAKAGAWA T, KOBAYASHI F. **RELATION BETWEEN OVERHEAD WORK AND COMPLAINTS OF PEAR AND APPLE ORCHARD WORKERS.** *Ergonomics* 1987; 30:805-15.

Abstract: The relation between working posture in overhead work and the complaints of farmers cultivating pears and apples were investigated by comparing pear work with apple work. The same 20 male and 28 female orchard workers were questioned about complaints associated with thinning out pears and bagging them, and bagging apples. The angle of forward flexion in the shoulder and neck extension was also measured in each job. The prevalence of tiredness, stiffness and pain in the neck, shoulders and arms was significantly higher in thinning out pears and bagging them than in bagging apples. Dizziness and tinnitus among female workers was more frequent in thinning pears. The posture of raising arms and bending the head backwards was higher in thinning and bagging pears. These results suggest that the working postures of elevated arms and backward head bending can cause symptoms in the neck, shoulders and arms. In some cases, they may also lead to symptoms of vertebral artery insufficiency.

STEELE VA, WHITE JA. **INJURY PREDICTION IN FEMALE GYMNASTS.** *Br J Sports Med* 1986; 20:31-3.

Abstract: In order to identify injury-proneness in female competitive gymnasts, 20 measures of flexibility, hypermobility, spinal posture and anthropometry were performed on 40 competitive gymnasts and injury scores were derived from the severity and extent of previous gymnastic injury and inherent hypermobility traits. Results were compared between contrasting groups of 'low' and 'high' injury gymnasts respectively (both $N=10$). Nine variables demonstrated significant differences between the 'low' and 'high' injury risk status groups namely, weight ($p<0.001$), height ($p<0.001$), age ($p<0.001$), mesomorphy ($p<0.01$), Quetelet Index ($p<0.01$), shoulder flexion ($p<0.05$) and lumbar extension ($p<0.05$), standing lumbar curvature and total peripheral flexibility score (both $p\leq 0.05$).

Multiple regression analysis was applied to determine the relative contribution of these variables to the estimation of injury-proneness as evidenced by previous history of injury and hypermobility traits. Using 9 independent variables, multiple regression yielded a multiple correlation coefficient (R)=0.840, accounting for over 70% of the observed variance ($R^2=0.706$) in injury scores among the total group of gymnasts. However, a subset of five variables, (weight, mesomorphy, standing lumbar curvature, age and height) yielded a multiple correlation coefficient (R) = 0.834 accounting for almost 70% of the observed variance ($R^2=0.696$). This was not significantly different from the larger subset.

Using injury classification system of 'low', 'medium', and 'high' risk categories, comparisons were made between predicted and observed injury scores in the respective risk categories. In 'high' risk and 'low' risk gymnasts, injury scores could be classified correctly with 70% and 79% accuracy respectively, so that relative risk status could be determined from simple physical tests which may be employed by practitioners in the field.

GAGNON M, SICARD C, SIROIS JP. **EVALUATION OF FORCES ON THE LUMBO-SACRAL JOINT AND ASSESSMENT OF WORK AND ENERGY TRANSFERS IN NURSING AIDES LIFTING PATIENTS.** *Ergonomics* 1986; 29:407-21.

Abstract: Tasks associated with patient handling may present nursing aides with some risk of injuring the lumbar spine. The purpose of this study was to estimate the forces at L5/S1 and to assess mechanical work and energy transfers in a task consisting of raising a patient (a 72.6 kg manikin) from a chair using three different methods: (A) with the hands; (B) with the forearms behind the patient's back at shoulder level; and (C) with a belt held at waist level. Six male subjects took part in the experiment. Spinal forces were estimated from a static and planar mathematical model used in conjunction with cinematography techniques, a force platform and EMG recordings. External forces and the internal forces (compression and shear at L5/S1) were determined from free-body diagrams and static equations. The model was analysed for its sensitivity in estimating patterns of EMG forces, intra-discal and musculo-ligamentous forces, intra-abdominal pressure and inertial forces. The model was found to discriminate between the relative demands imposed on the spine by the different lifting methods, but the absolute values of the forces remain uncertain because of the uncertainty residing in many of the model's hypotheses. The method requiring a belt to lift

the patient was found to be considerably more strenuous for the spine and also to require a larger amount of work; it should therefore not be recommended as a task for nursing aides.

KEYSERLING WM. POSTURAL ANALYSIS OF THE TRUNK AND SHOULDERS IN SIMULATED REAL TIME. *Ergonomics* 1986; 29:569-83.

Abstract: A new method for analysing and describing the posture of the trunk and shoulders was developed and used to describe the posture of workers performing automobile assembly operations. The system used a videotape to create a permanent record of the jobs and a personal computer to perform the clerical and time-keeping tasks associated with posture analysis. In experiments using an experienced analyst to evaluate a videotape, highly reproducible results were obtained. Furthermore, the new system required substantially less time than existing posture analysis methods to analyse and reduce postural data.

KARWOWSKI W, YATES JW. RELIABILITY OF THE PSYCHOPHYSICAL APPROACH TO MANUAL LIFTING OF LIQUIDS BY FEMALES. *Ergonomics* 1986; 29:237-48.

Abstract: The psychophysical method for setting lifting standards was evaluated by having seven, female college students lift at four different frequencies (1, 3, 6 and 12 lifts min⁻¹). Only one lifting session was performed in a 24 hour period. During the 4 hour lifting task, subjects were asked to select the amount of water that they believed they could life comfortably for 8 hours. Subjects were encouraged to make as many weight changes as they needed. Each time the weight was changed the carton was weighed and the time was recorded. At 15 min intervals, subjects were asked about their degree of confidence (DOC) that the current weight was the maximum acceptable one for an 8 hour shift. Oxygen consumption was measured at 30, 120 and 240 min of the task. The weights chosen by the subjects, at 30 min did not differ significantly from the 4 hour values for frequencies of 1, 3 and 6 lifts min⁻¹. However, at 12 lifts min⁻¹ the weight decreased with time such that the 4 hour value was 23% lower than the weight chosen after 30 min. DOC increased over time and did not differ significantly between frequencies. Oxygen consumption was unchanged over time and accounted for 19, 25, 35 and 45.5% of VO₂ max for frequencies 1, 3, 6 and 12 lifts min⁻¹, respectively. It was concluded that the psychophysical method in its present form should not be used to set lifting standards for frequencies higher than 6 lifts min⁻¹.

FRIEVALDS A. THE ERGONOMICS OF SHOVELLING AND SHOVEL DESIGN - AN EXPERIMENTAL STUDY. *Ergonomics* 1986; 29:19-30.

Abstract: In spite of increased automation, there is still a need for ergonomically designed manual tools in the modern consumer and industrial environment. For example, many studies have examined the work physiology involved in shovelling, but few have referred to the shovel-design parameters needed to make the task more efficient. To this end, a two-phase experimental study examined the effects of the following parameters: lift angle, the size and shape of the blade, the hollow- and the closed-back design, the handle length on shovelling performance, the energy expenditure, the predicted low-back compressive forces and the subjective ratings of perceived exertion. The results indicated the following recommendations in shovel design: a lift angle of approximately 32°, a large, square-point blade for shovelling, a round-point blade for digging, a hollow-back construction to reduce weight, a solid socket for strength in heavy duty uses, a step for digging in hard soil and a long tapered handle.

DALES JL, MacDONALD EB, ANDERSON JAD. TRUNCAL STRESS MEASUREMENT DURING MANUAL HANDLING. *Ergonomics* 1987; 30:89-102.

Abstract: The development of techniques for monitoring the trunk during exertion, such as intra-discal pressure, has made significant contributions to efforts aimed at preventing back pain at work. A new method of truncal stress measurement using strain gauges incorporated in a belt, and which is non-invasive, easily performed and relatively inexpensive, is described. The equipment response is shown to be reliable. Following a simple protocol, test of dynamic lifting from floor to knuckle height were performed by 14 male volunteers in order to determine the accuracy of repeatability of measures, and to explore associations between the load, subject and the truncal response. Testing was carried out at the place of work, and no subjects reported any difficulties with the apparatus.

The measures were reasonably reliable within sessions, errors decreasing relatively with increasing load. Between-session repeatability was generally good, exceptions pointing to improvements in the protocol. Analysis of variance and elementary regression analyses established that the individual's measured trunk stress was significantly associated ($P<0.01$) with the load lifted in nearly all the tests. Possible developments of the method are suggested.

BOUDRIFA H, DAVIES BT. **THE EFFECT OF BENDING AND ROTATION OF THE TRUNK ON THE INTRA-ABDOMINAL PRESSURE AND THE ERECTOR SPINAE MUSCLE WHEN LIFTING WHILE SITTING.** *Ergonomics* 1987; 30:103-9.

Abstract: The effect of bending and rotation of the trunk on the intra-abdominal pressure (IAP) and erector spinae muscle activity when lifting while sitting has been investigated. The analysis of the IAP results shows that the difference between lifting from the middle and lifting from either the left or right is highly significant ($P<0.01$), whereas the difference between mean values for lifting from the right and left is not significant. The iEMG results from the erector spinae of the left of L3 level show that the difference between the mean values of the iEMG when lifting from the right and left is highly significant ($P<0.01$). The difference between lifting from the right and middle is also significant ($P<0.01$). Back muscle activity from the erector spinae on the right of L3 level is lower when lifting with trunk rotated to the right and highest when it is rotated to the left as compared to lifting from the middle. Both parameters increased as bending of the trunk increased.

WILBY J, LINGE K, REILLY T, TROUP JDG. **SPINAL SHRINKAGE IN FEMALES: CIRCADIAN VARIATION AND THE EFFECTS OF CIRCUIT WEIGHT-TRAINING.** *Ergonomics* 1987; 30:47-54.

Abstract: Compressive loading of the spine leads to spinal shrinkage and loss of stature. The aim of this study was to measure the circadian variation in the stature of females and to examine differential effects of spinal loading with the time of day. Ten females aged 20-30 years were studied in nine measurements on a 24-hour period. Between rising and retiring to bed, the mean peak-to-trough variation was 15.4 mm (0.92% of stature). Subjects underwent two sequences of 20 min circuit-training with weights, followed by 20 min reclining in Fowler's position and 20 min standing erect, these being first thing in the morning after 7 hours of sleep and before retiring at midnight. Mean loss of height from circuit-training was 5.4 mm in the morning and 4.3 mm in the evening ($P<0.001$); mean height regained in Fowler's position was 4.5 mm and 3.4 mm respectively ($P<0.05$). There were significant height losses in the subsequent standing posture but no time of day effect. Height losses with exercise were related to the isometric strength of the back muscles and to the perceived exertion. Results support the hypothesis that height losses from a given spinal load will be of smaller amplitude when body height is in the trough of circadian variation.

CORLETT EN, EKLUND JAE, REILLY T, TROUP JDG. **ASSESSMENT OF WORKLOAD FROM MEASUREMENTS OF STATURE.** *Appl Ergonom* 1987; 18:65-71.

Abstract: The height of the body in the erect position varies by about 1% during the course of the day. It decreases rapidly after getting up and, depending on the pattern of work and rest, continues to reduce during the day; then overnight, it recovers. These changes result from changes in the height of the intervertebral discs. With conventional methods of measuring stature, these changes would go unrecognised. Apparatus has therefore been developed, allowing measurement to an accuracy of at least 1 mm. Studies have been made of static loading, dynamic lifting, running, in different types of seating and in resting postures. In general, height losses are proportional to the magnitude of lumbosacral compression, to the perception of exertion during physical exercise and to the levels of postural discomfort. Gains in height in positions of rest are proportional to the ratings for relaxation and comfort. For the ergonomist, therefore, the method offers a reliable means of assessing the effects on the spine of both physical work and rest-pauses.

HANSSON JE, EKLUND L, KIHLEBERG S, OSTERGEN CE. **VIBRATION IN CAR REPAIR WORK.** *Appl Ergonom* 1987; 18:57-63.

Abstract: The main objective of the study was to find efficient hand tools which caused only minor vibration loading. Vibration measurements were carried out under standardised working conditions. The time during which car body repairers in seven companies were exposed to vibration was determined.

Chisel hammers, impact wrenches, sanders and saws were the types of tools which generated the highest vibration accelerations. The average daily exposure at the different garages ranged from 22 to 70 min. The risk of vibration injury is currently rated as high. The difference between the highest and lowest levels of vibration was considerable in most tool categories. Therefore the choice of tool has a major impact on the magnitude of vibration exposure. The importance of choosing the right tools and working methods is discussed and a counselling service on vibration is proposed.

MAGNUSSON M, ORTENGREN R, ANDERSSON GBJ, PETERSEN I, SABEL B. **AN ERGONOMIC STUDY OF WORK METHODS AND PHYSICAL DISORDERS AMONG PROFESSIONAL BUTCHERS.** Appl Ergonom 1987; 18:43-50.

Abstract: Butchers considered that the back and the upper extremities were subjected to high loads from their work. Of the 92% with reported physical disorders, 80% had pains or complaints from more than one body area. Most frequent were disorders of the back and shoulders. 50% of the butchers had been on sick leave due to their disorders. By ergonomic analysis of the work, several work tasks which caused high loads on those body parts in which disorders had occurred were identified.

The high loads were found to have the following main causes, which occurred together in many work situations:

- (1) Exertion of high forces when cutting the meat.
- (2) Frequent and heavy manual materials handling.
- (3) Inappropriate working postures.

It appeared from the study that the workload on the butchers was unnecessarily high and that it could be the main reason for the high frequency of disorders amongst them. The strain on them was to a large extent caused by bad working postures, which could be improved by introducing improved equipment. The equipment should be such that the working-height may be adjusted both to the individual and for the task performed.

TAKALA EP, KUKKONEN R. **THE HANDLING OF PATIENTS ON GERIATRIC WARDS. A CHALLENGE FOR ON-THE-JOB TRAINING.** Appl Ergonom 1987; 18:17-22.

Abstract: Patient lifting habits were studied on seven geriatric wards in five hospitals. The methods used were workplace analysis, questionnaire and video analysis of lifts. Mechanical hoists were regularly used only on the ward that had well organised on-the-job-training. The reasons given for not using the hoist (lack of space or time, etc.) were similar on this and the other wards where hoists were used irregularly. Lifting with hoists is slower than without aids, but the total extra time needed for their use is only 3-6% of the 8-hour work shift. Stooped and twisted trunk positions occurred less often when lifting aids were used than without an aid. However, some nurses worked in bad spine-loading positions, even when using lifting aids. To eliminate these postures from nursing work, more attention should be paid to working postures during the organised training of patient handling.

BURTON AK, SANDOVER J. **BACK PAIN IN GRAND PRIX DRIVERS: A 'FOUND' EXPERIMENT.** Appl Ergonom 1987; 18:3-8.

Abstract: The 'found' experiment uses a natural change in conditions to investigate the possible effects of those conditions. In this case, the natural change was reduction in stiffness of Grand Prix suspensions between 1982 and 1983. The effects of this change on back pain in drivers were investigated and it was found that both the incidence and severity of back pain decreased significantly. Of the various possible sources of back pain, only the ride changed over the same period. This suggests that mechanical shock and vibration are a significant cause of driving related back pain.

KANNUS P, NITTYMAKI S, JARVINEN M. **SPORTS INJURIES IN WOMEN: A ONE-YEAR PROSPECTIVE FOLLOW-UP STUDY AT AN OUTPATIENT SPORTS CLINIC.** Br J Sports Med 1987; 21:37-9.

Abstract: A one-year prospective follow-up study of all patients visiting Tampere Research Station of Sports Medicine (TRSSM) was carried out in order to determine the specific features of women's sports injuries compared to those of

men. During this period 334 women (31%) and 745 men (69%) visited the station. Women were significantly younger than men and the ten most usual sports events causing the injury differed from those of men. In women acute dislocations, contusions, and fractures were significantly less common in men, while women had more frequent stress-related sports injuries. In both sexes the most common sites of trouble were knee, ankle, and lower back, but in women as opposed to men, the metatarsal area, the toes, and the sole were among the ten most usual sites of the injury. Fourteen women (4%) and 49 men (6%) required operative treatment of the injury. The knee was the most common site of operation in both sexes, in women significantly more frequently than in men.

PATTERSON P, CONGLETON J, KOPPA R, HUCHINGSON RD. **THE EFFECTS OF LOAD KNOWLEDGE ON STRESSES AT THE LOWER BACK DURING LIFTING.** *Ergonomics* 1987; 30:539-49.

Abstract: This study investigated the effects of load uncertainty on the lifting characteristics of 40 male volunteers during the initial portion of a lift. Twenty subjects were experienced weightlifters while another 20 were subjects who had never lifted weights nor held a job that required them to on a regular basis. The subjects each lifted a container 20x45x40 cm, with handles, from floor to waist height 12 times with loads of 6.8, 10.2 or 13.6 kg. The loads were lifted under conditions of either having or not having verbal and visual knowledge of the load magnitude prior to the lift. The subjects were allowed to perform the lift in a manner of their choosing. A 2 (groups) x 3 (loads) x 2 (load knowledge) ANOVA was performed on the data. Maximum force (F_{max}) value analysis revealed group and technique differences. The experienced lifters had lower stress levels at L4/L5 and utilised two technique strategies that were dependent upon the load knowledge condition, whereas the non-lifters used the same strategy for all lifts. Maximum moment values (M_{max}) were significantly higher for the inexperienced lifters under all conditions, indicating a greater dependence on the low back musculature for initiating the lifting of a load.

JIANG C, AYOUB MM. **MODELLING OF MAXIMUM ACCEPTABLE LOAD OF LIFTING BY PHYSICAL FACTORS.** *Ergonomics* 1987; 30:529-38.

Abstract: Matching the job demands to a person's physical characteristics is an effective method of reducing the risk involved in a manual materials-handling task. Seventy-three male and 73 female industrial workers served as subjects. Maximum Acceptable Load of Lifting (MAL) was determined psychophysically under each combination of the following task conditions: six ranges of lift (floor to knuckle, floor to shoulder, floor to reach, knuckle to shoulder, knuckle to reach and shoulder to reach); four lifting frequencies (2, 4, 6 and 81/min); and three box sizes (30.48, 45.72 and 60.96 cm). A factor-score-based model ($R^2=0.924$) is developed in this paper based on 100 subjects for predicting an individual's MAL and for describing his/her physical characteristics in terms of strength and anthropometric scores. The model was validated on the remaining 46 subjects and was shown to be superior to the previously developed models from the same data set.

MARRAS WS, RANGARAJULU SL, LAVENDER SA. **TRUNK LOADING AND EXPECTATION.** *Ergonomics* 1987; 30:551-62.

Abstract: Much of the epidemiological literature has reported that there is a link between sudden unexpected load handling and the risk of a low back injury. However, few biomechanical studies have investigated the effect of this type of loading on trunk muscular response. An experiment was performed to test the hypothesis that sudden unexpected loads would create excessive forces upon the trunk due to the overcompensation of the trunk muscles, and to quantify the degree of overcompensation. Twelve male subjects were asked to hold a box in a static lift position while weights ranging from 2.27 to 9.07 kg were dropped into the box from a constant height. Under some conditions (expected) the subjects were permitted to observe the weight drop while under other conditions (unexpected) the subjects were deprived of visual and auditory cues during the weight drop. Several components of the trunk response were observed. Mean muscle forces for the unexpected condition exceeded those in the expected condition by nearly two-and-a-half times, and peak muscle forces in the unexpected condition were on average 70% greater. In addition, the unexpected condition produced longer periods of force exertion, as well as more rapid increases in trunk force development. Generally, it was found that during sudden unexpected loading the trunk response resembled an expected loading of twice the weight value. These findings may provide guidelines for work situations where unexpected loading conditions are common.

DIMBERG L. **THE PREVALENCE AND CAUSATION OF TENNIS ELBOW (LATERAL HUMERAL EPICONDYLITIS) IN A POPULATION OF WORKERS IN AN ENGINEERING INDUSTRY.** *Ergonomics* 1987; 30:573-80.

Abstract: Lateral humeral epicondylitis (tennis elbow) is often considered to be work related but the incidence and prevalence among industrial workers has not previously been studied.

In this study the prevalence of this condition and its relationship to some work factors was investigated in 540 workers in a modern engineering industry.

The prevalence was 7.4% (40/540). Work was found to be the probable cause in 35%, tennis in 8% and other leisure activities in 27% of the patients. No cause was found in the remaining 30%. There was no correlation with sex, while a significant correlation was found with age, the incidence increasing with advancing age.

On the basis of job classification according to their elbow stress, it was found that those workers with work-related epicondylitis had higher elbow stress jobs compared to other sufferers and to the workforce as a whole.

HELIOVAARA M. **BODY HEIGHT, OBESITY, AND RISK OF HERNIATED LUMBAR INTERVERTEBRAL DISC.** *Spine* 1987; 12:469.

Abstract: Anthropometric measurements were studied for their prediction of herniated lumbar intervertebral disc in 332 men and women who had been discharged from hospital with this diagnosis during an 11-year follow-up. The patients were compared with 1,205 controls matched individually for sex, age, and place of residence. Men with a height of 180 cm or more showed a relative risk of 2.3 (95% confidence limits, 1.4-3.9) and women with a height of 170 cm or more 3.7 (1.6-8.6), compared with those who were more than 10 cm shorter (1.0). In men, but not in women, increased body mass index proved to be an independent risk factor for herniated lumbar disc, whereas the thickness of triceps skinfold had no predictive significance. Height and heavy body mass may be important contributors to the herniation of lumbar intervertebral disc.

PORTER RW. **DOES HARD WORK PREVENT DISC PROTRUSION?** *Clinical Biomechanics* 1987; 2:196-198.

Abstract: This study compares the prevalence of coal miners attending hospital with three defined back pain syndromes, with the number of miners in the working population. Of the men who attended hospital with back pain there were more miners than would be expected (2.78% of the miners compared with 1.99% of the non-miners). 0.32% of the miners had criteria of disc protrusion compared with 0.4% of non-miners; significantly more had syndromes associated with degenerative change. Relatively few men requiring disc excision were miners, whilst there were many who had decompressive surgery. This is compatible with the concept that heavy manual work strengthens the spine, restraining encroachment of a disc protrusion into the vertebral canal.

Relevance: These findings suggest a need to identify and encourage activities in early life which may develop annular and ligamentous strength. Furthermore, unfit workers should not be deployed to areas of heavy work and we should re-examine advice about light work after the first disc protrusions.

WANGENHEIM M, SAMUELSON B. **AUTOMATIC ERGONOMIC WORK ANALYSIS.** *Appl Ergonom* 1987; 18:1:9-15.

Abstract: To reduce occupation-related diseases, injuries and impairments to the musculoskeletal system, an ergonomics analysis of the work process is necessary. The authors describe a project to develop an automatic ergonomic work analysis method using existing and developed models of work stress factors. It was designed to record the work accurately without disrupting activities, and describe the situation so that production engineers and designers can be supplied with basic information for ameliorative measures. The system determines such parameters as the position and movement of 14 parts of the body, and such measurements as force exerted, range of movement and static stress. A pilot study with a prototype of the system has been completed and tested with simple work sequences.

MAGNUSSON M, ORTENGREN R. **INVESTIGATION OF OPTIMAL TABLE HEIGHT AND SURFACE ANGLE IN MEATCUTTING.** Appl Ergonom 1987; 18:146-52.

Abstract: Butchers have a high frequency of occupational disorders or pain localised to their hands, shoulders, low back and neck, compared with other occupational groups. It is likely that the disorders are caused by high loadings of these parts of the body during work. The high loadings have been found to be caused by high resistance when cutting, inappropriate working postures and by manual handling of material.

To improve the butchers' working conditions by providing means for appropriate working postures, cutting table with adjustable height and surface angle were constructed and tested. Evaluations were made during work in the laboratory and in the industry. The aim of these tests was to find the optimal height of the table for each butcher and to find out if a tilted surface would improve the working postures and be accepted by the butchers. The evaluations were made by biomechanical calculations from photos, ergonomic analysis of videotapes taken during the tests and by using ranking scales.

The results show that (1) one optimal height of the table was not to be found, meaning a height resulting in a posture that causes no load on both back and shoulders at the same time; (2) a table height of 17 to 22 cm below elbow height result in low loadings on both the low back and the shoulders and was ranked as the most comfortable height; (3) tilting of the surface 5° to 10° was accepted by the butchers and ergonomically favourable; (4) the possibility of altering the table height during the workday was perceived as unloading since the load could be shifted between different parts of the body.

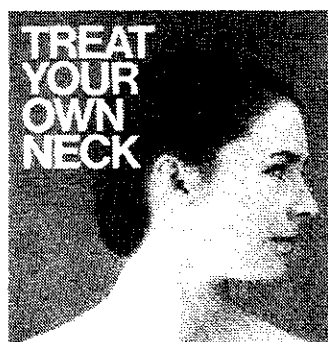
MANNING DP, AYERS IM. **DISABILITY RESULTING FROM UNDERFOOT FIRST EVENTS.** J Soc Occup Med 1987; 37:39-41.

Abstract: Studies of first unforeseen events (first events) in accidents have identified a group of related 'underfoot' first events including slipping, tripping and twisting of the foot or ankle, etc. In this study of 250 consecutive industrial injuries eighty-three (33 per cent) were associated with an underfoot first event. Disability caused by the accidents was measured by counting spells of absence and spells of restricted work. The underfoot first events were associated with significantly more spells of disability than all other first events ($P < 0.01$). Absences followed by periods of restricted work caused mainly by slipping, tripping and twisting of the foot or ankle accounted for most of the excess disability.

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BOOK REVIEW

Medical Treatment of Neck and Back Pain

by

James W Fisk, MD, DCH, MRCP

Publisher: Charles C Thomas, USA.

This book follows on from the earlier and very successful **"Practical Guide to Management of the Painful Neck and Back"** by the same author, published in 1977. The approach is similar, in the same readable, no-nonsense style, but full of remarks and witticisms characteristically and typically Jim Fisk. There are many personal observations and arguments put forward throughout the text which testify to the author's vast experience in the musculoskeletal field.

The opening chapter on Scheuermann's Disease is in particular an excellent summary of modern thinking and evidence concerning this perplexing and ill-understood condition. The chapter is full of observations and fact, much of it based on the author's own research, and supported by accurate references to research institutions and authorities which are internationally recognised. I know of no other reference concerning Scheuermann's Disease as comprehensive and informative as this one.

Good as his first book is, this 1987 publication is, to my mind, much better. It offers a far more comprehensive approach to the management of painful musculoskeletal conditions, with updated and new information, not only on Scheuermann's as already referred to, but also on articular neurology and reflexes referring frequently to the pioneering work of Dr. Barry Wyke. Muscle imbalance, pain, myofascial trigger points, and the "overloaded coping system syndrome" all receive more detailed attention than previously.

Any interested professional is presented with a sound basis on which to develop skills in history taking, examination, and treatment, especially by manual means, although acupuncture, TENS, steroid injections, exercises, and exercising, all receive attention.

The author's discussion on manipulation techniques is basic and uncomplicated, easy to understand and well illustrated, mainly with the same illustrations used in his first book. In general the methods proposed have stood the test of time and safety, and are recommended for general practitioners getting started. It is not the book's intention to describe the hundreds of methods of manipulation known and used over the world. However, reference to the growing trend towards neuromuscular therapy or muscle energy techniques of manual treatment would have been appropriate. Similarly, the hundreds of examination techniques and manoeuvres available to the diagnostician cannot be covered in a book such as this. What is described is a simple, logical examination sequence, well illustrated, admirably suited to the general practitioner.

Doctors interested in musculoskeletal medicine can purchase this book with confidence. It is recommended reading for anybody who is stimulated to explore the challenging new world of musculoskeletal medicine for the first time, but it will also serve as a valuable reference text for the more experienced.

Don Dalley (N.Z.)

The Back Book

by

Cover Stories

Available from P.O. Box 486, Boronia. Vic. 3155

The authors of this book remain anonymous but it is obviously written by someone who has had a lot of experience in treating low back pain.

The topic covered is basically that of lumbar pain and it outlines the possible causes of such pain and how it might be avoided. In the anatomical explanation of what is likely to happen the concept of the facet joint is not very clear and it might even have been better if a diagram depicting the facet joint had been left out. However, explanations of rather detailed medical and anatomical concepts have been well attempted and should be within the grasp of the person with average intelligence.

With many patients asking detailed questions of what their operation may entail or what their treatment may require, most of the answers will be found in this simple little booklet which requires probably no longer than 15 to 20 minutes of reading.

A major advantage of this little booklet is that the fact that it has a large fold out sheet of appropriate exercises to do. Here the practitioner has a choice of up to 40 exercises that the patient can be given for self physiotherapy which is an effective way of restoring adequate function. Of course, every practitioner would have to understand the benefit of each of these exercises. It is often found that when a patient is instructed in an exercise they have trouble remembering it correctly and this visual aid will go a long way towards providing better patient compliance.

Every practitioner dealing with the treatment of musculoskeletal pain would do well to have this booklet available for patient consumption.

Fifth Biennial Conference Proceedings Manipulative Therapists Association of Australia held in Melbourne, Victoria, November 25-28, 1987

**This publication of the MTAA Conference Proceedings
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CONSTITUTION OF THE AUSTRALIAN ASSOCIATION OF MUSCULOSKELETAL MEDICINE

(Incorporating the Australian Association of Manipulative Medicine)

1. NAME

The name of the association shall be the Australian Association of Musculoskeletal Medicine, incorporating the Australian Association of Manipulative Medicine.

2. OBJECTS

- (a) To promote the science of the musculoskeletal system and the study of its disorders, particularly mechanical disorders.
- (b) To promote the treatment of musculoskeletal disorders by all methods consistent with scientific principles, but favouring the least invasive method appropriate to each individual patient.
- (c) To promote the teaching of manipulative therapy and other modalities of treatment specifically related to the musculoskeletal system.
- (d) To promote research into manipulative medicine and all other aspects of musculoskeletal medicine.
- (e) To constitute the Australian branch of the International Federation of Manual Medicine.
- (f) To further these objects by holding meetings; by co-operation and, where possible, close association, with other Associations both national and international; by arranging demonstrations of manipulative medicine; by encouraging articles and papers to be written by members and circulating copies thereof to all members and to other interested persons.

3. MEMBERSHIP

- (a) Membership of the Association shall be limited to medical practitioners registered in Australia.
- (b) Medical practitioners with adequate qualifications but not registered in Australia, and medical students, shall be eligible at the discretion of the Committee for election as Associate Members. Associate Membership shall confer all privileges of membership except voting rights.
- (c) Notwithstanding anything contained in paragraphs 3(a) and 3(b) above, the Committee may, at its discretion offer to, or confer upon deserving persons Honorary Membership, Life Membership or Honorary Life Membership of the Association.

4. ELECTION OF MEMBERS

- (a) Applications for membership shall be sent to the Secretary and will be decided by the Committee, who may refuse any such application without assigning any reason therefore.
- (b) A Member may be deprived of his membership by a Special Resolution passed by a two-thirds majority of those present and voting at a meeting of the Committee duly convened for that purpose. Such Member shall be entitled to be heard at such meeting.

5. COMMITTEE

- (a) The Committee shall consist of the Executive Officers of the Association, who shall be a President, a Treasurer and a Secretary, and Committee Members to constitute a Committee of up to ten persons.
- (b) The Committee shall be elected at the Annual General Meeting of the Association and shall hold office until the next Annual General Meeting after their election. They may offer themselves for re-election.
- (c) The Committee shall meet as often as the business of the Association shall require, and in any event at least once in each six months. Four members of the Committee shall constitute a quorum.
- (d) The Committee shall have power to co-opt Members to be additional members of the Committee or any sub-committee.

6. STATE REPRESENTATIVES

- (a) The Association may nominate at the Annual General Meeting one or two Members from each State of Australia to act as the Association's representatives in that State. Nomination as a State Representative shall not per se confer ex-officio membership of the Committee.
- (b) The State Representatives shall refer to the Committee for its information and advice matters in which they may become involved as Representatives of the Association.

7. SUBSCRIPTION

- (a) Every Member (except an Honorary Member) shall pay an annual subscription which shall become payable on the first day of November in each year. A Member whose subscription is in arrears more than one year shall not be entitled to vote at any meeting.
- (b) Notwithstanding the provisions of paragraph (a) above, it is provided that when the spouse of a Member who pays the usual subscription is or becomes a Member, such spouse shall pay an annual subscription equal to one half of the usual Member's subscription.

8. FINANCES

- (a) The income and property of the Association shall be applied solely towards the promotion of the objects of the Association as set forth in Article 2 hereof and no portion thereof shall be paid or transferred, directly or indirectly by way of dividend, bonus or otherwise, to any Member of the Association; provided that nothing herein contained shall prevent the payment in good faith of remuneration to any officers or servants of the Association or to any Member of the Association in return for any services rendered to the Association.
- (b) Cheques drawn on the Association's account shall be signed by two officers of the Association.
- (c) The Committee shall cause proper accounts to be kept of all assets of the Association including proper records of all receipts and expenditure. Such accounts shall be audited in every year and an audited income and expenditure accounts shall be presented to each Annual General Meeting. The accounts shall, subject to any reasonable restrictions imposed by the Committee, be available for inspection by Members.
- (d) In the event of the Association being dissolved, any income and property of the Association remaining after satisfaction of all debts of the Association shall be transferred by way of gift to any charitable institution listed in Sec. 78(1)(a) of the Income Tax Assessment Act which the Executive Officers of the Association deem appropriate.

9. PROCEEDINGS AT MEETINGS

- (a) At all meetings of the Association and of the Committee every Member of the Association or of the Executive Committee as the case may be, who is present in person, and who is not disqualified by being in arrears of subscription, shall be entitled to one vote.
- (b) The Committee shall convene an Annual General Meeting of the Association once in every year, and the First Annual General Meeting after the Inaugural Meeting shall be held in 1972.
- (c) At every General Meeting of the Association, ten Members personally present, or one quarter of the total membership (whichever number is the less) shall be a quorum.
- (d) The Committee may at any time convene an Extraordinary General Meeting upon receipt of a resolution signed by at least seven Members specifying the nature of the business for which the meeting is to be called.
- (e) At least four weeks' notice of all General Meetings shall be given to all Members who have notified an address in Australia to the Secretary; such notice shall specify the date, time and place of the meeting and in the case of an Extraordinary General Meeting, the nature of the business to be transacted thereat.
- (f) Postal votes received by the Hon. Secretary will be accepted at all General Meetings. Proxy votes shall not be accepted.

10. AMENDMENT OF CONSTITUTION

A three-quarters majority of Members voting at a specially convened Extraordinary General Meeting shall be required to add to, abrogate, vary or modify the Constitution.

MAIL BAG Letters to the editor

"I had written him a letter....."



Dear Sir,

I would like to describe a case of shoulder pain.

A male patient aged 48 presented with a deep aching pain in the posterior shoulder which he had become aware of since operating a hand drill with his arm abducted from the shoulder to 90 degrees and elbow flexed to 90 degrees also.

Physical findings were almost normal, with the most obvious sign being the evocation of his pain after passively elevating his involved arm above his shoulder, the pain being produced at the last 5-10 degrees of elevation. He also had minimal discomfort with resisted internal rotation of the arm. The significant palpatory finding was of a trigger point in *teres minor*.

I would like now to relate my findings to what is described by Travell and Simons in "The Trigger Point Manual".

It is interesting to note that this muscle is involved in shoulder pain in only 7% of cases, hence our experience with it would be limited and this is my main reason for describing my observations.

Travell and Simons state that its activity is maximal at 120 degrees abduction of the arm. My patient had his arm abducted to 90 degrees for a prolonged period. Also they state the muscle externally rotates the arm, however with this patient pain was evoked with the resisted internal rotation; perhaps there is a silent trigger point in *subscapularis* or *supraspinatus* which make up the myotatic unit. Apart from the palpation of the trigger point, the most significant physical finding was of pain evoked by a hyper-elevation which is very similar to the position the authors suggest for treating the arm for stretch and spray. This finding is not discussed in the trigger point manual and I suggest it may be a valuable screening test for trigger points in the *teres major*, *teres minor* and *infraspinatus* muscles, particularly as other tests described in the book (hand-to-shoulder blade test and hand-mouth wrap around test) were all normal.

Basically, most of what Travell and Simons state about this interesting muscle is verified by my experience. However I was impressed by hyper-elevation as a screening test and also by the relationship to the manner of hand drilling I described. This is a common way for people to use this tool and this posture is not described in the manual; rather they believe reaching out and backwards is the main way of activating such trigger points.

This common drilling posture should, I believe, now be regarded as a factor in producing posterior shoulder trigger point activity and be discouraged. Perhaps the ergonomists and biomechanics have discovered this already.

Yours faithfully,

(Dr.) Peter J Bourke
Quirindi, NSW.

WHAT'S HAPPENING IN NEW ZEALAND

From the New Zealand Association of Musculo Skeletal Medicine Newsletter - March 1988

This will be a very exciting, busy and crucial year for the N.Z. Association. Busy and exciting because the Association is now extending the series of courses in musculo skeletal medicine started last year. These courses are well designed, comprehensive and integrated. Crucial too, in that continued membership, interest and support in the Association is essential. The educational programme offered cannot be done by a few people, therefore active participation and encouragement from all members is needed.

The financial membership numbers are down a little from the previous year. Perhaps many thought there was little in the Association, once an introductory course was done, so why continue to be members! Well, please read on through this newsletter. Don't let your membership lapse. Show this letter to your practising partners, GP registrar or hospital colleagues. Encourage them to join and attend the courses. New members can contact the Hon. Sec. or write to NZMA direct, by completing the enclosed application form.

Courses

In the future courses will be offered alternating between Christchurch and Auckland. Two of these courses will be offered in the same year.

Course I	Diagnosis and examination of the spine. (plus repetition course)	5 days.
Course II	Extremities and peripheral joints - Diagnosis and therapy (plus repetition course)	5 days
Course III	Therapy of the spine - Mobilisation, neuromuscular therapy (plus repetition course)	5 days
Course IV	Therapy of the spine, including manipulation (plus repetition course)	5 days
Course V, VI	Clinical courses	

The repetition following each major course is an integral part of that course.

In 1988 and 1989, the sequence of courses will be altered temporarily. Those members doing the Diploma of Musculo Skeletal Medicine will be able to cross credit Courses I and II, and vice versa.

1988 Courses

A. Revision course in Auckland. Two weekends, details later. An update and revision is being offered to:

1. Those who have attended the Introductory course in Auckland 1987.
2. Any other member who has done any of the Association's introductory courses.

B. 1. Revision course in Christchurch, over one weekend, for those who attended the Introductory course 1987, in Christchurch.

2. Course III will be run in Christchurch later in the year. Details later.

Please note that those who have attended the revision courses will be given preference to attend the Peripheral Joint, Course II, by Dr Jiri Dvůřák (see below) and will be eligible to attend Course III in Auckland next year.

The Auckland courses should appeal to all members who want to learn newer techniques and is an ideal opportunity to get into the course system. Revision has always been mentioned at previous courses. It is now a reality.

AGM & Pre-Conference Course

The AGM will be held from 4-6 November 1988. The venue has been changed to the Hyatt Hotel in Rotorua, by popular demand, and to accommodate the course. The pre-conference course commences 31 October.

This year we are very pleased to be able to invite Dr Karel Lewit, from Czechoslovakia, to lead the course and be the guest speaker at the conference.

The course will be over 5 days, covering mobilisation and post isometric relaxation therapy. Dr Lewit is widely known for his work and publications in musculoskeletal disorders. It will be an excellent opportunity to see and learn from him in person.

Conference details will be forwarded to you later.

Refresher Courses for Teachers

The teachers of the Association's courses will meet 2-3 times this year to revise manuals, slides etc, and standardise teaching methods. Ten teachers have undergone an intensive training programme taken by Dr J Dvůrák, this year. This group is keen and dedicated and will need other teachers soon.

1988 Courses

Course II Extremities and Peripheral Joint - Diagnosis and Therapy.
February. Auckland.

Lead by Dr Jiri Dvůrák who is keen and willing to come to New Zealand again, just to take this course.

I think that all members have wished that such a course could take place.

In following years Course II will be offered in the correct sequence.

Please note that those members who have attended this year's revision courses, at least, will be given preference to attend. It is hoped that many who have completed a Course III will also attend, so that in a short time many members will have completed Courses I, II and III. We are fortunate in having our courses lead by doctors of such international standing in the field of musculoskeletal medicine.

N.Z. Association of Musculo Skeletal Medicine

A.G.M. & Conference

Rotorua, 4-6 November 1988

and *Pre Conference Course*

Speaker: Dr Karel Lewit

31 October for 5 days.

CONTACT:

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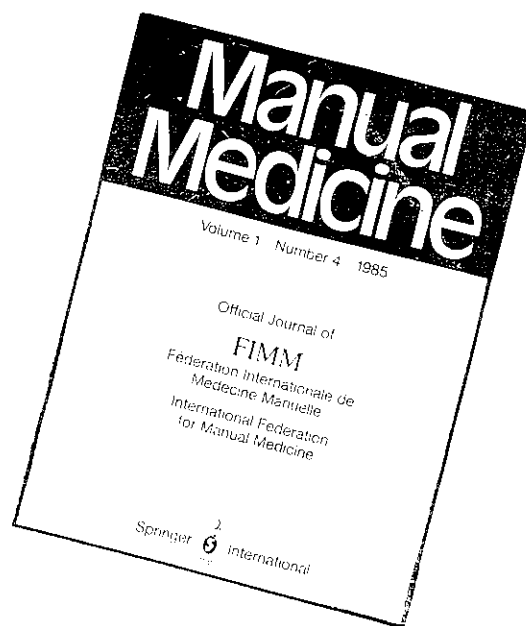
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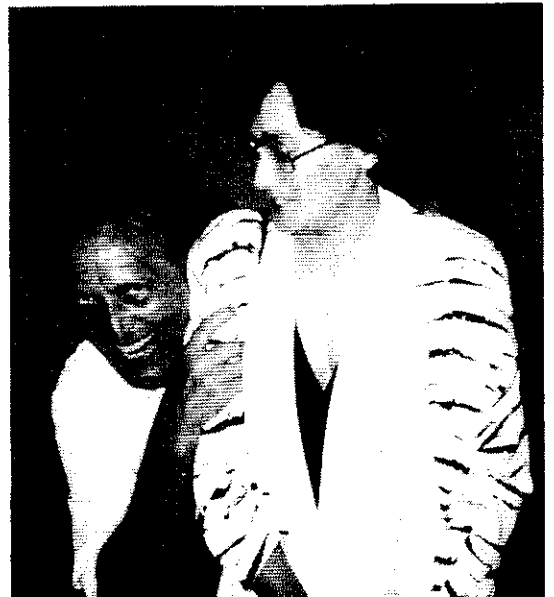
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BULLETIN PICTURE QUIZ

These pictures illustrate the great variety of palpatory techniques demonstrated at the last annual conference in Brisbane. Members are invited to study them and to answer the questions below.



- a) Is it preferable for the subject to be undressed before being palpated?
- b) Is it preferable for the operator to be undressed before beginning palpation?
- c) Does palpation normally make the operator aggressive and the subject submissive?
- d) Would you buy a used car from any of these men?
- e) Should the Fitzgerald Enquiry be informed?



Responses should be forwarded to the Hon. Sec.

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of the**

Australian Association of Musculoskeletal Medicine

to be held in

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on

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Theme: "Injections in Musculoskeletal Medicine"

