

ORTHOPAEDIC PROBLEMS VIEWED IN THE LIGHT OF BIOMECHANICS

by

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The biomechanical laboratory which today forms an integral part of the Gothenburg Department of Orthopaedic Surgery, had its origin 20 years ago in Professor Sten Friberg's clinic at Karolinska Institutet in Stockholm. Later, the laboratory has followed us from Stockholm to Uppsala and again to Gothenburg. We can look back upon its development with satisfaction and gratitude. Professor Friberg's interest in research, his insight into technical problems and his gift for finding ways and means to finance new projects provided an indispensable support at the start. All of us who have been privileged to pursue this attractive subject join in expressing our appreciation and gratitude to Professor Sten Friberg.

One of the main functions of the skeleton is to provide stability, that is, to permit the body weight to be balanced so that a state of mechanical equilibrium can be achieved.

The laws of mechanics governing our planet must apply to biological questions too. It must be assumed that the movements of the body follow these laws. It is, indeed, a long established concept that form and structure of the skeleton are conditioned by the requirements set by the mechanical problems confronting the locomotive organs. Biomechanics is an interplay of given forms and external forces, of organic structure and the law of gravitation.

It may reasonably be assumed that the inner architecture of the skeleton must be the issue of mechanical requirements. Knowledge of the physical properties of different skeletal structures should be helpful in elucidating the processes reflected in strains of various kinds. Determination of the magnitude of the forces acting on different skele-

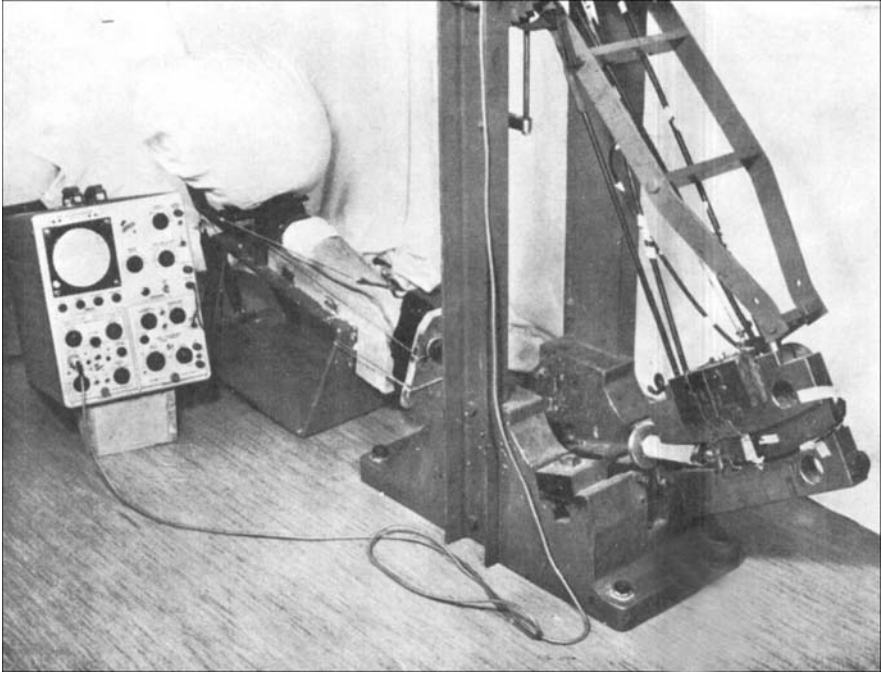


Fig. 1.

Experimental studies on os calcis fractures (*Thorén*). A fresh autopsy specimen is mounted. Muscles action on the foot is produced by pulleys. The foot is hit by a force. An oscilloscope records the stress distribution while the fracture develops.

tal regions under varying conditions should provide additional data of fundamental importance for a correct interpretation of these mechanical processes.

Whereas we possess today a wealth of information about the morphology of the locomotive organs, our knowledge of the biophysical significance of the various elements is considerably scantier. Each movement requires a whole series of operations, in every phase of which a state of mechanical equilibrium is established, determined by the action called into play by a distribution of force. Every external force tends to deform a body. The form assumed by the body is determined by the opposing forces it can muster through its physical properties.

When a skeletal part is placed under stress, it is not only the bone itself which reacts – surrounding structures, such as cartilage, ligaments, capsules, musculature, fasciae, and fluid matter, all join in a concerted effort to distribute the stress so as to achieve a state of equi-

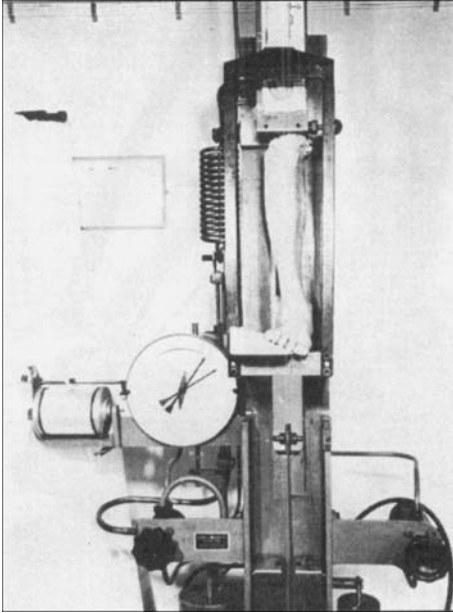


Fig. 2.
Experimental studies on the ankle-
reactions to forces (*Lewis*).

librium. Every mechanical stress, consequently, starts a chain reaction with the mechanical aim of providing relief.

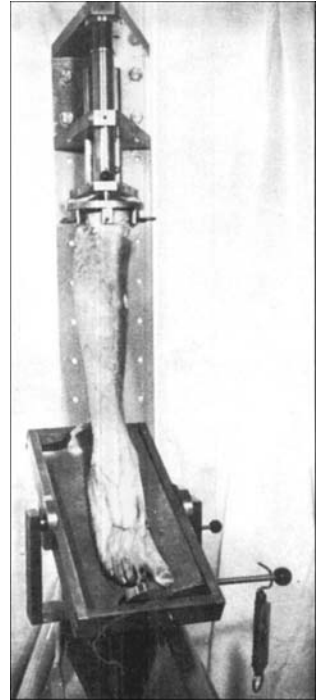
Presupposing this harmonious combination of forces to take place, it must be assumed that it is governed by some form of co-ordinating intelligence. We know today that muscles, capsules, ligaments, and tendons contain various kinds of sensitive terminal organs. Skeletal and cartilaginous tissues were believed to lack this kind of organ. Quite recently such informative organs have also been demonstrated in the trabecular structures of bone (*Miller*). It seems likely, therefore, that a mechanical stress on a skeletal structure elicits a chain of reactions in the surrounding soft tissues, so that this part of the extremity as a whole contributes to the stress distribution required for equilibrium.

Experimental research has shown that the distribution of the strain developed in a skeletal structure subjected to mechanical stress is influenced by muscular forces (*Pauwels, Frankel, Hirsch, among others*). In other words, the distribution of the strain can be directed by the action of the muscles.

In such an interaction governing the transmission of force in the skeleton, with the musculature taking an active part in the distribution of stresses, it seems logical to assume the presence of "stress stimuli" from the skeleton to the muscles. The sensitive terminal organs which

Fig. 3.

Device for testing the ankle reactions to different types of movements under compression.



have been demonstrated in the skeleton may very well form the anatomical contact between the skeleton and the muscular system.

The physical properties of the skeleton vary with age. Moreover, they vary in different skeletal structures in the same human body, depending on the functional requirements of a given skeletal region. The physical properties even vary in closely adjoining parts of the same bone (*Kalén, Forssblad*), indicating that mechanical function is highly dissociated and the transmission of force strictly bound to definite pathways. Certain regions have a greater weight bearing capacity than others (*Hisch & Brodetti*).

The physical properties of cartilage and its role in the transmission of force have prompted additional approaches (*Hirsch, Nachemson*).

Interpretation of the "stress routes" and the way in which they may be influenced is of value to clinical orthopaedics in the search for suitable reconstructive techniques. Arthrodesis is, in fact, one solution to a problem of force transmission. Arthroplasty, the most desirable operation for joint repair, presents problems which as yet cannot be resolved in terms of mechanics. Low friction, good stability and favour-

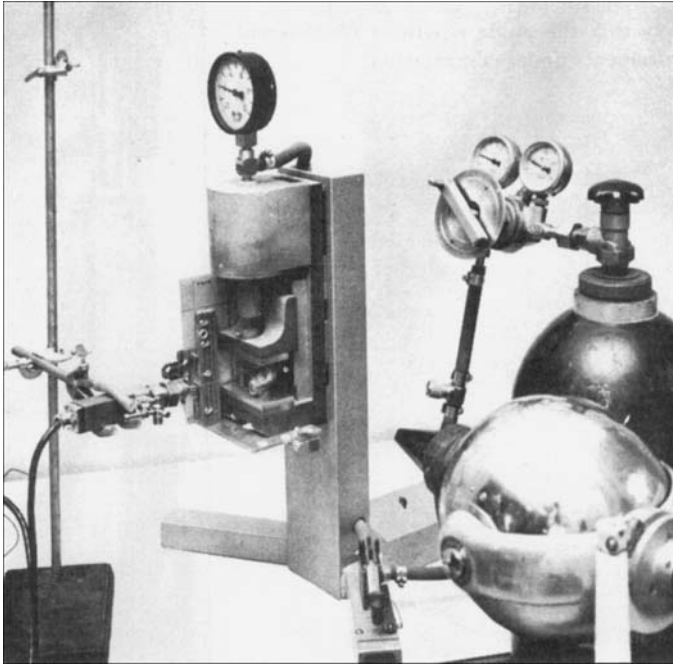


Fig. 4.

Intradiscal pressure measurements (*Nachemson*).

A mechanical-electrical pressure transducer attached to a needle with plastic tubing inserted into a disc. The specimen is in a pneumatic clamp.

able equilibrium conditions are some general desiderata. Osteotomy, myelotomy, fasciotomy and myototomy too, all include a component of force transmission, the nature of which can at present not be analyzed in full detail because we lack methods for recording and checking the effect of these procedures. As yet we are unable to measure strains in bone *in vivo*. This is a goal which should be beyond our reach. We must develop intra-osseous strain receptors – something which the technician may be able to give us.

In addition to the problems of distinct basic research which a bio-mechanical laboratory must include in its program, more palpable objects offer for clinical use. A logical object of study is the mechanism producing common fractures, because such experiments, carried out on fresh autopsy material, may reveal the extent of the injuries and suggest approaches to their management.

The mechanism underlying medial neck fractures (*Frankel*), the

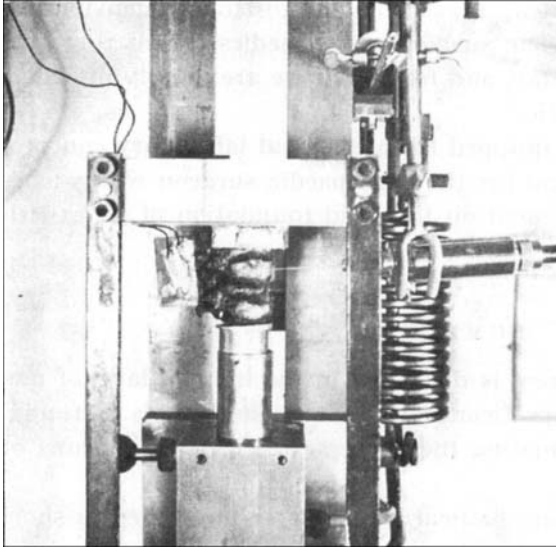


Fig. 5.

Mechanical probl. in lumbar spine fusion (*Rolander*).

Fresh autopsy specimen fused by graft, fixed in plastic/glue grafts. Strain-gauges inserted and connected with measuring bridges. The specimen is tilted under compression and the stability of the construction is checked by electronic picup's in contact with various parts of the vertebral bodies.

various forms of calcaneus fractures (*Thorén*), the injuries involving the ankle joint (*Lewis*) and the nature of vertebral fractures (*Perey*) are some examples of studies inspired by clinical biomechanics. Technical problems of therapeutic interest constitute another logical field of inquiry. Tests can be made to determine the effectiveness of various methods of lumbar osteosynthesis in eliminating intervertebral motion (*Rolander*). Internal fixation of femoral neck fractures still offers numerous problems (*Harvey, Frankel, Rydell, Brodetti*). Altogether, a well equipped laboratory offers ample opportunity for analysis of practical clinical problems.

Prosthetics can no longer function without a biomechanical background. The need for analysis of patterns and systems of motion becomes increasingly clear with every attempt to develop a new type of prosthesis. High speed cameras to register patterns of motion and electromyography to study intermuscular co-ordination have given us new testing methods. At present, we have great expectations of electronic recording of gait.

Biomechanics as an orthopaedic research tool has since the early nineteen-forties enjoyed an ever increasing interest, perhaps mainly due to the new methods made available by technical progress and prompting application to problems of long-standing clinical speculation. During the early years of this century a lively clinical empiricism

produced a wealth of surgical approaches suggested by men tending towards practical results. The surgical orthopaedics which form the mainspring of our work today, and for which we are greatly indebted, now invite further penetration.

We learned that a well equipped biomechanical laboratory can provide a gratifying background for the orthopaedic surgeon who wishes to base his clinical management on the solid foundation of an experimental technical approach.

S U M M A R Y

The musculoskeletal system is discussed in the light of laws of mechanics. The biophysical significance of various elements is of fundamental importance in elucidating the processes reflected in strains of various kinds.

The program for the biomechanical laboratory is presented in short reports of work published and under progress. Basic information about stress and strain analysis on bone and cartilage is mentioned. Mechanical problems in fracture mechanism and reconstructive bone surgery are revealed. Illustrations of experimental set-up's aim to elucidate the way the laboratory works.

R E S U M E

Le système musculo-squelettique est discuté à la lumière des lois de la mécanique. La valeur biophysique des différents éléments est d'une importance fondamentale pour éclaircir les processus qui se reflètent par des tensions de différentes natures.

Le programme du Laboratoire bio-mécanique est présenté dans un court compte rendu des ouvrages publiés et en cours de préparation. Des informations de base concernant l'analyse des effets de la force et de la tension sur les os et les cartilages sont mentionnés. Les problèmes mécaniques du mécanisme des fractures et de la chirurgie reconstructive des os sont indiqués. Des illustrations des expériences effectuées contribuent à montrer la manière dont le Laboratoire travaille.

Z U S A M M E N F A S S U N G

Das Muskel-Skelettsystem wird unter Bezugnahme auf die Gesetze der Mechanik besprochen. Die biophysische Bedeutung verschiedener

Elemente ist von grundlegender Wichtigkeit zur Aufklärung der Prozesse, die sich bei Überbeanspruchung verschiedener Art äussern.

Das Programm des biomechanischen Laboratoriums wird in kurzen Berichten über die bereits veröffentlichten und die im Fortschreiten begriffenen Arbeiten vorgelegt. Grundlegende Erkenntnisse der Analyse von Überbelastung des Knochens und Knorpels werden erwähnt. Mechanische Probleme der Bruchmechanismen und der wiederherstellenden Knochenchirurgie werden aufgezeigt. Illustrationen von experimentellen Einrichtungen bezwecken die Weise, in der das Laboratorium arbeitet, zu erläutern.

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