European Society of Biomechanics

Newsletter

DECEMBER 1997

Editor: *Dr. Patrick J. Prendergast.* Editorial Office: *Department of Mechanical Engineering, Trinity College, Dublin 2, Ireland. Fax: +353.1.6795554 email: pprender@tcd.ie*

Toulouse for "just" clinicians

Leif Ryd, President of the ESB

Lund University, Sweden

The 10th Conference of the ESB is rapidly approaching. Marie-Christine Hobatho and her group are doing a great job in planning the meeting, which will feature a number of novelties such as, for example, a student research award and a pre-course titled "Biomechanics for Clinicians".

At a time when time is increasingly scarce and the number of meetings is spiralling we must ask ourselves: why should we go to the ESB conference in Toulouse. Some may answer that members of a society should attend its meetings, others may think that fraternisation with other engineers under convivial conditions usually is productive and others yet may think that Toulouse is nice in the summer. All reasons are valid but I would like to offer yet a better one: In Toulouse you can discuss with other people than 'just' engineers; you can discuss with clinicians.

Now, questions can only be asked by those who know the problems – to a large extent the clinician

Personally, I believe that the advancement of our age (if we agree that our age is indeed advanced, which is arguable) depends on communication. Modern telecommunication and the Net are marvellous and inexhaustible sources of data. The answer to any question can be obtained. Irritatingly, questions still need to be asked. In the same way that PC's don't write scientific papers by themselves, the Net has to be approached with a question. If you only have the right question, the prize-winning answer is 'just' an experiment or FEM-analysis down the road. Now, questions can only be asked by those who know the problems – to a large extent the clinician. The ESB conferences provide a unique opportunity for engineers and doctors interested in mechanical problems of biology to meet.

Clinicians complain that they no longer understand Biomechanics. The models are too complicated, the methods are impenetrable.

The problem, however, is to get the clinicians to go to Toulouse and that may be no mean feat. Clinicians complain that they no longer understand Biomechanics. The models are too complicated, the methods are impenetrable. For this reason a number of well-known engineers have agreed to run a pre-course for clinicians in Toulouse. There they (the clinicians) will be taken through the paces of the art. So before you (the engineers) arrive there will be a concerted action to provide those who ask with a dictionary to those who answer. So let us all help to persuade clinicians to go to Toulouse. With good organisation and the Garonne by night over some wine, the meeting will be just right.

Optical Metrology in Biomechanics

Maurice Whelan, PhD, Member of the ESB, describes optical measurement techniques and how they may be used to investigate biomechanical systems. Address correspondence to: European Commission Joint Research Centre, Institute for Systems, Informatics and Safety, 21020 Ispra (VA), Italy.
For information about the CEC Joint Research Center see, www.jrc.org

Over the last twenty years optical measurement techniques such as holographic interferometry, Moiré and near-field photogrammetry and have been applied in a number of areas of biomechanics, from *in vitro* experimental stress analysis of implant-bone systems to the study of human gait[1]. Typically optical techniques are non-contact, offer a high level of sensitivity and can provide a full-field quantitative analysis of object deformation, displacement or shape. However, the complexity of more traditional optical metrology setups and the level of expertise required of users has meant that only a small portion of the biomechanics community has had the opportunity to exploit the potential of these techniques.

Only a small portion of the biomechanics community has had the opportunity to exploit the potential of these techniques

The Laser and Applied Optics Group at the JRC has been active for many years in the development of optical metrology tools for application in many different fields. Methods such as holographic interferometry, pulsed laser interferometry, Electronic Speckle Pattern Interferometry (ESPI), laser profilometry and optical fibre sensors have been used to look at problems ranging from the protection of cultural heritage to the in vivo diagnosis of cancer. Recently, attention has focused on the development of compact, robust, user-friendly optical metrology tools for use in biomechanics. In particular, the goal is to produce reliable portable systems that can be easily installed in the field and whose automated operation allows the user to concentrate on the actual test rather than the operation of the optical measurement tool. Recently, compact devices for the measurement of in-plane and out-of-plane deformation of objects based on Electronic Speckle Pattern Interferometry (ESPI) have been demonstrated. These systems show much potential for application in the area of mechanical testing of natural and synthetic biomaterials and may help to provide a more complete experimental data set useful in the definition and validation of numerical models (e.g. finite element analysis).

These systems provide a more complete experimental data set useful in the definition and validation of numerical models (e.g. finite element analysis)

A number of robust and portable ESPI systems have been developed in which specimen loading, optical inspection, image processing and data-acquisition are fully automated. The use of modern optical components (e.g. laser diodes and single-mode optical fibre light-guides) and new-generation image acquisition hardware has meant that advanced optical measurement algorithms for quantitative analysis such as Digital Phase Shifting Interferometry (DSPI) and phase-unwrapping can be implemented in a compact and user-friendly system. Since the custom control software has a high degree of portability (i.e. can be used on different platforms with different hardware) and the optical assembly is modular in design, the cost and effort of putting together a powerful ESPI system has been kept to a minimum.

The full-field deformation information obtained from the ESPI systems can be combined with standard load-deflection data acquisition to assess the actual quality of the mechanical test itself. This approach helps to reduce the amount of spurious experimental data obtained and increases the reliability of any mechanical properties derived. Thus, the increased influence of undesirable experimental artifacts such as excessive end-effects, non-ideal clamping, error in load application and inaccurate displacement or strain measurement can be observed and usually avoided. As an example of the non-contact and full-field aspects the ESPI method, Figure 1 shows a close-up image of a ceramic specimen loaded in compression which has a standard electrical resistance strain-gauge mounted at its center. Each ESPI fringe or contour represents a vertical in-plane displacement of approximately 266 nm. The non-uniformity of the fringes resulted from the reinforcing effect that the epoxy, used to bond the gauge on to the specimen surface, had on the ceramic once it entered its pores.

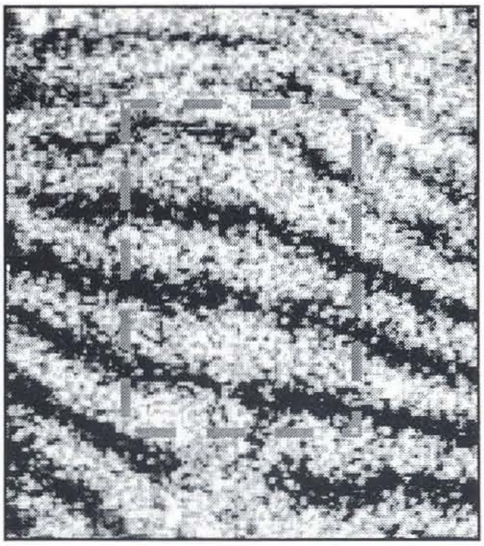


Figure 1: ESPI fringe plot of the vertical displacement field observed on the surface of a ceramic specimen in compression which has a centrally mounted strain-gauge (dashed outline).

With optical metrology techniques like ESPI, complex material behaviour such as non-linearity, non-homogeneity and crack propagation can be studied more effectively in comparison with standard techniques (e.g. strain gauging) since the full deformation field can be observed during the test in real-time. However, only through continuing the development of practical, cost effective metrology tools and by increasing the awareness of the potential of the many techniques available can this technology be more effectively transferred to the biomechanics community.

[1]For a comprehensive review of optical techniques and their application in biomechanics refer to "Optical measurement methods in Biomechanics", edited by J.F. Orr and J.C. Shelton, Chapman & Hall (1997).

Memory Lane

The European Society of Biomechanics as founded at a meeting of 20 scientists from 11 countries, organised in Brussels on May 21, 1976, on the initiative of Dr Franz Burny. The following have served as President of the Society:

J. T. Scales, 1976-82; (Great Britain)

F. Burny, 1982-84; (Belgium)

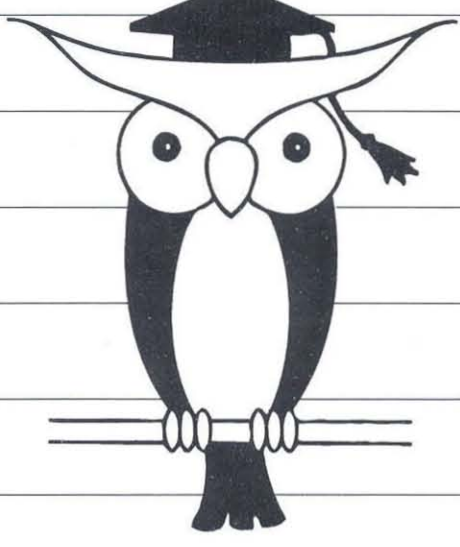
S. Perren, 1984-88; (Switzerland)

R. Huiskes, 1988-90; (The Netherlands)

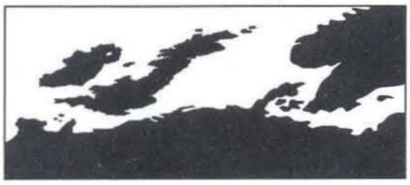
P. S. Walker, 1990-94; (Great Britain)

E. Schneider, 1994-96; (Germany)

L. Ryd, 1996-present. (Sweden)



European Research Forum



Professor Georges Van der Perre, vice-president of the ESB, and Hans Druyts describe a BIOMED I project entitled "Assessment of Bone Quality in Osteoporosis". This project involved ten European countries; Belgium, Switzerland, Czech Republic, Germany, France, Great Britain, Italy, Latvia, The Netherlands, and Poland. As this article shows, it represents a massive effort on the part of the European biomechanics community.

PROJECT LEADER:

J. Dequeker, Arthritis & Metabolic Bone Disease Research Unit, Pellenberg, BE

PARTICIPANTS:

G. Van der Perre, G. Lowet, Biomechanics and Engineering Design, KU Leuven, Leuven, BE (Experimental research co-ordination)

W.B. Stern, Geochemical Laboratory, University of Basel, Basel, CH

P. Rüegsegger, Inst. for Biomech. Eng. & Med. Informatics, Univ. Zürich, Zürich, CH

M. Rakovic, Inst. of Biophysics, 1st Medical Faculty, Charles University, Prague, CZ

D. Felsenberg, Abt. Röntgendiagnostik, Univ. klinik. Benjamin Franklin, Berlin, DE

W. Kalender, Siemens Medical Systems, CTMP, Erlangen, DE

P. Laugier, Laboratoire d'Imagerie Paramétrique, Université Paris VI, Paris, FR

A.M. Laval-Jeantet, Université Paris VII, Paris, FR

M.C. Hobatho, INSERM U305, Centre Hospitalier Hotel Dieu, Toulouse, FR

C. Langton, Dept. of Med. Physics, Univ. of Hull, Princess Royal Hospital, Hull, GB

A. Boyde, Dept. of Anatomy & Develop. Biol., Univ. College London, London, GB

P. Bianco, Dept. of Human, Biopathology, Univ. of Rome La Sapienza, Roma, IT

Yu. Dekhtyar, Dept. of Microelectronics, Riga Technical University, Riga, LV

P. Lips, Dept. of Endocrinology, Free Univ. Hospital, Amsterdam, NL

J. Galas, Inst. of Applied Optics, Optical & Digital Data Processing Lab., Warsaw, PL

A. Sawicki, Nat. Food & Nutrition Inst., Min. Metab. and Bone Dis. Dept., Warsaw, PL

INTRODUCTION:

Osteoporosis is now the most common bone disease of the Western World. It is defined as an age-related increase in the susceptibility to bone fracture, typically at the distal radius, vertebral body and proximal femur. In the European Union as many as 40 million women are affected with an estimated cost of 5 billion ECU annually. Bone mass measurements, despite being important determinants of bone strength, do not satisfactorily predict osteoporotic fracture risk *in vivo.* Clearly more fundamental studies on quality of bone in normal and pathological conditions are necessary in order to improve our knowledge and to allow the development of techniques to screen patients at risk for osteoporotic fractures.

OBJECTIVES AND APPROACHES:

- The first objective is to explore the relationship between bone composition, micro-macrostructure and bone physical properties (material and whole bone), leading to techniques for measurement of physical properties *in vivo.* The ultimate aim is to find, with a multi modality approach, new ways of determining bone strength and fracture resistance.
- The second objective is to assess the role of ultrasound to serve as primary screening tool for osteoporosis, complementary to established ionising radiation based techniques.
- The third objective is to standardise the present commercially available ultrasound systems by creating European reference and calibration phantoms along the lines done in the previous COMAC-BME Quantitative Assessment of Osteoporosis Study.

Sixteen European centres with recognised expertise in assessment of bone, micro-macrostructure, biochemistry and biomechanics concerted their findings on *ex vivo* material. A unique collection of bone tissue samples of 75 cadavers (vertebrae, iliac crest, proximal femur and calcaneus) was prepared in the research centre of the project leader. Bone samples were recruited in the post-mortem room in standardised conditions from subjects of all ages and different pathological conditions. Bone samples have been studied, first by non-destructive techniques as x-ray, QCT (Quantitative Computed Tomography), DXA (Dual X-Ray Absorptiometry), ultrasound, backscattered-electron microscopy, three dimensional imaging and secondly using destructive investigations as histomorphometry, biochemistry, x-ray diffraction and mechanical testing.

A unique collection of bone tissue samples of 75 cadavers (vertebrae, iliac crest, proximal femur and calcaneus) was prepared in the research centre of the project leader.

Mechanical testing was performed on whole bones as well as bone samples, and provides information on stiffness, strength, and energy absorption under well defined loading conditions (Fig. 1). Ultrasound investigation on the reference bone samples was an important aspect of this project, because of the non-invasive nature of this technique, the easy availability and the additional information provided.

SOME RESULTS:

Vertebral compression strength is only partially explained by bone mineral density (r^2=0.65) indicating that geometry and trabecular architecture are also important. Bone mass is more important in determining femoral strength in men than in women, indicating that structure and geometry may play a bigger role in women.

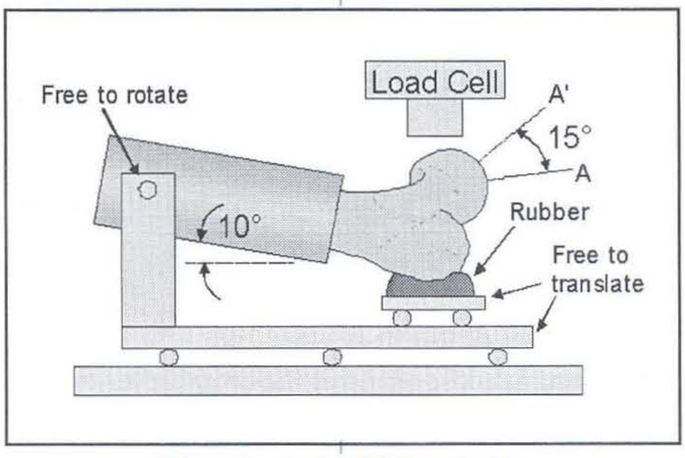


Figure 1: simulated fall on the hip

All DXA BMD values are highly correlated with femoral neck strength. However, trochantric BMD correlates best with strength and should be included in clinical setting. As for QCT measurements good correlations are found between cortical bone area and strength, while cortical BMD is poorly correlated with bone strength. Therefore, cortical area should be included in QCT cortical bone measurements. Femoral neck width and hip axis length account for 21-24% in the variance of bone strength, the neck shaft angle is not significantly correlated with femoral strength. Neck width could be combined with DXA BMD to improve strength prediction.

Ultrasound of the calcaneus has only limited ability to provide information on femoral and vertebral strength and failed to contribute in addition to BMD in predicting L_3 ultimate load and stress.

Reference:

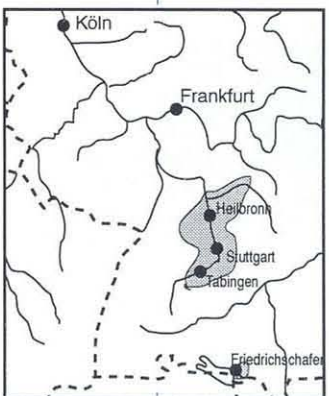
Dequeker J., Assessment of Quality of Bone in Osteoporosis – BIOMED I: Fundamental Study of Relevant Bone, *Clin. Rheumatology*, 1994, 13, Suppl. 1, 7-12.

Editor's note: This is the third contribution in a series reporting on Biomechanics Research funded by the EU. Previous contributions were by Dr. K.E. Tanner (GB) and Professor Ivars Knets (LV).

Biomechanics of Hearing
Euromech 368

A Meeting on the "Biomechanics of Hearing" was held as a EUROMECH Colloquium, at the University of Stuttgart, , Germany, on 10th - 12th, September 1997. Peter Ferris from the Bioengineering Group, Trinity College, Dublin, was there and here is what he has to say....

The aim of the Colloquium was to help form a bridge between acoustical and medical scientists coming from a surgical and audiology background on one hand and mechanical and control engineering background on the other. For successful research in this field, there is need for inter-disciplinary co-operation.



The scientific program consisted of twelve lecture sessions discussing challenging topics ranging from mechanical sound processing, biomechanical aspects of the ear, descriptions of the hearing process using computer models (including finite element models), to cochlear mechanics.

Many of the leading experts in this relatively small and specialised field were present. It was a special honour for me to present our work before such a distinguished international audience.

Each evening a well organised social program saw the participants gather in a more relaxed setting. The agenda for the first evening was a reception at the "International Communication Centre IBZ" of the University of Stuttgart. The highlight of the second evening was a small dinner and wine tasting in a wine cellar in the Rems Valley near Stuttgart.

This was a much livelier occasion as most participants had already finished presenting their work and the prospects of a sore head the following morning didn't perhaps seem so bad.

All in all the meeting was of a very high calibre. Papers will be published in the journal *Audiology and Neuro-Otology* after review. For further information, contact Prof.Dr.Dr. h.c. W. Schiehlen & Dr.-Ing. A. Eiber, Institute B for Mechanics, University of Stuttgart, Pfaffenwaldring 9, D-70550, Stuttgart, Germany.

European Society for Engineering and Medicine

WORKSHOP: BIOMEDICAL RESEARCH AND INDUSTRIAL PARTICIPATION IN EUROPE: TRENDS AND FUTURE

APRIL 27–28, 1998, BRUSSELS

The main goal of this workshop, organized in the Université Catholique de Louvain , is to allow the consortia of the different European Research projects belonging mainly to BIOMED 2 to get more precise information to solve problems linked with the management and exploitation of these projects. The workshop is open to all scientists working in the overlapping area of medicine and technology.

Professor Pierre Rabischong
President of ESEM
Montpellier, FRANCE
ph: +33 4 67 63 27 48
fax: +33 4 67 54 27 29
email: bjboyer101@aol.com

Professor Jos Vander Sloten
General Secretary ESEM
Leuven, BELGIUM
ph: +32 16 327 099
fax: +32 16 327 994
email: jos.vandersloten@mech.kuleuven.ac.be

Impressions of the 10th Conference of the European Society of Biomechanics

Kozaburo Hayashi, Masaso Tanaka, and Hiromichi Fujie, from the Department of Mechanical Engineering, Faculty of Engineering Science, Osaka University, Toyonaka, Osaka 560, Japan, present a perspective on the Leuven Meeting

Fortunately we could attend the 10th Conference of the European Society of Biomechanics which was held in Leuven, Belgium, on 28-31 August, 1996. This is a short report of the Conference, including our impressions.

The scientific programme covered almost all areas of biomechanics research, including cell and soft tissue biomechanics, cardiovascular biomechanics, bone biomechanics and remodelling, joint biomechanics, artificial limbs and joints, biomaterials and implants, and human kinematics and dynamics. Many up-to-date and interesting papers were presented at the Conference.

Even with the most microscopic model, the simulation algorithm cannot describe the real mechanism of remodelling at this moment.

One of the most notable events was an open forum entitled "The Biomechanics Challenge" which was broadcast live in EU countries as a TV programme through the EuroPACE 2000 trans-European network. Professors F. Kajiya from Japan, B. Nigg from Canada and M. H. Pope from USA joined the forum through satellite internetwork media. We are sure that the forum successfully attracted many of the public to biomechanics and also motivated us to challenge new fields of biomechanics.

This might be a common understanding; models are validated from phenomenological viewpoints and the validation depends on scale

Many sessions were organised for bone biomechanics, which include special symposia on 'Ultrasound Research in Bone', 'Bone Architecture and the Competence of Bone' and 'Validation of Computer Simulations of Bone Adaptation'. Above all, topics of bone remodelling seemed to be one of the highlights of the Conference. Several of these sessions were arranged in parallel, and it was not easy to select sessions for one of the authors (M.T.) to attend, because there were many interesting papers.

There were quite a number of papers on the three-dimensional reconstruction of micro structure of cancellous bone using non-invasive tools such as micro-computed tomography and high-resolution magnetic resonance imaging. Realistically reconstructed micro structures are useful for the evaluation of bone quality of an individual person. The usefulness of morphological measures such as the width, spacing and structural connectivity of trabecular bone was discussed for additional parameters to a more primitive one, that is, bone volume. These parameters were also discussed in relation to the anisotropic mechanical properties of bone which are obtained from in vitro tests and finite element analyses based on reconstructed structural morphology. Several of these studies are being carried out as a part of the EU joint project BIOMED 1 "Assessment of Bone Quality in Osteoporosis", which may be a reason for the involvement of many scientists in this particular subject.

In the structural regulation and adaptation of bone, two topics were of interest. One of them was flow/ transportation phenomenon in the bone, and the role of interstitial fluid flow and shear strain caused by tissue deformation in bone remodelling was discussed in a wide range from cell biology to numerical simulation. The other topic was on the validation of mathematical models of bone remodelling. The models discussed at the Conference covered a wide range of scale, from cortical bone to trabecular bone, and from macroscopic to microscopic levels. Even with the most microscopic model, the simulation algorithm cannot describe the real mechanism of remodelling at this moment. This might be a common understanding; models are validated from phenomenological viewpoints and the validation depends on scale. It would be characteristic to model-based simulation approach.

Sessions on joint biomechanics and soft tissue biomechanics at which one of the authors (H.F.) spent much time were well attended, and many interesting papers of high quality were presented, followed by hot discussion. The majority of the papers were more or less on the application of basic mechanical engineering to the studies of joint function and the mechanical properties of joint tissues. Some of these studies were directly related to clinical problems, but the others were not and were mostly on the mathematical description of joint mechanics and mechanical properties of tissue.

There were only three oral sessions for cardiovascular mechanics, which was similar to the 8th Conference held in Rome in 1992 (K.H. one of the authors). This was very different from similar conferences held in Japan and the U.S.A., where many sessions on cardiac mechanics, hemodynamics, vascular mechanics and related topics are organised. Although there were not so many participants in the sessions of cardiovascular biomechanics, many interesting and important papers were presented, followed by very heated discussion. In particular, the audience enjoyed enthusiastic discussion on the residual stress in the arterial wall and the remodelling of wall in growing and hypertensive animals. These subjects are related to the optimal operation and functional adaptation of biological tissues, and have been rather extensively studied for the past several years. We know that there are many active cardiovascular biomechanicians in European countries. Why don't they attend the ESB Conferences? Or, why doesn't the ESB invite them enthusiastically? It is common sense that interdisciplinary approach and viewpoint are indispensable for the progress of science. For example, Orthopaedic biomechanicians can obtain a lot of important knowledge and information from cardiovascular biomechanics and vice versa.

Orthopaedic biomechanicians can obtain a lot of important knowledge and information from cardiovascular biomechanics and vice-versa

Finally, we would like to heartily congratulate Prof. Van der Perre and his colleagues on the great success of ESB96. We really enjoyed the Conference. Thank you very much and we look forward to getting together again at the next ESB Conference in Toulouse, as well as at the Third World Congress of biomechanics in Sapporo, Japan, both held in 1998.

Teaching Biomechanics to Physiotherapists

The Bioengineering Group in Trinity College are responsible for lecturing a module on Biomechanics on the M.Sc. course in physiotherapy. What do physiotherapists want to learn from Biomechanics? This brief note describes some experiences with the course.

When I was asked to prepare a lecture course on Biomechanics for Physiotherapists, the topics suggested by the course organisers were: A: Basic Concepts of Mechanics; B: Musculoskeletal Biomechanics; C: Gait Analysis; D: Rehabilitation Biomechanics, and E: Biomechancis of Bone. Despite having done university physics courses, many concepts are only partially understood; concepts such as 'addition of forces' or 'gravitation'. For me, lecturing this basic physics was the most challenging part of the course; how does one best answer the question "What is the difference between a torque, a moment, and a couple?". In the Musculoskeletal Biomechanics part, we dealt with concepts such as the instant centre of rotation of joints and stability of joints which do not prove difficult for the students. Physiotherapists have an excellent appreciation for joint mechanics, ranges of motion and so forth; they tend to trust intuition rather than calculations and tend to be frustrated by the simplification needed for mathematical modelling. The part on the Biomechanics of Bone allowed me to introduce elements of our own research. Students were particularly interested in the determinants of bone strength and the fact that this could be measured and a function of bone mineral density and porosity.

It seems that many physiotherapists see the advantages of 'knowing some Biomechanics'; however the lack of a background in 'ordinary' mechanics makes it difficult if not impossible to tackle problems of practical interest, such as spinal mechanics for example. In conclusion, I would recommend teaching Biomechanics to physiotherapists as a rewarding and challenging experience.

P.J. Prendergast