Orthopaedic and Sports physical therapy

Edited by

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VOLUME TWO

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with **819** *illustrations*

LINE DRAWINGS BY JODY FULKS, M.S.
COVER ILLUSTRATION BY JACK TANDY

The C.V. Mosby Company

ST. LOUIS • TORONTO • PRINCETON 1985

MOSBY

A TRADITION OF PUBLISHING EXCELLENCE

Editor: Rosa L. Kasper
Assistant editor: Connie Leinicke
Manuscript editor: Helen C. Hudlin
Book design: Jeanne Genz
Cover design: Kathy Johnson
Production: Jeanne A. Gulledge, Susan Trail

THREE VOLUMES

Printed in the United States of America

The C.V. Mosby Company
11830 Westline Industrial Drive, St. Louis, Missouri 63146

Library of Congress Cataloging in Publication Data
Main entry under title:

Orthopaedic and sports physical therapy.

(Physical therapy; v. 2)
Bibliography: p.
Includes index.
1. Physical therapy. 2. Orthopedia. 3. Sports medicine. I. Gould, James A. II. Davies, George J. III. Series: Physical therapy (Saint Louis, Mo.); v. 3. [DNLM: 1. Orthopedics. 2. Physical Therapy. 3. Sports Medicine. WB 460 077]
RD736.P47078 1984 615.8′2 84-16570
ISBN 0-8016-2513-0

C/VH/VH 9 8 7 6 5 4 3 2 1 02/A/224

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To my parents, Don and Dorothy Gould, who raised and guided me;
to my in-laws, Henry and Dorothy Keller, who supported the effort,
and most of all to my most ardent supporters, my wife,
Deborah, and my daughter, Kimberly.

JAG

To my family and particularly to my wife, Carol, and sons,
Scott and Steven, for their loving support.

GJD

PREFACE

In recent years individuals in our society have developed a greater interest in their own health and are making lifestyle changes that include increased participation in fitness activities as well as leisure sports. Concomitant with this increase in athletic activities has come an epidemic increase in related orthopaedic and sports injuries. Over the past decade the physical therapy profession has seen the advent of a systematic approach to the treatment of these musculoskeletal problems through the evolution of orthopaedic and sports physical therapeutic procedures based on researched documentation.

This book is written for physical therapy students as well as practitioners specializing in orthopaedic and sports physical therapy. However, it also contains a depth of information regarding the present status of physical treatment of orthopaedic and sports-related dysfunctions that would be a valuable reference for physicians, osteopaths, chiropractors, podiatrists, and other allied health practitioners.

The book is divided into five major sections. Part one, Basic Sciences: Musculoskeletal System, presents discussions of the mechanical properties of bone, afferent neurobiology of the joint, and basic biomechanics related to orthopaedic and sports concerns.

Part two, Trauma, describes the inflammatory response of the synovial joint structures to trauma and discusses fracture stabilization and healing. Also included is a chapter on muscle-tendon–unit injuries.

Part three, Examination, Rehabilitation, and Prevention, offers a complete overview of the role of orthopaedic and sports physical therapy in client care. The key components in the practice of orthopaedic and sports physical therapy are discussed in detail. Chapters include evaluation of musculoskeletal disorders, rehabilitation concepts, physical agents, passive orthopaedic manual therapy, active-resistive training, and conditioning programs as well as lower extremity and spinal immobilization devices.

Part four, Regional Considerations, presents the anatomy, examination, testing, and treatment techniques for each part of the musculoskeletal system. The anatomical review is offered as a focusing device for the primary topic of each chapter—the examination process. The examination plans demonstrate how to develop a subjective and objective data base for subsequent treatment programs.

Part five, Sports Physical Therapy, explores preseason screening and the musculoskeletal problems that may accompany adolescent participation in sports. Many factors related to sports injuries are also discussed in this part as well as in the preceding sections.

Various features of this book make it particularly useful as a textbook for physical therapy students in the areas of orthopaedics and sports as well as a valuable reference for the practicing clinician. Each chapter is designed to stand independently for quick, complete reference to an area or topic. However, to gain a better understanding of the scope of orthopaedic and sports physical therapy practice, one should review the entire book.

Since clients with orthopaedic injuries frequently require neurological and cardiopulmonary intervention, we have provided a detailed index to Volume One, *Cardiopulmonary Physical Therapy,* and Volume Three, *Neurological Rehabilitation*. We hope that students and practitioners use the foundation offered in these three volumes to explore new frontiers in the practice of physical therapy and rehabilitation.

As clinicians, educators, and researchers, we believe that this book will provide a comprehensive source of information on the current state of the art in orthopaedic and sports-related physical therapeutic procedures. Our hope is that it will facilitate more effective management of clients with orthopaedic and sports dysfunctions.

Any book, particularly one that blends the latest scientific and clinical information into one source, is a tremendous undertaking. Therefore we would like to thank and extend our appreciation to the many people who have contributed to and supported the completion of this book.

We would like initially to thank all the gifted clinicians, educators, and researchers who have taken the time to share their contributions with all of us.

Our special thanks go to the thousands of clients who

have taught us, shared with us, and improved because of us.

Our most important thanks are extended to our most important support—our families: Deborah and Kimberly Gould and Carol, Scott, and Steven Davies.

James A. Gould III
George J. Davies

CONTENTS

PART FIVE
Sports physical therapy

PART ONE

BASIC SCIENCES: MUSCULOSKELETAL SYSTEM

1

CHERYL L. RIEGGER

Mechanical properties of bone

Bone is a dynamically adaptable material that continually undergoes subtle remodeling. This fact is the key to understanding the mechanical properties and behavior of bone.[56] There are seven categories of bone.[56,67]

1. Long bones are tubular in shape—usually longer than they are wide—with a shaft or body and two articular ends, which are either convex or concave. The shaft usually contains a hollow center, the medullary cavity.
2. Short bones, consisting of the carpals and tarsals, are cuboidal. Of their six surfaces, four or less are articular and two or more serve as attachment sites for tendons and ligaments or entry sites for blood vessels.
3. Flat bones are formed by two plates of compact bone with cancellous bone and marrow located centrally. The skull, sternum, and scapula are examples.
4. Irregular bones, such as the facial bones and vertebrae, are usually composed of various nonuniform shapes.
5. Pneumatic bone, such as the mastoid part of the temporal bone, contain air cells or sinuses.
6. Sesamoid bones are round or oval bones located within tendons. They not only protect the tendon but also increase the mechanical advantage of the muscle involved by increasing the angle of application at the muscle attachment site. Examples of sesamoid bones are the patella and the bones connected to the flexor pollicis brevis and flexor hallucis brevis.
7. Accessory or supernumerary bones develop when an extra ossification center appears in, or a usually occurring ossification center fails to fuse with, the main part of the bone.

The main functions of bones are to provide support for the body, to facilitate joint movement, to produce red blood cells (including some lymphocytes, granulocytic white blood cells, and platelets), to protect various body structures and organs, and to store calcium, phosphorus, and magnesium salts.

MECHANICAL PROPERTIES OF MATERIALS

External forces acting on tissues, as well as other structures, can be defined in mechanical terms. Such forces cause internal reactions within a structure. These internal reactions can be expressed in many forms, such as load, deformation, stress (σ) or load/unit area, and strain (ϵ) or the percentage of deformation occurring within a structure. Units of measure for force, deformation, stress, and strain are listed in Table 1-1. Types of stresses and strains are listed in Table 1-2.

Tension is generated in response to equal and opposite external loads, which tend to pull a structure apart. The structure tends to elongate and tensile stress and strain result. Maximal tensile stress occurs on a plane perpendicular to the applied load; that is, if stresses were assessed on a plane other than a perpendicular one, a reduced tensile stress would occur (Fig. 1-1).

External loads equally applied on opposite surfaces of a structure produce compression and tend to shorten and widen a structure, resulting in compressive stress and strain. Maximal compressive stress also occurs on a plane perpendicular to the applied load. These stresses represent resistance to crushing loads (Fig. 1-2).

Shear stresses occur when equal but *not* directly opposite loads are applied to opposing surfaces or structures. Normal shear strain is a linear deformation that occurs as molecules move past each other (Fig. 1-3). Shear stresses and strains result when both tensile and compressive loads are applied to a structure. At any point within the structure, tension and compression are maximal in two orthogonal planes and these maxima are called the principal stresses. At the same point, the shear stress and strain are zero in the direction of the principal stresses and maximal in a plane at a 45-degree angle to the principal stresses (Fig. 1-4). Angular shear strain results when shear stresses

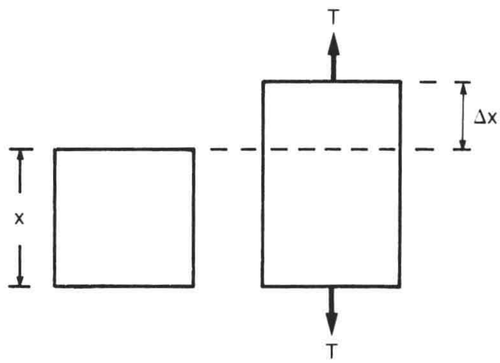
I would like to thank Dr. Christopher Ruff, for guidance in the development of this paper, and my mentor, Dr. Whitney Powers. My thanks also go to Ms. Debbie Kinsella, Mrs. Kay Castignetti, Ms. Nancy O'Hare, and Mr. Barry Kurth for their typing and technical assistance.

Table 1-1. Units of measure (examples)

Force	Deformation	Stress	Strain
Pound Kilogram Newton (N) (A newton is 1 m-kg/sec^2 and is the force which, when applied to a mass of 1 kg, gives an acceleration of 1 m/sec^2)	Millimeter Centimeter Inch	Pounds/inch^2 Pascal (Pa) (A pascal is 1 N/m^2 and is the pressure produced by the force of 1 N applied uniformly over an area of 1 m^2) Megapascal (million) (MPa) Gigapascal (billion) (GPa)	Percentage

Table 1-2. Types of stresses and strains

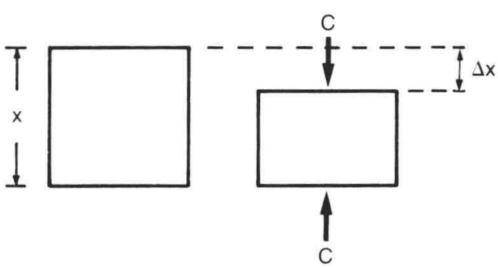
Reaction	Symbol	Method of determination
Tensile stress	$T\sigma$	Force/unit area
Tensile strain	$T\epsilon$	Increase in length/original length
Compressive stress	$C\sigma$	Force/unit area
Compressive strain	$C\epsilon$	Decrease in length/original length
Shear stress	$\tau\sigma$	Force/unit area
Shear strain—normal	$\tau\epsilon_\eta$	Deformation in length/original length
Shear strain—angular	$\tau\epsilon_\sphericalangle$	Angular deformation/original length



$$T\sigma = \frac{T}{\text{Area over which T is applied}}$$

$$T\epsilon = \frac{\Delta x}{x}$$

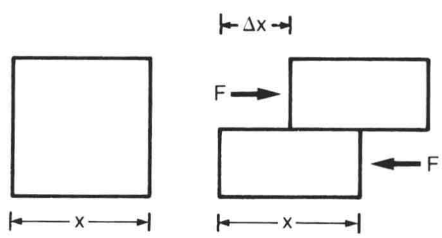
Fig. 1-1. Tensile stress and strain.



$$C\sigma = \frac{C}{\text{Area over which C is applied}}$$

$$C\epsilon = \frac{\Delta x}{x}$$

Fig. 1-2. Compressive stress and strain.



$$\tau\sigma = \frac{F}{\text{Area over which F is applied}}$$

$$\tau\epsilon_\eta = \frac{\Delta x}{x}$$

Fig.1-3. Shear stress and strain.

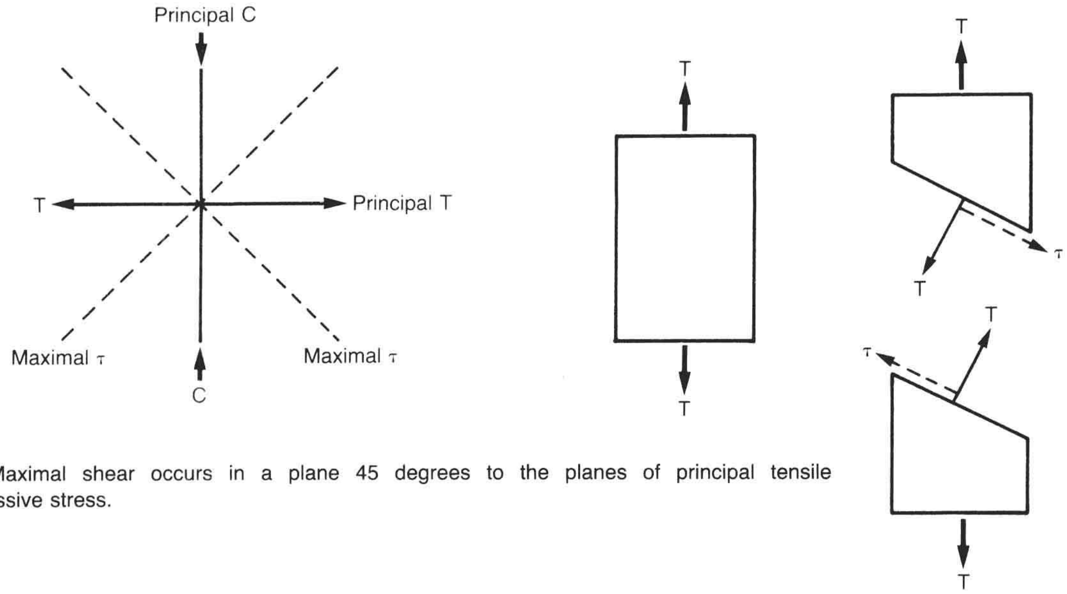


Fig. 1-4. Maximal shear occurs in a plane 45 degrees to the planes of principal tensile and compressive stress.

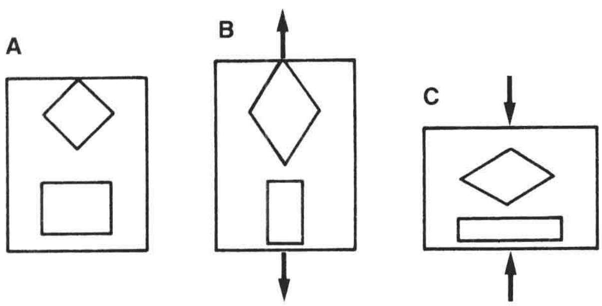


Fig. 1-5. Angular deformation occurs in a structure because shear strain is caused when loading in tension or compression occurs. The unloaded condition, **A,** can be compared to tensile loading, **B,** and compressive loading, **C,** with the resultant deformation in each case.

and strains are caused by tensile or compressive stresses (Fig. 1-5).

The strength of a material—as defined by the area under the load-deformation curve [energy storage] or by the ultimate failure point—and its stiffness—as defined by the load/deformation ratio or slope in the curve in the region of elastic deformation—can easily be studied by drawing a load-deformation curve for that material. However, for comparison of different materials, it is necessary to standardize loads as loads/unit area and deformations as deformations/unit length or percent of deformation. The result is a stress-strain curve.[35] Many important measurements can be determined directly from this curve[10,35,72] (Fig. 1-6). The measurements that can be determined include:

1. Strength—the area under the load-deformation curve or the stress-strain curve area defined by the ultimate failure point.
2. Yield point—that point (Y) at which the material no longer reacts elastically; that is, some deformation is maintained after the release of the load.
3. Ultimate failure point—that point (U) where ultimate failure occurs.
4. Stiffness (modulus of elasticity, Young's modulus, E)—the slope of the elastic portion of the stress-strain curve for tensile or compressive loads, σ/ϵ. For an elastic material or a material loaded within an elastic range, stress and strain are linearly related such that stress = E strain (Hooke's law).
5. Shear modulus of elasticity—the slope of the elastic portion of the stress-strain curve for shear loads or, sometimes, the slope in the initial portion of the torque-angular deformation curve, τ/ϵ.
6. Ultimate stress—a ratio that can be expressed as load at failure/initial area of the cross section of the material = the stress at the point of failure.
7. Ultimate strain—the strain at the point of failure.

Materials are either ductile or brittle or some combination of the two, depending on the amount of deformation they can withstand before failure.[35] A ductile material de-

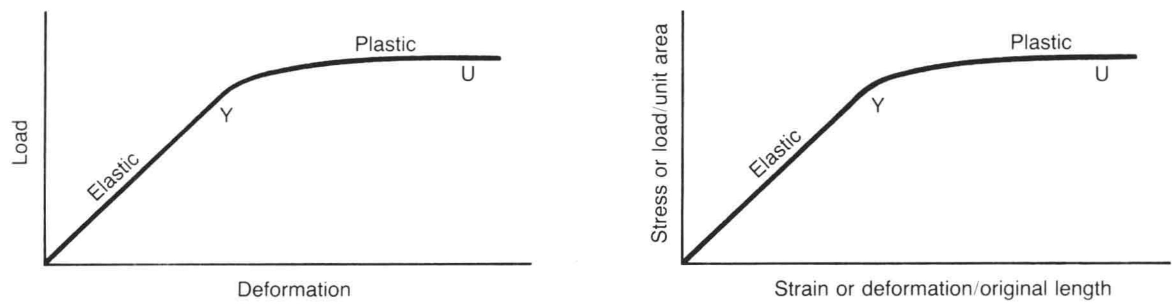


Fig. 1-6. Load-deformation and stress-strain curves.

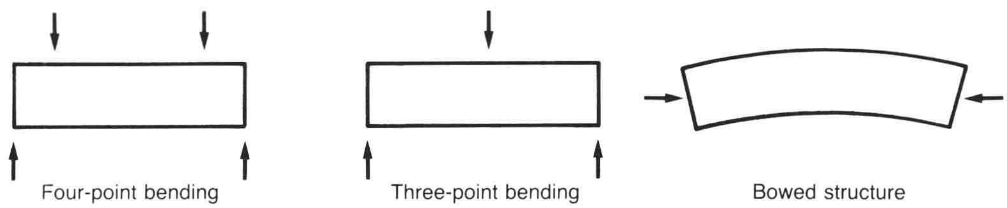


Fig. 1-7. Four-point bending, three-point bending, and axial loading of a bowed structure.

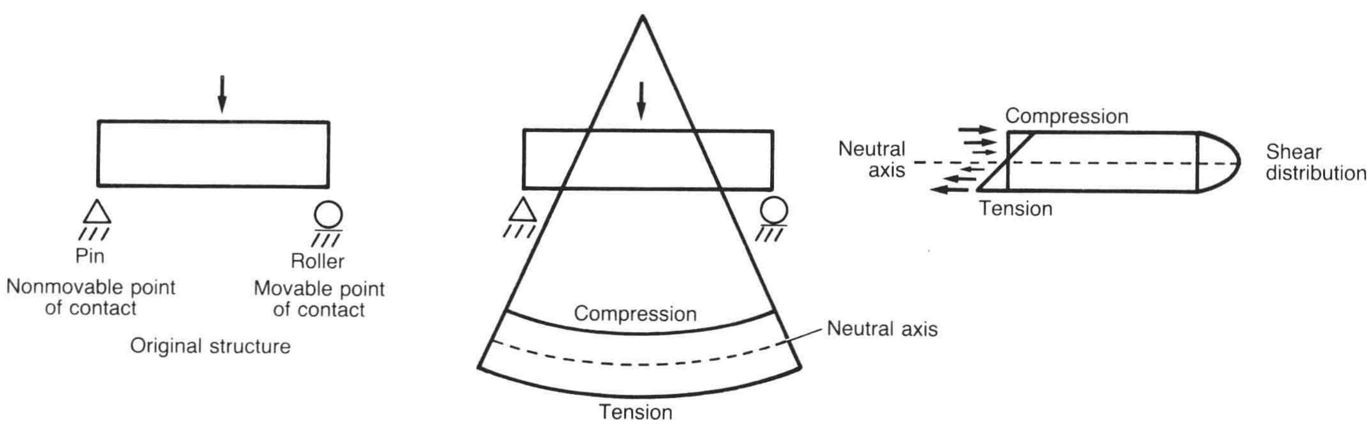


Fig. 1-8. Bending results in tensile, compressive, and shear stresses and strains.