Newsletter

Prosthetics and Orthotics Clinic

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Rehabilitation Engineering and Prosthetics/Orthotics

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The words "Rehabilitation Engineering" are now commonly used to mean a paramedical practice which in its job characteristics and their demands, in the basic technical background needed, in its high activity level, and in its human service slant, is an extrapolation of professional prosthetics and orthotics. Prosthetics and orthotics are in fact very significant components.

Rehabilitation engineering is defined as that broad discipline having as its ultimate objective the *application* of technology to enhance life's quality for the disabled. It includes subsidiary goals in research, development and education. But one doesn't need to be an engineer to *practice* rehabilitation engineering!

With the recent advances in technical aids, prosthetics and orthotics included, there has been increasing need for those who currently serve the disabled with technology to expand the range of their commitment requiring a persistent demand for more knowledge. At the same time, there are counterpressures:—the potentially harmful low rates of increase in the numbers of practitioners. Fewer people are trying to do more while also needing more information for what they do. The effects that Government budget restraints will produce in this situation are difficult to predict, but clearly seen is that the pressures will be greater, that there will be real need for increased efficiency in all parts of society and more so for us committed to the delivery of high quality service to the disabled: increased productivity and more knowledge are conjointly required.

Much of what rehabilitation engineering means in real practice is the selection of devices, the making of special systems, or the design of environments, and then the delivery of these, customizing them even further when necessary, and applying them to assist the disabled. Demanded is the achievement of independence through function and/or access with both comfort and control maximized. Training of the client is essential. These efforts are effected in a precise and deliberate process with full understanding of the patterns of disability presented and a substantial awareness of the personal wishes of the disabled person being served (and his/her family).

Rehabilitation engineering includes aids fitted directly to the client as in prosthetics and orthotics, tools such as communication devices, and adaptations to environment, to work sites, to the home, or to the vehicles used to reach one or the other or to those mobility devices operated within an environment. Some of the technical aids may be very simple in design; most of those which are custom-made require biomechanically sound, creative, and often inventive approaches. The simplest may require the most creativity.

In the rehabilitation engineering applications process, in supporting the physician's role in prescription or in the selection of aids and then in their application, the knowledgeable and interested prosthetist, orthotist, and therapist (physical, occupational, speech) can play the key roles. Especially *productive* and *cost effective* is the involvement of the skilled technician, an essential member of the rehabilitation engineering team. The team concept is crucial in that the knowledge needed comes out of the sharing of training and experience—and the creativity sought can usually come from the synergism in the group, especially including the client. The actual "making" although involving all to various degrees becomes the special province of the technician, with the "fitting" itself being a product of the team. The required contribution to benefit the patient will be a scenario of analysis and synthesis, idea and response, search and research, give and take, and then plain work.

That which is rehabilitation engineering has been performed for many years, before it became stylish to use this

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expression to represent a special technology. But there is now in place an acceleration in the development of new technology in products and processes, many so recent that they are not known to members of the rehabilitation team who received preparatory training or post-graduate courses years earlier. Even now the newer information needed is not obtained in structured formats. Pathways should be constructed for each member of the team to broaden his/her own discipline to include constantly updated knowledge about all technology necessary for his/her personal professional contribution to the rehabilitation engineering team. And not to be overlooked is that the payers for services need to be instructed on the cost benefits of rehabilitation engineering.

We recommend that these professionals (the prosthetist, orthotist, and therapist) have their own societies' publications and conferences include the information about the advance in rehabilitation engineering. They should also participate in those societies which meld the team, the *Rehabilitation Engineering Society of North America* and the *International Society for Prosthetics and Orthotics*, thereby advancing the practice of rehabilitation engineering through contacts with the other team members. Special seminars need to be structured for the 3rd party payers.

In the team, or even in the individual practices, the added knowledge about rehabilitation engineering aids can only benefit. If the prosthetist or orthotist fitting a patient with an *upper-limb* deficit relates his fitting in part to the vehicle controls the disabled person may need to use, shouldn't he or she be knowledgeable about such controls and their installation? Beyond that, shouldn't both (prosthesis or orthosis *and control*) be "installed" under such professional supervision? Yet still, in this decade of rapidly advancing technology and of certification of those who dispense it, ordinary automobile repair garages install hand controls for licensed vehicles for disabled drivers. Why not the orthotist or prosthetist overseeing his/her technician?

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There are often frustrating limits to the mobility which can be provided in lower limb orthotic or prosthetic care. Under what circumstances does one use a wheelchair as a supplement or as a last resort? How is it selected? In what way should it be modified if at all? What kind of buttock and trunk support are required? Here the prosthetist, the orthotist, and the therapist should be involved for aren't these the professionals who can be and should be closely associated with wheelchair prescription and modification? In a national workshop held in 1978, WHEELCHAIR I,* mention was repeatedly made about the need for a "wheelchairist", a person to be concerned exclusively with wheelchair prescription and fitting. If prosthetists, orthotists, and therapists are indeed responsible for other aids for mobility, why not then the wheelchair? Isn't a functioning rehabilitation engineering team the "wheelchairist" sought?

From the clinic team setting or from the counselor's desk, the usual site for the final selection and customization of technical aids and then their application is not unlike a prosthetics/orthotics laboratory, there blessed with talented technician support. In a recent paper,** we recommended that the prosthetics/orthotics profession develop the practice of rehabilitation engineering:

"Recommended is that prosthetics and orthotics, with their foundation in clinical technology, constitute the basis for the establishment and certification of a broadly based rehabilitation engineering capability in the United States. Indeed, it would be well for prosthetists and orthotists to start expanding their scope to include the other technical aids in rehabilitation engineering and in collaboration with other members of the rehabilitation team, especially the orthopedic surgeon, provide the means for a wider coverage in the delivery of technology to restore independence and function to many handicapped individuals who are not now receiving the full, broad spectrum services they deserve."

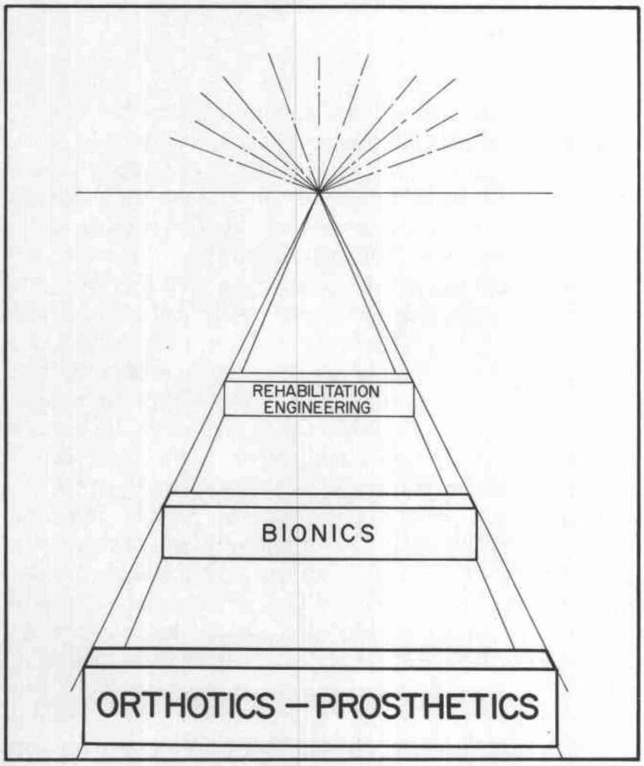
Is there then really need for the engineer, the graduate of a formal engineering curriculum to be the *applier*, the "clinical" practitioner of rehabilitation engineering? The rehabilitation *engineer* has a role: in design, development, research, and perhaps in management. The prosthetist, orthotist and therapist especially with technician support, as a team and as individuals can and should respond to the total technical needs of the patients presented to them; rehabilitation engineers should identify with the other (consulting) members of the medical-technical professional structure in the overall rehabilitation effort. To be called on only in the case of *special*, more complex problems, the engineer should be mostly involved in leading generalized design and development efforts, these to include others of the team as well.

Total need, as the prosthetist, orthotist, and therapist well know, includes "tender loving care," this in the past demonstrated by the experiences of these professionals in analyzing then defining the problems of the disabled. For patients with the severer disabilities, those requiring broader rehabilitation engineering efforts, good practice requires more of such empathic yet deliberate reasoning to seek solutions: devices which yield function in a real sense and are more than just tolerated, used for their novelty, or accepted to please someone else. Seating, wheelchair designs, licensed vehicle modifications, electrical stimulation for pain relief or function, and home and job modifications are all parts of an armamentarium which spans the spectrum from modifications to the shoe to those to the motorcar, for mobility; from a mouth stick to a robotic system, for independent "prehensile" function; from a simple word-display board to synthetic speech, for communciation.

Then, do we really need to cultivate large numbers of graduate engineers for rehabilitation engineering practices (other than for the employment of some smaller number in research and development)? Yes, if the prosthetist/orthotist does not accept the alternative recommended: proper management of his/her practice integrating it with those of other team members and with the very significant role of their skilled technicians who become key constituents in that practice.

Apparently some prosthetists and orthotists see an expanding future. The excellent document describing the professions of prosthetics and orthotics and recently published by the American Academy of Orthotists and Prosthetists***refers to the directions being taken by its professions, based for now on "bionics" referring specifically to automatic control of knee function and myoelectric control of powered upper-limb prostheses. These are presented as steps toward encompassing more and more technology, components of a rehabilitation engineering commitment. In fact the logo of this publication (shown here) presents the transition from orthotics and prosthetics to rehabilitation engineering over a natural pathway (or track) for growth.

The essential initiatives now have to come from the current practitioners. In fact they could also abdicate their "clinical" role to the rehabilitation engineering equipment dealers!



*Moss Rehabilitation Hospital (REC) *Wheelchair I*; Report of a Workshop sponsored by RSA and VAPC, Dec. 6-8, 1977, Philadelphia, Pa.

**Staros, A. and G. Rubin, *The Orthopedic Surgeon and Rehabilitation Engineering* in Orthopedics, March/April 1978, Volume 1/Number 2, Charles B. Slack, Inc., Thorofare, N.J.

***The Academy brochure can be ordered from the National Office for $1.25 each.

Meetings and Events

Please notify the National Office immediately concerning additional meeting dates. It is important to get meeting notices in as early as possible. In the case of Regional Meetings, check with the National Office prior to confirming dates to avoid conflicts in scheduling.

1981, October 27—November 1, AOPA National Assembly, Sahara Hotel, Las Vegas, Nevada.

1981, November 20—21, AAOP California Seminar Workshop, Pasadena, California.

1981, December 9—12, AAOS Seminar, Sheraton, Miami Beach, Florida.

1981, December 12—13, AAOP Seminar, Sheraton, Miami Beach, Florida.

1982, February 18—20, AAOP Annual Meeting and Round-up Seminar, Royal Sonesta Hotel, New Orleans, Louisiana.

1982, April 16—17, AOPA Region I Meeting, Marriott Hotel, Worchester, Massachusetts.

1982, April 29—May 2, AOPA Regions VII and VIII Combined Meeting, Alamada Plaza, Kansas City, Missouri (Tentative).

1982, May 6—9, AOPA Region IV Meeting, Radisson Plaza Hotel, Nashville, Tennessee.

1982, May 10—13, Advanced Course on Below-Knee and Through-Knee Amputations and Prosthetics, ISPO, Copenhagen, Denmark.

1982, June 4—6, AOPA Region IX, COPA, AAOP California Chapters Combined Regional Meeting, Harrah's, South Lake Tahoe, Nevada.

1982, June 10—13, AOPA Regions II and III Combined Claridge Hotel, Atlantic City, New Jersey.

1982, June 17—20, AOPA Region VI Meeting, Indian Lakes Resort, Bloomington, Illinois.

1982, September 8—10, Second Annual Advanced Course of Lower Extremity Prosthetics, Nassau County Medical Center, East Meadow, New York.

1982, October 17—24, AOPA National Assembly, Shamrock Hilton, Houston, Texas.

1983, May 12—14, AOPA Region II and III Combined Meeting, Colonial Williamsburg, Williamsburg, Virginia.

Summer Honorarium

Warren Frisina, BE and James A. Reeve, BS have been awarded the $100 honorarium for their article, "Feedback For Electrically Powered Prostheses and Orthoses."

Editorial

Rehabilitation Engineering emphasizes the application of the physical, medical, allied health and social sciences to ameliorate the handicaps of persons with disabilities. A handicap is the consequence of a disability that interferes with a person's life goals in daily living, vocation, avocation and recreation. The degree of a handicap depends on the interaction of a disability and a particular environment as well as the nature of the life goals of or for a person with a disability. Thus technology can reduce a handicap by overcoming functional barriers but it may increase a handicap by raising a person's life goals to a level that cannot yet technically be achieved or, if developed, effectively delivered.

For me, the most important words in the previous paragraph are "effectively delivered." While it cannot be denied that the frontiers of research and development in technology for the handicapped are still largely unexplored, the fact is that a great many persons with disabilities are denied the benefits of present technology. The reasons are many, including lack of information, lack of evaluation capability on which information may be based, lack of manufacture and distribution, lack of appropriate authorization and payment, and lack of effective service delivery systems.

It is the last item mentioned that most relates to Orthotist/Prosthetist. Effective delivery of technology to persons with disabilities requires at best an interdisciplinary team, but at a minimum, professional collaboration between the health professional and the technical professional must exist. The Orthotist/Prosthetist as a role model represents for the Rehabilitation Engineer much of what he/she must learn to practice. Working with technology but understanding physiology as well, the Orthotist/Prosthetist is above all a deliverer of service. He/she functions in the real world of private enterprise, relating to prescribing physicians and allied health persons, dealing with third party payors, and on a one-to-one basis with the patient or client wherein he/she is immediately faced with the results of his/her efforts and accountability for consequences. It is this responsibility and the training and skills required to meet it that makes the Orthotist/Prosthetist a true professional. The Rehabilitation Engineer must achieve the same level of responsibility if he/she is to be seen as a professional person.

Anthony Staros, in his lead article, deals with these issues as well as others. There is a great need for skilled persons to make the potential of technology a reality for the persons who need it. While Orthotists/Prosthetists will fill some of this need, the task is much larger than represented by their profession. The challenge to them is to join with those entering Rehabilitation Engineering from other fields to use their history, skills and experience to find the best way to bring the products of technology to the handicapped persons who really need them.

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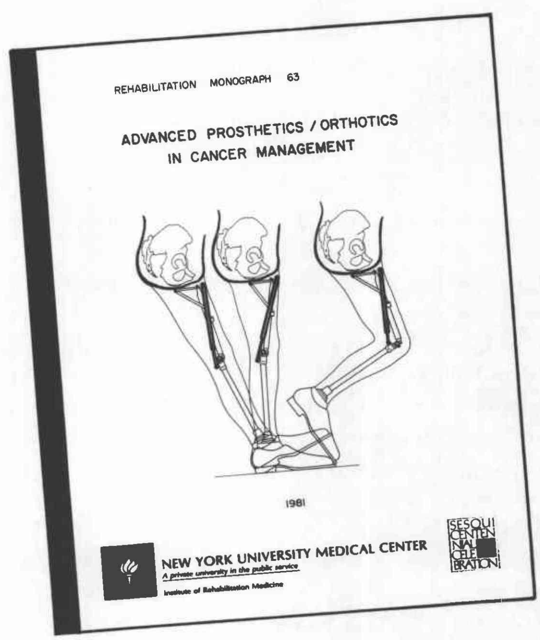

Knee Orthoses: Biomechanics[1]

Charles H. Pritham, C.P.O.[2]

Irrespective of etiology, deformities of the knee can be divided into three broad categories: angular (genu valgum, genu varum, genu recurvatum), rotary (internal, external rotation of the tibia relative to the femur), translatory (anterior/posterior subluxation of the tibia relative to the femur). They can be further categorized as either flexible (secondary to flaccid musculature and/or ligamentous and capsular laxity) or fixed (secondary to spastic musculature and/or ligamentous and capsular tightness). For a variety of reasons orthotics has traditionally devoted the majority of its attention to cases of angular deformity and coped with instances of rotary or translatory deformity only secondarily as they arise as complications of angular deformity. For that reason, then, the majority of discussion will focus on this aspect of the situation.

Viewed in the frontal plane (the case is the same in the sagittal plane) with the body aligned so that the weightbearing line coincides exactly with the mechanical axis of the leg (Fig. 1), there is no tendency for the knee to bend into either genu valgum or genu varum. If the weightbearing line deviates to one side, a bending moment or torque is created (Fig. 2) that causes a change in angle (angle of deformity, 0) of the femur relative to the tibia. The bending moment can be quantified by multiplying the deforming force (body weight, W) times the perpendicular distance (x) from the line of action to the center of rotation. As body weight is essentially constant, any increase in angle of deformity will lead to an increase in distance x and an increase in the deforming moment. In real life this tends to create a vicious circle since the deformity is resisted by the capsular and ligamentous elements on the opposite side of the knee. The stress is greatest on those elements farthest away from the center of rotation, as they are best positioned by virtue of their longer lever arm to oppose the deforming force. When the stress becomes intolerable, they yield, and the load falls on elements less strategically placed. As the angle of deformity increases, distance x increases, the deforming moment increases, and a compromised knee is jeopardized further. To correct this situation and prevent further damage, it is necessary to introduce a corrective moment and reduce the angle of deformity.

This corrective moment is created by a three-point pressure system (Fig. 3). For the laws of equilibrium to be satisfied, the forces acting on each side of the structure must be equal, and the clockwise moments acting about the center of rotation must be equal to the counterclockwise moments. The farther forces H and A

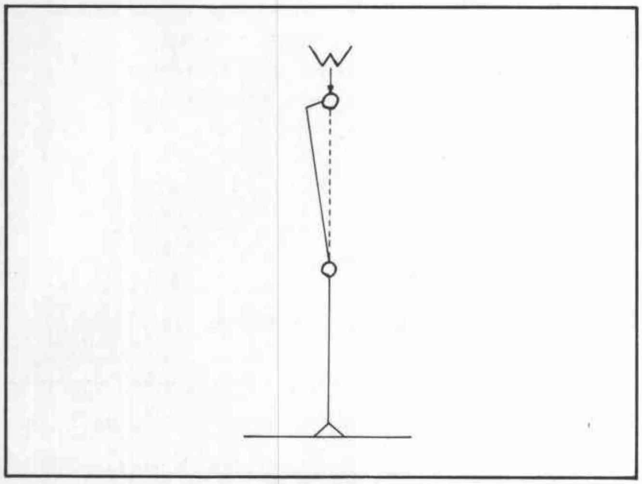

Fig. 1. Lower limb positioned so that weightbearing axis falls through the mechanical axis of the limb.

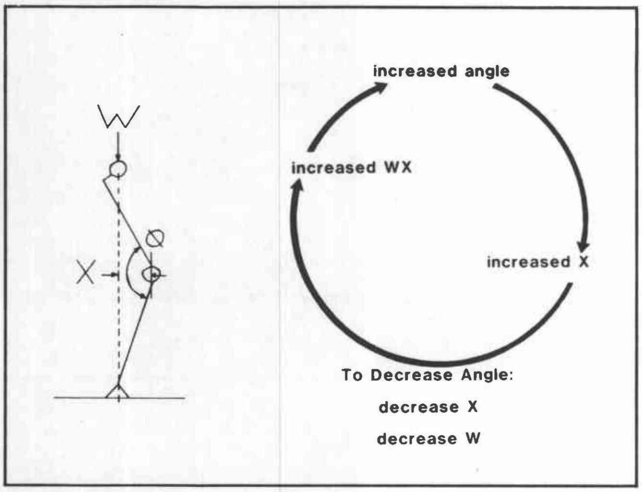

Fig. 2. As the weightbearing axis deviates to one side a bending moment or torque is created.

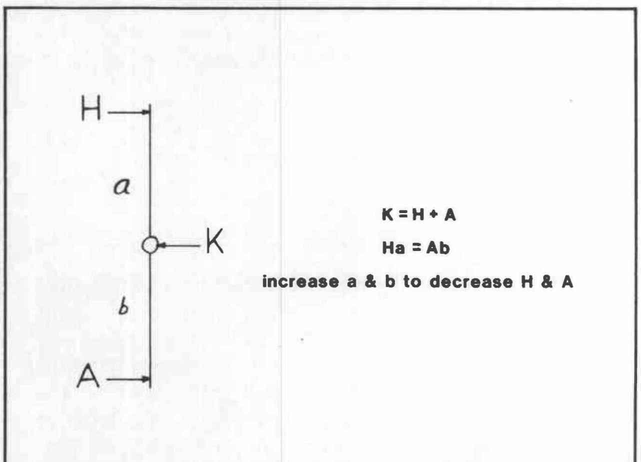

Fig. 3. Three-point pressure system acting about the knee.

1. Derived from a lecture given at the ISPO Lower Limb Orthotics Course, Dallas, Texas, March 9-13, 1981.
2. Formerly Director, Prosthetics and Orthotics Laboratory, Rehabilitation Engineering Center, Moss Rehabilitation Hospital, Philadelphia. Presently Branch Manager, Snell's of Louisville.

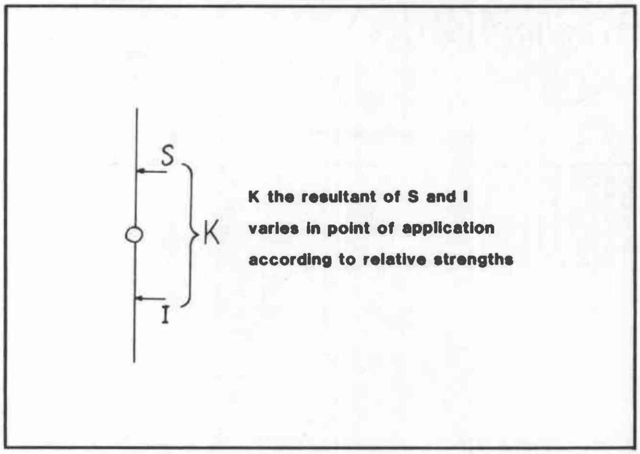

Fig. 4. Force K acting as two sub-forces, S and I.

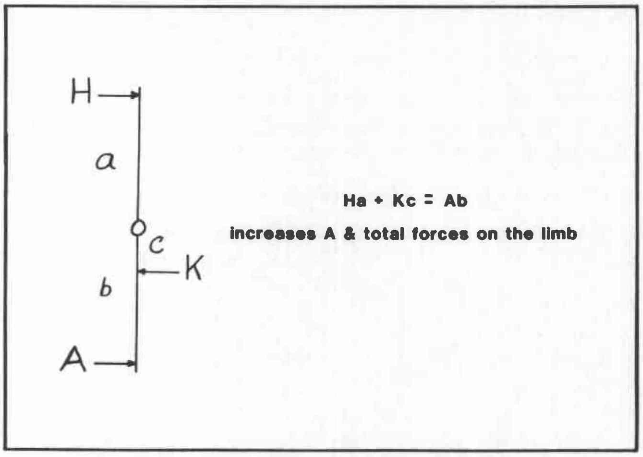

Fig. 5. As force K moves away from the knee the total force on the limb increases.

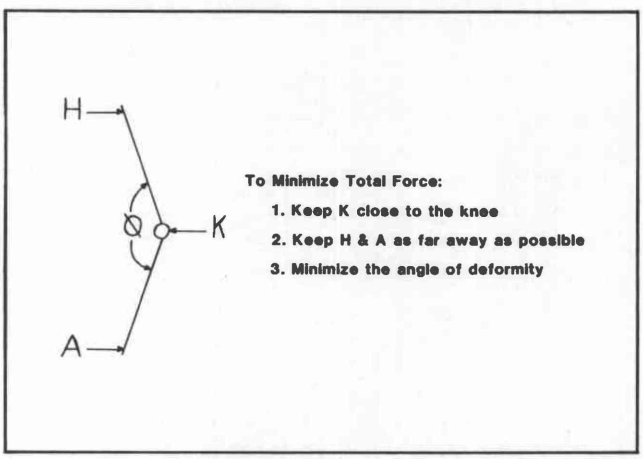

Fig. 6. A summarization of criteria necessary to minimize the force on the limb.

are from the center of rotation, the smaller they can be, due to increased lengths of their lever arms a and b. Force K can seldom be applied directly at the center of rotation (Fig. 4), as the anatomical structures vary in their ability to tolerate the pressure. It may very well prove necessary to locate force K some distance from the knee and apply it as two sub-elements, S and I. K would be equal to the sum of the two and vary in point of application according to their relative strength. As K moves away from the center of rotation (Fig. 5), it increases the bending moment acting in one direction or another, and if the laws of equilibrium are to be satisfied, the opposing moment will have to increase in magnitude, leading to an increase in total force on the limb. Figure 6 summarizes the discussion thus far. It should be noted that any orthosis fabricated to satisfy these conditions must be strong enough to do so without yielding or bending as the old pattern of the vicious circle (Fig. 2) will assert itself. Yet another factor to be taken into account is the familiar relationship of pressure, force, and area (Fig. 7). The need to satisfy these conditions and thus reduce the total force exerted must be, of course, balanced with the desire not to encumber adjacent joints, and to keep the orthosis as cool and light as possible.

Another way to tackle the problem is to use a weightbearing brim (Fig.8). This, of course, reduces the deforming force and thus the deforming moment. What is not so apparent is that it might very well change the length of the lever arm x and reduce the bending mo-

$P = F/A$
To keep P at tolerable limits:
minimize F
maximize A

Fig. 7. The relationship of pressure to force and area.

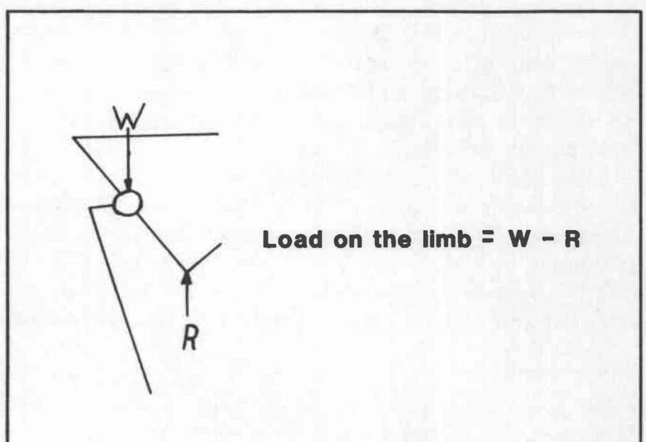

Fig. 8. Use of a weightbearing brim creates a proximally acting force, R, that counteracts weight, W.

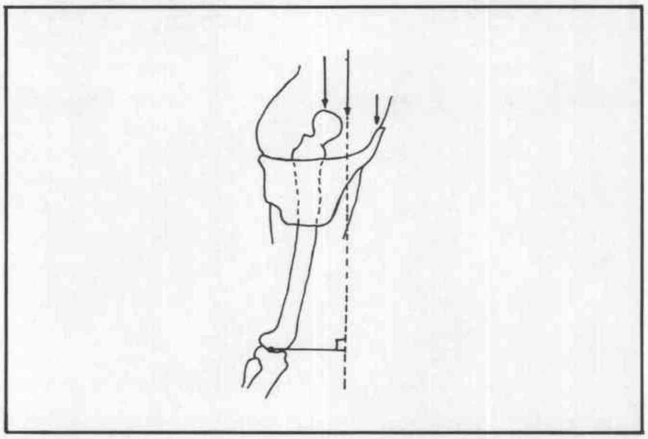

Fig. 9. Forces applied to the higher anterior wall of a quadrilateral brim tend to move the weightbearing axis anterior to the head of the femur, and the knee center.

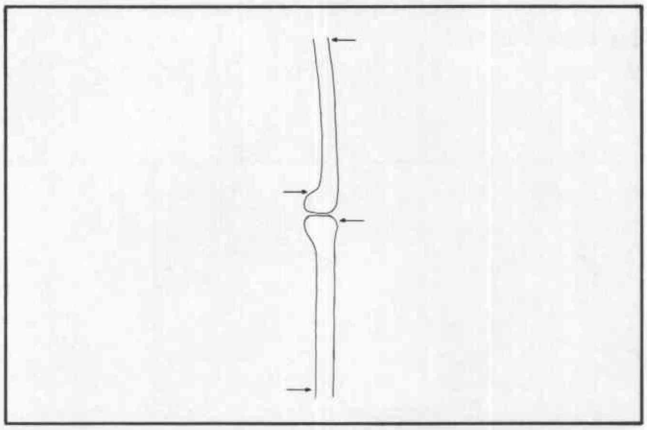

Fig. 10. Use of force couples acting on the femur and tibia to prevent anterior subluxation of the tibia relative to the femur. The force system would be reversed in an instance of posterior subluxation. A system of force couples is subject to the same sort of analysis and criteria as a three-point pressure system.

ment. If some of the body weight is borne medially on an ischial seat, it would tend to shift the line of action of the body weight medial to its usual course through the head of the femur. This phenomenon is at work when a KAFO with a quadrilateral brim is used in cases of gluteus medium lurch. It might very well have implications in cases of genu varum and genu valgum. In the sagittal plane (Fig. 9), a similar situation is identified in the UCLA Functional Long Leg Brace (Ref. 2). Moving the line of action of the weight line anterior by virtue of the load on the Scarpa's Triangle, a knee extension moment is generated. Knee extension is further aided by the intimate fit of the quadrilaterial brim and a firm fit of the foot in the shoe which produces a distractive effect on the leg, straightening it, as would pulling on opposite ends of a rope.

Subluxation of the tibia (such as might occur due to the pull of the quadriceps secondarily to ligamentous laxity in cases of genu valgum in arthritis, a situation described by Smith, et al., in reference 2), can be combatted by separate force couples acting on the femur and the tibia (Fig. 10). This is a feature of the University of Michigan Arthritic Knee Brace.

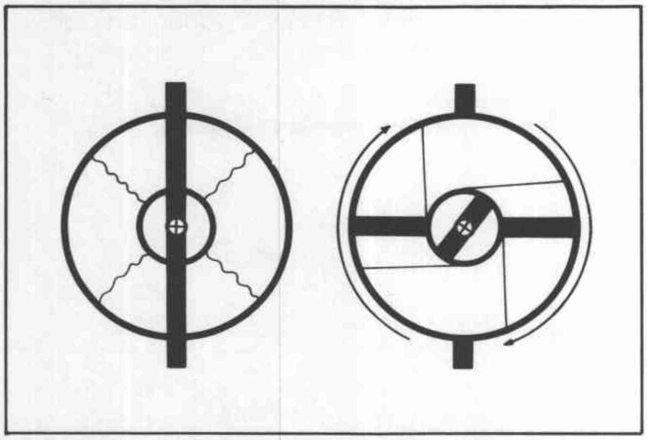

Fig. 11. Schematic cross-section of a limb, on the left, with the skin (outer circle) connected to the bone (middle circle) by soft tissue (radiating rippling lines) and acting about the center of rotation (innermost circle). The broad vertical line is for reference. As rotary forces (arrows) are applied, on the right, the force is transmitted from the skin to the bone by the soft tissue. As slack in the soft tissue must be taken up it becomes apparent that the bone moves less than the skin.

In the absence of direct action on the skeleton, control of rotation is more problematical. As the proximal portion of the shin is triangular, considerable rotational control can be achieved as in the PTB prosthesis, the spiral ankle-foot orthosis (AFO), and the hemi-spiral AFO. Purchase about the condyles of the femur and the patella can be achieved, but is compromised by the necessity for unencumbered knee flexion. It is, of course, possible to use a quadrilateral brim to gain a purchase on the proximal structures, but any prosthetist will be glad to regale his orthotist companion with tales or rotary instability in above-knee prostheses. The last alternative is a frictional coupling between the soft tissue and broad elastic straps as in the Lenox Hill Derotation Orthosis (Fig. 11). As considerable slack must be taken up in the soft tissues, 20 degrees of motion at the surface may result in only 10 degrees of motion of the femur about its axis. Moreover, the efficacy of even the best such measures is called into question considering the magnitude of the bending moment generated by the action of the center of gravity about the long axis of the leg and comparing it with the moments that can be induced about the same axis by the maximum tolerable force acting at the surface of the leg.

In conclusion, some of the biomechanical factors involved in the function of knee orthoses are reviewed. Due consideration of these factors, the anatomical structures involved, and the intended purpose of the orthosis at the time of prescription should inevitably lead to a more functional orthosis.

References:

1. *Final Report, Functional Long Leg Brace Research.* University of California, Los Angeles. Prosthetics/Orthotics Education Program, March 30, 1971.
2. Edwin M. Smith, M.D., Robert C. Juvinall, M.S.M.E., Edward B. Correll, M.S.M.E., and Victor J. Nyboer, M.D., "Bracing the Unstable Arthritic Knee," *Archives of Physical Medicine and Rehabilitation*, Vol. 51, No. 1, Jan. 1970, pp. 22-28, and 36.

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