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Report of the committee on research and education*

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The chairman would like to express a few words about the philosophy that has prevailed in the production of this rather substantial and difficult type of work. In the first place, sports medicine involves many disciplines of science, which study not only how a human reacts to sports and their demands, but also how athletic activities in their various forms are composed and their challenges to us as performers. Physical education, engineering, and anthropology, mingled together with physiology, the medical aspects of sports, and trauma, are so intermingled that there is great difficulty to get universal agreement on the factors that the committee has undertaken.

We have taken the attitude that those of us interested in orthopaedics, in spite of the routine work that we are doing, whether it is replacing joints or removing disks or taking care of the growing child or arthritic elder, are seeing as much as 75% of those patients in practice who fall into the sports medicine total fitness concept. Many like to think of sports medicine as an anatomic region involved in their diagnostic scheme. Much of the confusion was, to some extent, resolved by the American Medical Association's *Handbook of Nomenclature*. However, a great problem exists for our committee as it does for any one concerned with sports medicine who is an orthopaedic surgeon. One can take a specific sport and detail its involvement and the demands on us, in vertical fashion, such as skiing, football, tennis, or track and field. Your chairman strongly believes that the danger of this is that, it does not permit the broadening of the orthopaedic surgeon to the vast literature on sports medicine, and the contributions made to it by many other specific fields, such as from rehabilitation and physical medicine, biomechanics, exercise physiology, and the vast literature on the medical aspects of sports medicine that dates back to Sir Adolphe Abrahams and so many others. Patients of all ages do not usually go to the orthopaedist so subtle injuries to the musculoskeletal system are seen by a family practitioner or by no one. However, since patients with sports injuries are usually competitive by nature, the orthopaedist is eventally given the task of helping them recover enough not only to function well, but also to resume participation in their sport. This applies to adolescents and to the handicapped elders. We think it is easier for orthopaedists to be cognizant with physiology than for physiologists to treat injury. In this context we are attempting to define some areas that our specialty must be concerned with, such as performance, motion, certainly instability of the knee, and the running mechanism, biomechanics; all of which are inescapably intertwined with the research that is going on in physical education and physical fitness, and modified by different ages in the total lifetime picture. We recognize that no one discipline or organization can embrace or control all of sports medicine. We do not have adequate research in epidemiology yet, nor have we adequately pinpointed which are the most vital athletic injury problems in the different parts of the country as they relate to sports. Surveys have shown how little is being taught in medical school. We have very little information on the maturation effect of playing high-demand sports on our children's joints or of the environmental types of sports people play, which a multitude of orthopaedists must grapple with in a totally different part of the country due to jet travel. We have very little

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knowledge on how the injured joint proceeds to the development of arthritis over what course of time, and how much of the arthritis we see in practice is a result of an earlier untreated sports injury. We do not have adequate information as to how to prevent injuries in sports, and prevention has not kept pace with the excellent early diagnostic abilities of many of our doctors for conditions such as painful shoulder, elbow, patella, and acute knee. The lack of our familiarity with the physiology of training, as well as the methods of training, have been submerged in our residency programs to other areas of actually less importance in numbers and cost, if one looks at our in-training and certifying examinations. We feel that it is a rightful domain, in the education of our residents, that they not only know of the biomechanics of joint motion as relates to the constrained or nonconstrained joint, but also how to train, to acquire fitness, and to understand the relation of physical condition to disuse as well as abuse in individuals who have damaged joints and who play sports. We recognize that orthopaedic surgery is not just the "carpenter's bench" of the human body. In sports medicine we deal with the incredible machinery of our bones and joints coupled to a working heart, neurohumeral mechanisms, a control of peripheral blood flow as well as the biomechanical aspects of the skeleton; all part of the integrated network that constitutes the primary responses of the musculoskeletal system in a thinking personality to the work performed in sports. In all of these areas, the Committee on Research and Education of the AOSSM and our journal and media relationships have a task ahead to accomplish. We have to select from these areas which studies are achievable and effective for the future. This particular report represents our first cooperative effort in this context. It is hoped that our successors will be able to take this report as an indication of what we think is a workable philosophy for those of us who teach, research, and work in sports medicine as orthopaedic surgeons. Our present report refers to locomotion, defines terms, and then concentrates on the running mechanism, biomechanics and knee instability.

ENCLOSURE 1

We prepared a definition of the terms of the common motions used in sports, and the running mechanism was prepared by Dr. James. Since these have been published by Brubaker, Slocum, and James, this particular classification is well established and should be utilized in the future when discussing nomenclature and mechanism in the study of running.

ENCLOSURE 2

This concerns performance traits in sports, a composition of the definitions, especially in the physical education literature as well as in kinesiology. There may be some criticism about the areas of personal subjective performance such as intelligence. We invite help, but work in the area of psychometrics is limited. "Coachability," for example, has been suggested by Dr. Ellison as a factor to be considered. However, for present purposes it is felt that these factors will give one a good background of the literature today in the physiology of performance and the demands of sports on us.

ENCLOSURE 3

This is a glossary prepared by Dr. Allen on biomechanics and is limited only to definitions without any specific relationship implied at this time to sports. However, all motions in sports as well as injuries are related to the reactive forces acting on joints. This glossary offers a simple start to a later revision of the most important biomechanical concepts in sports medicine.

ENCLOSURE 4

This represents a unified conception of the committee at this time on knee instability. It is suggested that the student utilize this nomenclature for knee instability until evidence otherwise develops for other terminology. If we can understand and agree to this particular type of model, then it should serve to help us in the discussion of instabilities of other joints, such as the ankle, thumb, and shoulder. This section was prepared by Dr. Kennedy.

We are deeply indebted for all their hard work.

NOMENCLATURE FOR RUNNING

Running

A form of locomotion in which the body is alternately supported by each lower extremity with an intervening airborne period.

1. Stride: A stride is a complete cycle of the lower extremity, generally described as starting at the precise moment the foot strikes the running surface until the same foot reaches the same relative position.

2. Step: A step is that part of a stride commencing at the precise moment of foot strike and continuing until the opposite foot is in the same relative position. A stride consists of two steps.
3. Support Phase: That period of time during the running stride when either foot is in contact with the running surface. Each stride consists of two support phases. The support phase is divided into three periods which are as follows: foot strike, foot support, and takeoff.
4. Foot Strike: Foot strike begins when the foot touches the running surface and continues for a brief moment, during which the foot becomes securely fixed.
5. Types of Foot Strike: Heel-toe—Contact with the running surface is first made with the heel. The ankle is then plantar flexed, bringing the forefoot into contact with the running surface. This is a pattern common to distance runners. Foot flat—Simultaneous hindfoot and forefoot contact with the running surface, which is often used by middle distance runners. Forefoot—Contact on the running surface is made across the forefoot. The heel may or may not be completely lowered to the running surface. This type of foot strike is commonly used by sprinters. The foot is normally in a supinated position at foot strike regardless of the type utilized, thus the outer border of the heel and/or forefoot contacts the running surface initially. Pronation then occurs, bringing the foot into full contact with the running surface.
6. Midsupport: Midsupport starts once the foot is fixed to the running surface and continues until the heel begins to rise away from the running surface. The body's center of gravity reaches its lowest point in relation to the running surface.
7. Takeoff: Takeoff begins when the heel starts to rise and continues until the foot breaks contact with the running surface. The body's center of gravity reaches the highest point at, or shortly after, takeoff.
8. Nonsupport Phase: That period of the stride during which neither foot is in contact with the running surface and the subject is airborne. Each stride contains two nonsupport phases.
9. Right (Left) Recovery Phase: That period of the stride during which the nonsupport extremity is brought from a position behind the body to one in front of the body in preparation for the next support phase. The recovery phase is divided into the following three periods: follow-through, forward swing, and foot descent.
10. Follow-through: Follow-through begins as the trailing foot leaves the ground and continues until the foot ceases its rearward motion in relation to the body.
11. Forward Swing: Forward swing starts with forward motion of the foot and terminates when the foot reaches its most forward position in relation to the body.
12. Foot Descent: Foot descent begins after the recovery foot reaches the most forward position and reverses direction. It continues as the foot descends toward the running surface in a rearward direction and terminates with foot strike.
13. Cross-over Step: An abrupt change in direction during the act of running accomplished by rotating the body in the direction of the support extremity and bringing the recovery extremity across in front of the support extremity, so that the subsequent foot strike deviates markedly to one side of the line of progression. The directional change is toward the support extremity.
14. Cutting: An abrupt change in direction while running, accomplished by turning the body away from the support extremity while the recovery extremity moves laterally away from the support extremity in preparation for the next foot strike. The directional change is away from the support extremity.
15. Pronation: Motion about the subtalar joint occurring during early support and characterized by eversion, abduction, and dorsiflexion about the subtalar joint axis. This unlocks the midtarsal joints causing the longitudinal arch to lower, the tibia to internally rotate, and creates relative instability of the foot along with increased flexibility. This allows the foot to adapt to the running surface.
16. Supination: Motion about the subtalar joint axis consisting of inversion, adduction, and plantar flexion about the subtalar axis, which enhances the stability of the midtarsal joint, heightens the arch, and causes an obligatory external tibial rotation. The foot becomes a more rigid lever for takeoff.
17. Pelvic Rotation: Rotation of the pelvis about a vertical axis.
18. Pelvic Tilt: Rotation about an anteroposterior axis.

PERFORMANCE TRAITS IN SPORTS—COMPOSITION AND DEFINITIONS

The capacities by which athletes are to perform can be broken down into a number of performance traits. Definitions of such traits are elaborate and may be specific to sports, in terms or in disciplines such as kinesiology or biomechanics. However, we shall attempt to keep the nomenclature simplified. There are 13 traits associated with neuromuscular factors, 5 with psychologic factors, and 3 with the environment.

Neuromuscular Factors

1. Muscular Strength: There are three types: explosive, dynamic, and static. The ability to do work against a specified resistance usually at a peak performance (maximum isometric contraction). Various sports impose different demands for strength of varying types on the individual. Strength may also be defined as a contractive power of muscles, as a result of a single maximum effort.

2. Endurance: May be defined as the ability of the individual to respond repetitively for a relatively long time. Another definition is the number of successive movements of muscular strength or power, at a given rate of speed over an extended period of time. Time, then is an important component in endurance. Speed of force development is regarded as *power.*

3. Body Type: A performance factor in which the physical characteristics that involve height, weight, sex, body mobility, and other anthropologic characteristics refer to body type. Mesomorphy is an example of such an expression. Individuals may be tall, short, bulky, loose, or tight, and so on.

4. Balance: Defined as a coordinated neuromuscular response of the body to maintain a defined position, such as the upright position. It is a state of equilibrium in response to changing: (1) tactile, (2) visual, (3) kinesthetic, or (4) other stimuli. It can be static, dynamic, or objective. When one holds a steady position, it is stance or static balance. When one is moving the body, whether in running, kicking, jumping, or throwing, and maintains an upright position, even with changing bases of support, we have an example of *dynamic* balance. *Objective* balance is seen in someone who is juggling a forward pass after catching it or while in the act of juggling itself, so that it involves an implemental relationship to the maintenance of body control of its position.

5. Agility: Defined as a trait with accuracy on repetition, and the ease by which the body can change direction of movement. The quality of agility is actually a functional integration of a number of traits. These include balance, speed, coordination, endurance, and strength possessed by the athletic performer. Another way to define agility is the speed, plus the ability to make a sudden change in the direction of movement. Quantitative variations in agility demanded by different sports under different conditions of play are characteristic of different sports.

6. Speed: The capacity to perform successive movements of the same type at a fast rate, by all or single parts of the body. When *fatigue* occurs, it limits the amount of time in which speed can be maintained. Fatigue can occur in seconds, minutes, and hours depending on the sport and conditions.

7. Coordination: This is a trait involved in some degree with all of the performance demands. The essence of coordination has been defined as the ability to integrate the separate abilities in a complex task. These integrated movements of different types are best if smooth, efficient, effective, and accurate. There are many types of coordination in man's interplay between the limbs, eyes, and other sensory functions. These include, eye-hand coordination and foot-hand corrdination. Combinations of movements of the entire body may be involved at the same times, such as in jumping, hopping, and skipping, while under pursuit or in difficult ballet steps set to music.

8. Alertness: Can be defined as a degree of immediate awareness of sensory stimulation. Alertness results from efficient interpretive function as well as knowledge, intelligence, training, and, to some extent, fitness.

9. Rhythm: A trait common to all sports, characterized by synchronized movements that can be associated with thought, motion, and sound in the particular skill of a sport, and producing a pattern of ease and efficiency. The possession of coordination is an important contribution to developing rhythm.

10. Timing: This is one of the most important and frequently required of all performance factors. It is the adaptation, the initiation, and integration of all of the movements. These integrated components make up timing motion, and often change in motion and skills of movement. Timing is best developed through repetition and practice.

11. Reaction Time: Can be thought of as the stimulus-response mechanism. It is measured by the lapse of time between the appearance of one or more stimuli to the motor responses evoked. There are multiple stimuli in sports requiring integrated reaction time.

12. Steadiness: Is defined in sports as the ability to control the mental and physical facilities, while seeking maximum efficiency during all situations that are encountered both within the body and the surrounding environment.

13. Flexibility: Is one of the most important areas demanded of the body in performance. It is defined as combinations of joint movement. It can be regarded as looseness within the joint, or within the extremity or entire linkage of the joints of an extremity, or trunk, or upper, and lower extremities. It is often a combined trait of all of those segments. Flexibility is a combination of a wide range of movements. It may be composed of limb movements on the body, or body movements on the limb, or both. These jointed limbs are regarded as links in such an arrangement.

Psychologic Factors of Performance

1. Motivation: This is important to all human performance achievements and is stressed particularly in sports. It can be defined as a force of energy and personal desire that propels one to seek a goal and/or satisfy a need or striving of intent or purpose. Coaches stress motivation as one of the most important traits, using how much time one is willing to devote to an activity as an index of one's degree of motivation.

2. Intelligence: This is the most difficult area to define, because so little is known of it. It can be defined as the ability to (1) initiate perception of the environment; (2) integrate the sensation into a total configuration; and (3) attribute meaning in terms of past experience with an appropriate response to new perceptions. Intelligence, however, has many other components that we are unable to assess because much is not understood, especially in athletics. Intelligence is composed of three types: abstract, mechanical, and social. *Abstract* intelligence has been defined as a capacity to understand and manage abstract ideas and symbols. *Mechanical* intelligence is the ability to understand and manage mechanisms. *Social* intelligence can be defined as the capacity to act reasonably and wisely in regard to human relations and social affairs.

3. Creativity: This is important in sports, and it is the ability to use one's imagination to create something new or different.

4. Discipline: Is a performance that is the most frequently demanded of psychometric traits. It involves the conscious limitation of impulses, wishes, and tendencies, so that one can suppress instincts and affects. Motivation, creativity, and discipline are important complimentary factors in sports. There are conscious and unconscious creativities in motivation, both seeking to propel a person to seek a goal and/or to satisfy a need for striving, incentive, and purpose as the end of successful performance.

5. Accuracy: Is a summation of the demands imposed on individuals by sports, so that precision in the achievement of the sport is the goal, whether the standard is a measure of time, weight, or other goal of sport.

Environmental Factors—Importance in how Sports are Performed

There are three basic factors:

1. Equipment: Defined as all implements and supplies used as a direct or indirect function of sport, and which may enhance effective sports ability in order to secure top quality performance.

2. Practice: Represents a demand that must be met by repetition, in order to perform a sports skill imposed on the performer. Also, it may be defined as the specific requirement of each sport to assure effective participation to a continual repetition of sports movement.

3. Playing Conditions: These are an important performance factor. They can be defined as the degree to which the playing surface or area, and the surrounding environmental conditions in which each sport is played, affect performance.

CONCLUSIONS

Each sport has different demands in the traits as defined for the performer. Each performer differs from the other in his ability to react to the sport and its demands. The five most frequent traits demanded in some studies are: (1) timing, (2) practice, (3) coordination, (4) accuracy, and (5) discipline. Notice that pure physical factors, such as strength or flexibility, are not in this group. Hence, one may overcome physical deficiencies and handicaps, and still meet the demands of many sports.

DEFINITION OF TERMS OF MOTIONS USED IN SPORTS

Walking: A form of bipedal locomotion in which the alternate support phases of the legs are usually linked by a transitional phase when both feet contact the ground. At no time are both feet off of the ground simultaneously.

Running: A form of bipedal locomotion in which the alternate support phases of the legs are linked by a float phase, when both feet are off of the ground.
Jumping: A ballistic motion of the legs propelling the body away from, or over a weight-supporting surface.
Kicking: A ballistic motion of the lower extremity, whereby its center of mass (and/or that of an external object) is propelled about or away from the body's center of mass.
Throwing: A ballistic motion of the upper extremity whereby its center of mass (and/or that of an external object) is propelled about or away from the body's center of mass.
Stance: Maintenance of a specific functional posture over a period of time.

GLOSSARY—BIOMECHANICS

Acceleration: A measure of the time rate of change of velocity. It is also a vector quantity that possesses magnitude, direction, sense, and point of application in a manner similar to velocity.
Angular Acceleration: The time rate of change of the angular velocity.
Angular Velocity: The time rate of change of the angular position of a line.
Area Moment of Inertia: That property of the cross-sectional area of a body that takes into account not only the amount of area, but also the disposition of the area with respect to the neutral axis or centroidal axis. It is represented by an *I*.
Boundary Lubrication: Molecules of a lubricating fluid adhere to and fill in irregularities of the contact surfaces.
Centipoise: The viscosity of water at 20 C and atmospheric pressure.
Centroid: See polode.
Coefficient of Friction: A proportionality constant used to calculate friction force. It is dependent upon velocity only for very small velocities, however, is dependent upon the surface adhesiveness of the two bodies in motion.
Compression: The state of normal stress in which portions of the body tend to crush together under the load.
Couple: Two equal and opposite forces that act along parallel lines.
Dynamics: The study of the action of forces on bodies not in equilibrium.
Equilibrium: A body moving at a constant velocity.
Energy: The ability to perform work. There are many forms of energy such as chemical, atomic, thermal, electromagnetic, and mechanical.
Force: Energy or power. That which originates or arrests motion. May be thought of as either a push or a pull. It may be defined, however, according to its effects upon the body on which it is acting. Forces possess four definite characteristics: (1) magnitude, i.e., kilogram force or pound force; (2) line of application, i.e., vertical, horizontal, or north by west; (3) sense, i.e., upward along a vertical or downward along a vertical; and (4) point of application, i.e., heel of foot, tibial tubercle, or tip of arrow.
Free Body Analysis: A method for determining unknown forces on an isolated body where all known and unknown forces are recognized.
Friction: A general term that describes the resistance two bodies develop when undergoing relative sliding motion.
Hydrodynamic or Thick Film Lubrication: The fluid thickness is observed to be at least several hundred times the molecular size of the fluid, and as two surfaces move in relationship to each other a wedge of lubrication fluid developes at the leading edge.
Instant Center of Rotation: A point in space about which a body is moving at any particular instant. The velocity of any point on the moving body is perpendicular to the direction from that point to the point in space of the center of rotation.
Isotropic: Having like properties in all directions, as in a cubic crystal or a piece of glass. A material is isotropic when the material properties are not dependent on the orientation of the material in the test specimen.
Jerk: The time rate of change in acceleration or the differential of acceleration.
Jerk Test: A clinical examination of the knee used to elucidate anterolateral subluxation of the tibia on the femur. The word "jerk" is used here as the engineer would use the word.
Kinematics: The study of the relative motion that can exist between rigid bodies, which are called links.
Kinetic Energy: The energy possessed by a mass by virtue of its velocity relative to a reference mass. The formula for kinetic energy is $KE = \frac{1}{2} mv^2$.
Linear Acceleration: A measure of the rate of change of linear velocity.
Linear Velocity: The time rate of change of a linear position of a particle.
Line of Application: A characteristic of force.

Longitudinal Strain: The ratio of the change in length of a line to its original length, the units of this strain are inch/inch or mm/mm. Longitudinal strain is designated by ϵ.
Magnitude: A characteristic of force.
Modulus of Elasticity: The ratio of change in stress to change in strain, represented by E. Mathematically it is written as $E = \delta/\epsilon$. (Since the units of stress are kg/mm^2 and those of strain are mm/mm, the units of E, the modulus of elasticity, are kg/mm^2.)
Modulus of Rigidity: The ratio of sheer stress to sheer strain. It is represented by G. The units of modulus of rigidity are kg/mm^2.
Moment: May be visualized as the twisting or turning effect of a force. Moments, like forces, have both internal and external effects upon the body in which they are acting. The external effect of a moment on a body is to change or attempt to change the angular or rotational velocity of the body. The internal effects of moments are to cause a state of strain. A moment is necessary to produce angular acceleration. Moments, like forces and vectors, possess four characteristics. (1) Magnitude, which is represented by the product of the units of force and distance so that a moment produced by a force about a point is equal to the product of the force and the perpendicular distance between the line of application of the force and the point. By convention, the unit of weight is placed first and the unit of distance is placed second, i.e., a moment of 6 lbs/inch equals a force of ½ lb/foot. (2) Line of application is defined by convention and in the case of a moment applied to a jar lid, the line of application of the moment is aligned perpendicular to the surface of the lid. (3) Sense, the sense of the moment is arbitrarily defined by the right hand rule. If the fingers of the right hand are wrapped in the direction of the application of the moment, the extended right thumb indicates that sense of the moment vector. (4) The point of application is the intersection of the moment vector and the plane in which the moment is acting.
Newtonian Fluid: A fluid in which viscosity is independent of the velocity gradient, e.g., water.
Newton's Second Law of Motion: The time rate of change of velocity, i.e., the acceleration is proportional to the resultant applied force written as $F = M \times a$. F is measured in kg and M is the mass measured in kg/sec^2 divided by mm (kg/sec^2/mm). a is the acceleration measured in mm/sec^2.
Normal Stress: The force per unit area acting perpendicular to the area under consideration.
Point of Application: A characteristic of force.
Polar Moment of Inertia: A quantity similar in nature to the moment of inertia used in bending. It is a measure of distribution of the area with respect to a central point not a line, as in the case of area moment of inertia. The polar moment of inertia is illustrated by J.
Polodes-Centrodes: A curve formed by the instant center points. The puloid curves contain most of the information necessary to visualize or analyze the kinematic motion of a body.
Potential Energy: The energy possessed by a mass by virtue of its height above a reference data. Units are foot-lbs/kg/cm.
Radian: The angle where arc length is equal to the radius of the circle.
Right Hand Rule: See moment.
Sheer Strain: The angular deformation suffered by a right angle, two lines of this element that were originally at right angles will now undergo relative angular motion. Sheer strain is measured as a change in an angle. The units of measurements are radians. Sheer strain is designated by γ.
Sheer Stress: A force per unit area acting parallel to the area under consideration.
Strain: The change in geometric configuration that a body undergoes, usually seen with the application of external forces to the body. Strain may also be caused by changes in temperature.
Strain Energy: The energy a body is capable of absorbing by virtue of the body's changing shape under the application of external loads.
Statics: The study of the external effects of forces on bodies in equilibrium.
Stress: The internal force per unit area that a part of a body on one side of a plane exerts on that part of the body on the other side of the plane.
Tension: When the normal stress on a portion of a body tends to separate this section.
Thixotropic Fluid: The viscosity of the fluid varied with the velocity gradient.
Torque: Moment, see moment.
Vector: Force, see force. A quantity possessing magnitude, line of application, sense, and point of application, and commonly represented by a straight line resembling an arrow. The length of the line denotes magnitude, the arrowhead denotes direction, and the position of the line with respect to an axis of reference denotes sense, direction includes line of application and sense.
Velocity: A vector quantity possessing magnitude,

direction, sense, and point of application. The magnitude of the velocity is often called speed and is measured in such units as feet/sec or mph.

Viscoelastic: Having both viscus and elastic properties in appreciable degree.

Viscosity: Like the coefficient of friction, it is not a direct measure of the actual friction force, but is a material property that must be considered in combination with another variable of the system before frictional forces can be calculated. Pertains to liquid systems.

Wire Strain Gauge: A fine filament mounted on a supporting structure upon which the strain is to be measured. As the underlying surface is strained, the length of adherent wire in the strain guage is changed. This change in length in the wire produces a change in its electrical resistance, which may be detected through the use of a Wheatstone bridge.

Work: The effect of a force moving through a distance.

CLASSIFICATION OF KNEE JOINT INSTABILITY RESULTING FROM LIGAMENTOUS DAMAGE

At present, our working classification for knee joint instability is confusing, but we are struggling to clarify its terminology by pooling resources from major knee centres throughout North America just as was done 1 decade ago with scoliosis.

In the past dislocations of the knee were simply, but perhaps incorrectly classified as medial, lateral, posterior, anterior, and rotatory on the basis of the direction in which the tibia was displaced.

Although useful, the classification represented oversimplification, avoiding three-plane instabilities that commonly occur with disrupted knees. This classification attempts to describe the instability by the direction of the tibial displacement and, if possible, by structural deficits. It refers to instability occurring from acute trauma or from acute instability progressing to a chronic state, ignoring congenital and acquired instability from other causes (i.e., tibial plateau fractures, congenital hyperextension, etc.).

Our working classification for knee joint instability resulting from ligamentous damage includes the following: (1) one-plane instabilities: medial, lateral, posterior, and anterior; (2) rotatory instabilities: anteromedial, anterolateral (in flexion, approaching extension), posterolateral, and posteromedial; and (3) combined instabilities: anterolateral-posterolateral rotatory, anterolateral-anteromedial rotatory, and anteromedial-posteromedial rotatory.

DISCUSSION

This is an anatomic classification, i.e., one-plane medial instability means the tibia is moving away from the femur on the medial side. Anteromedial rotatory instability indicates that the tibia rotates anteriorly and moves away from the femur on the medial side.

The problem becomes more complex as attempts are made to include structural deficits. This is quite understandable. Individual surgeons encounter different pathologic lesions which, unfortunately, stand out in their minds as *the* lesion producing a specific instability. In addition, biomechanical interpretation of cadaveric dissections often differ from accurate clinical and operative observations. Equally important is the realization that acute and chronic lesions of a structure may not follow identical pathologic patterns about the knee joint.

One-plane Instabilities

One-plane Medial Instability (Tested with the Knee in Complete Extension): A valgus opening with the knee in complete extension represents one-plane medial instability. The knee opens on the medial side, the tibia moving away from the femur. This represents a major instability. There is involvement of the tibial collateral ligament, medial capsular ligament, anterior cruciate ligament, posterior oblique ligament, and medial portion of the posterior capsule. It strongly suggests involvement of the posterior cruciate ligament but does not totally indite this structure.

One-plane Medial Instability (Tested with the Knee in 30° of Flexion): There are a group of patients in which the tibia moves away from the femur in flexion, without appreciable clinical rotatory elements (i.e., Grade I or Grade II knee sprains). This depends on the severity of the involvement of medial structures.

One-plane Lateral Instability (Tested with the Knee in Extension): The knee opens on the lateral side, the tibia moving away from the femur. Structures involved include the lateral capsular ligament, fibular collateral ligament, biceps tendon (either partial or complete), arcuate popliteus complex (partial or complete), anterior cruciate ligament, and commonly the posterior cruciate ligament. This is a major instability approaching the proportions of a dislocation.

One-plane Lateral Instability (Tested with 'the Knee in 30° of Flexion): One should again be cognizant that minor one-plane lateral instability may be present in 30° of flexion without major pathology.

One-plane Posterior Instability: In this situation the tibia is displaced posteriorly with the knee in a semiflexed position (i.e., dashboard injury or direct blow on the tibial crest). The structures involved include the posterior cruciate ligament, arcuate ligament complex (partial or complete), and posterior oblique ligament complex (partial or complete). Although initially the damage may seem confined solely to the posterior cruciate ligament, chronic one-plane posterior instability eventually may involve the posteromedial and posterolateral corners, such areas demanding close evaluation and consideration for reinforcement when dealing with this instability.

One-plane Anterior Instability: Because of diverse theories currently in vogue, this disability is difficult to fully comprehend. The tibia in neutral position moves forward on the femur. Structures involved naturally include the anterior cruciate ligament, lateral capsular ligament (partial or complete), and medial capsular ligament (partial or complete).

The anterior drawer sign is positive in neutral position if the anterior cruciate ligament is involved with immediate or *subsequent* stretching of the medial and lateral capsules. Although laboratory studies suggest involvement of only a portion of the anterior cruciate ligament in producing an anterior drawer sign, the injury clinically suggests loss of functional integrity of the entire ligament.

Rotatory Instabilities

Anteromedial Rotatory Instability: In this situation the medial plateau of the tibia rotates anteriorly with the joint opening on the medial side. Structures involved include the medial capsular ligament, tibial collateral ligament, posterior oblique ligament, and anterior cruciate ligament.

This instability seems best understood. The researcher merely has to cut these structures in sequence in the cadaver to see the sequential and orderly progression of anteromedial rotatory instability.

Anterolateral Rotatory Instability: In flexion this instability has really little to do with major anterior displacement of the tibia. The lateral tibial plateau rotates forward in relationship to the femur at 90 degrees, with excessive lateral opening (a tendency for excessive internal rotation of the tibia on the femur with the knee in flexion). Structures involved include the lateral capsular ligament, arcuate ligament complex (partial), and anterior cruciate ligament (partial or complete).

With a specific test the lateral tibial plateau subluxates forward on the femur as the knee approaches extension. Structures in approaching extension (anterior subluxation of the lateral tibial plateau), involved include the anterior cruciate ligament and possible involvement of the lateral capsular ligament. With the knee coming into extension, one has the dramatic anterior subluxation of the lateral tibial plateau as the weight-bearing extremity begins to extend.

Posterolateral Rotatory Instability: The lateral tibial plateau rotates posteriorly in relationship to the femur with lateral opening. Structures involved include the arcuate ligament complex, biceps tendon, anterior cruciate ligament (partial or complete), lateral capsular ligament, and at times stretching or loss of integrity of the posterior cruciate ligament.

It is important to distinguish this type of instability from one plane posterior instability resulting from a tear of the posterior cruciate ligament. In the disability under discussion, the posterolateral corner of the tibia drops off the back of the femur, and there is a varus opening.

Posteromedial Rotatory Instability: In this situation, the medial tibial plateau rotates posteriorly in reference to the femur with medial opening. Structures involved include the tibial collateral ligament, medial capsular ligament, posterior oblique ligament, anterior cruciate ligament, medial portion of the posterior capsule, and stretching or major involvement of the semimembranosus system.

A hyperextension valgus force can tear these structures, the anterior cruciate ligament tearing before the posterior cruciate ligament (which is only mildly stretched), resulting in this instability (i.e., sagging back of the posteromedial corner of the tibia on the femur with valgus opening).

Combined Instabilities

One-plane and rotatory instabilities are soon understood. Structural deficits are mildly debatable with such instabilities. However, combined instabilities compound this problem. To this end, each orthopaedic surgeon will have to satisfy his own beliefs as to what structures are specifically damaged, and their relative degree of involvement in combined instabilities.

Combined Anterolateral-Posterolateral Rotatory Instability: In this situation the lateral tibial plateau rotates in a posterior direction. However, when additionally tested, there is excessive forward displacement of the lateral tibial plateau on the femur. Naturally, the lateral instability is great with excessive damage to the majority of structures on the lateral side of the knee.

Combined Anterolateral-Anteromedial Rotatory Instability: This is a common instability. The major posterior structures are spared. The examiner may demonstrate excessive anterior rotation of the medial tibial plateau (i.e., abnormal external rotatory instability). In addition, the examiner can readily produce positive anterior subluxation of the lateral tibial plateau as the knee approaches extension.

Combined Anteromedial-Posteromedial Rotatory Instability: In this situation medial and posteromedial structures are severely involved. The knee opens on the medial side, the tibia moving away from the femur. The tibia may rotate anteriorly when tested; however, with additional testing, the tibia moves in the opposite direction, rotating posteriorly and dropping off the posteromedial corner.

All medial structures, including the semimembranosus complex, are involved in combination with the anterior and most likely the posterior cruciate ligaments.

Further Combined Instabilities: An outline of further combined instabilities that would include three-plane or even six-plane dimensions would be both confusing and impractical. The variation in structural deficits would create major confusion. By using the above classification, the orthopaedic surgeon should gain an insight and understanding of the more complex instabilities.