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Risk factors, sports medicine and the orthopedic system: An overview*

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INTEREST EXPLOSION IN SPORTS MEDICINE

Dr. Jack Hughston, second President of the American Orthopedic Society for Sports Medicine stated that Hippocrates was the Father of Sports Medicine.[1] Dr. Joe W. King, our present and fourth President, stated that Sports Medicine is one of the most popular areas of interest among orthopedic surgeons in this country.[2] Since the time of Hippocrates, Sports Medicine has evolved to encompass such widely diverse areas as social medicine and the biological and physical sciences. Many important contributions from the world over, in such disciplines as physiology, physical education, bioengineering and the medical sciences, have been produced and have not received adequate recognition. In the twentieth century, interest, stimulated by expanding television and communications media, has now produced a marriage between the sciences dealing with recreational activity and medicine. In October 1974 the American Broadcasting company produced a documentary program called "DANGERS IN SPORTS" narrated by Jules Bergman. An astonishing number of requests, flooded the offices of ABC and the Institute of Sports Medicine at Lenox Hill Hospital. Newspaper columnists around the country discussed sports medicine in the context of this program. Requests for information were received from many professionals in widely diverse fields of interest (Figure 1).

This remarkable response was analyzed and tabulated. Thirty basic questions emerged. Eighty percent of the questions dealt with health care. The most frequently asked questions concerned injury prevention, risks of athletic injury, and, available instructional materials in the care of the athlete. This massive public display of interest in sports safety indicates how much Sports Medicine has come of age. It brought attention to the need for increased cooperation between physicians, scientists and other health-care professionals. It also demonstrated a new public awareness of the quality of medical care received by athletes.

In the preparation of this program we learned how important it is to have trained personnel utilizing a teamwork approach when dealing with specialists in the fields of health, fitness, recreational activity, therapeutics and medicine.

There is no way at the present time for 8,000 or 10,000 surgeons, well trained in

* Chairman's report to the Committee on Education and Research, American Orthopedic Society for Sports Medicine, 4th Annual Meeting, New Orleans, Louisiana, July, 1975.

Trainers
Coaches
Lawyers
Physical Educators
College Heads
Graduate Students
Nurses
Athletes
Athletic Directors
Armed Forces Personnel
Space Systems Personnel
School Board Directors
Medical Deans
School Participants
Senators
Congressmen
Radio and TV Network Personnel
Equipment Manufacturers
Paramedical Groups

Figure 1—*This list illustrates the diversity of professionals (in addition to physicians) who have written letters in response to the ABC documentary in October, 1974.*

trauma, to treat the huge number of individuals acutely injured in daily athletic performance. Even 200,000 practicing physicians could not, at this time adequately render proper care to the athlete at the site of injury, given the opportunity and available expertise. *The continuing interrelated education of all of these diverse groups is what sports medicine is about.* New federal and state legislation in conjunction with increased consumer advocacy, have become part of the sports medicine scene. It has been said that there is no need to train more orthopedic surgeons because the country's physician-patient ratio will have reached the saturation point by 1980. We do not agree. Since sports and recreational activities involve injury to the musculoskeletal system, more personnel with special skills in this area are needed. Indeed, the American Academy of Orthopedic Surgeons recognized this, when its report revealed that the knee joint and sports medicine ranked first and fourth respectively in importance to the orthopedic surgeon.[4] The success of the continuing education courses of the AAOS Committee on Sports Medicine; the development of the AOSSM; the ACSM and the numerous sports medicine groups which have been founded in the last few years, are testimony to the urgent need for more information in this area.

CHARACTERISTICS OF SPORTS PARTICIPANTS

We at the Institute of Sports Medicine and Athletic Trauma have devised four basic life-segment categories which help to explain why certain types of injuries are more prevalent during particular age periods.

Pre-Puberal Adolescent Period
Age 5–17

During this time, the opportunity to participate in sports and recreational activities is greatest. It is a period of rapid growth and maturation during which the musculoskeletal system is subjected to varying degrees of development. These imbalances in strength and endurance contribute to the vulnerability to injury in young athletes.

Prime Age Period
Age 18–35

During this period, career and family responsibilities compete with the individual's athletic interests for leisure time. These individuals may play too hard and for limited times. Unlike prime-aged professional athletes who are at their best during this time, many pseudo-athletes are not fit for strenous bouts of athletics and are insufficiently trained.

Middle Age Period
Age 36–55

As the family grows and as occupational pursuits have stabilized, more leisure time develops. The athletic-minded individual, while no longer able to meet the demands of some strenous sports, is still motivated to play hard but with decreasing physical ability. Overuse syndromes often occur during this period.

Retirement Period
Age 55 and over

Here, leisure time has been greatly expanded. Hobbies and recreational activity are often tempered with loss of expertise and fitness. Older, athletic-minded individuals may have problems which reduce their tolerance to stress, eg, cardiac disease, arthritis, failing senses, organ damage.

However, in spite of physical impairment associated with aging, competitive recreational pursuits continue to fulfill a very important need in many individuals. Their health-care requirements must be considered in this light.

In this context, then, Sports Medicine ranges from early life to senescence, and requires appropriate medical knowledge in dealing with the problems associated with these life-periods. Certainly orthopedic problems are different in each group.

Investigators such as Jokl, Astrand, Grueninger, Hunsicker, Bucher, Klein, Cureton, Larsen, Nelson, have become associated with such clinicians as Robert Jones, Shaeffer, Osgood, Thorndike, Bennett, O'Donoghue, Slocum, Hughston, Ryan, Allman and others too numerous to mention. To this list we can add the names of those now gaining in prominence such as Garrick, Torg, Marshall, Clancy, James and Hacke as well as Wilmore, Tipton and Klein. The list is endless, and includes thousands of others busily working and producing new data. Integrating all of this new data and making it available to the practicing physician will be a difficult yet challenging task.

CURRENT EDUCATIONAL AND RESEARCH AREAS

Modern sports medicine will require research and organization in a number of broad areas. Some of the most important among these include:
(1) Epidemiology; (2) the community role; public education; (3) the physical factors and their measurement; (4) the composition of athletic performance; (5) the care of the striken athlete.

A large number of training programs, institutes, foundations, and other research bodies have been developed to investigate and organize these areas. Biomechanics, statistics, kinesiology, neurophysiology, engineering, and radiology are but a few of the related disciplines utilized in this effort. Physical educators at Penn State University, Illinois, Iowa, Indiana, and Oregon are studying the athlete in a disciplined and integrated effort. Many other study programs exist, but they are limited to the study of prime/age athletes who are not pathologically afflicted. Studies have not been made in terms of the four age groups previously outlined.

We need a type of integrated research method utilizing a liaison between the physical educator, athletic trainer, orthopedist, coach and practitioner interested in sports such as never before accomplished in this country.

WHAT WE KNOW AND DO NOT KNOW ABOUT INJURIES

In 1974 the National Electronic Injury Surveillance System (NEISS), a reporting system of the United States Department of Health, Education and Welfare, began publishing a detailed report of incidence of injuries related to product safety. Although it is not all encompassing it is the best means to date by which recreational injuries, categorized as sports, have been tabulated. However, there are many injuries in a wide range of recreational leisure time activities which were not listed in this report. The injury rate data alluded to by the NEISS network in 1974 were collected from emergency room statistics from 110 hospitals. The rate of injury was projected at 446.48 per 100,000 population or roughly 8½ million athletic accidents per year. An important omission however, was the rate of injury to the middle aged and older amateur athlete. Many of these individuals did not go to the emergency rooms to seek treatment. Often they sought attention from a private physician, or more often just lived with their condition until "the pain went away". Therefore, the NEISS figures for those over

the age of 35, do not represent the total number of sports injuries in this country (Fig. 2). Practically no epidemiologic data exists for sports injury to the middle aged or older individual. Recognition of the importance of the role of paramedical personnel as the prime source for such data is necessary. The dissemination of information from the various research centers throughout the country to these individuals is equally important.

We need to collect data in our older age group in sports. This is an expensive proposition. Much needs to be learned as to how such information can be dispersed to the individual at a cost that is not prohibitive. Athletic injury for the most part, occurs at a site well away from a teaching institution or patient care facility. It may or may not be the responsibility of a coach, trainer, or the athletic participant and his friends to record pertinent injury data. Usually no one is around. Trainers are few and far between. Moreover, there are so many "cultist" type of physical programs throughout the country where medical problems may occur, that a continuous state of despair can develop for those of us who are trying to study epidemiology apart from the school system.

One of our tasks will also be to establish necessary and acceptable injury definitions (such as proposed by the AMA or the I.C.S.M.) in an effort to accurately describe sports injuries as they occur.

The liaison between medical, pediatric, coaching, training, physical education and other consultants has been demonstrated to be valuable in enlarging practical standards for safety in sports in high school programs. It is of epidemiologic interest that the conduct of athletic events can change from one generation to the next and from one geographical region to another. Figure 3 demonstrates the number of participants per year in some sports as rated by Neilsen. At the moment the fastest growing public participant sport is tennis, reported as having over 20 million participants.

The work of Cahill in the Peoria school system[5] and Garrick's excellent work[6] in his studies on high school injury in Washington are examples of valuable epidemiologic studies in this area. Why not extend the Neilsen rating system for the 10 most popular sports, to encompass geographic and demographic entities. Such a survey can be used in the future to sample geographical differences and relate these trends to types of sports. Epidemiology, then, must be supported by research grants throughout the country. By collaboration with various bodies interested in recreational and sports activities such as the American College of Sports Medicine, the AAHPER, the NATA, the American Academy of Pediatrics, the AMA Committee on the Medical Aspects of Sports, the President's Council on Physical Fitness, the Committee on Sports Medicine of the American Academy of Orthopedic Surgeons and other groups such as professional and college sports programs, much can be accomplished to develop an appropriate national epidemiologic system. This is a prime priority project. The emphasis on preventive medicine depends upon such projects.

Age Group	Percent Injured
0–4	.7
5–14	35.3
15–24	48.7
25–64	15.2
over 65	.1

Figure 2—*Sports injuries.**

* National Electronic Injury Surveillance System (NEISS) Network Matrix reports, 1200 series, 7/1/73 6/30/74 with adaptation by ISMAT.

THE NEED TO COORDINATE DATA

Physicians have begun to appreciate the importance of sports medicine in its relation to trauma and orthopedics. As previously pointed out, a number of institutes have developed which give promise to producing excellent work in the area of sports medicine. Many medical students are now interested in this field as a career. High school and college students have expressed increased interest in related fields so that additional educational programs will be required in the future. Such institutes, *must develop close liaison* with one another, so as to supplement one another without duplicating. Numerous journals, texts, and publica-

Sport	Millions Participating
SWIMMING	107
BICYCLING	65
FISHING	61
CAMPING	54
BOWLING	38
TABLE TENNIS	33
POOL	33
BOATING	32
SOFTBALL	26
ICE SKATING	25

Figure 3—*Incidences of sports participation.**

* Compiled by the A.C. Neilson Company and reprinted in the New York Times, March 24, 1974.

	Performance Totals
1) STRENGTH	111
2) ENDURANCE	124
3) BODY TYPE	76
4) FLEXIBILITY	97
5) BALANCE	139
6) AGILITY	121
7) SPEED	91
8) COORDINATION	153
9) TIMING	156
10) REACTION TIME	139
11) RHYTHM	135
12) STEADINESS	128
13) ACCURACY	146
14) INTELLIGENCE	55
15) CREATIVITY	94
16) ALERTNESS	151
17) MOTIVATION	134
18) DISCIPLINE	142
19) PLAYING CONDITIONS	96
20) EQUIPMENT	105
21) PRACTICE	154

ating of frequency distribution of sports perform-

tions in sports medicine have become increasingly popular. Some of these are listed in Figure 5. A major task will be to integrate this literature for the orthopedic surgeon's education. It should be remembered that Sports Medicine is social medicine and those involved with it should treat its problems with this in mind.

THE COMPOSITION OF ATHLETIC PERFORMANCE

One of the first questions that needs to be answered is: How much is demanded of the individual when he plays a certain sport? We are indebted to Cureton[7], Gruninger[8], Hunsicker[9] for their pioneering work in the study of physical performance. We feel that it is feasible to develop physical rating systems in sports performance, which could be used by paramedical personnel at the local level, and to some extent, by the individual performers themselves.

ISMAT PERFORMANCE CHART

We have divided player performance factors into three broad categories: (1) neuromuscular factors; (2) mental psychometric factors; and (3) environmental factors (Appendix I).

We have also classified all sports performance in terms of motion: (1) stance; (2) walk; (3) run; (4) jump; (5) throw; (6) kick. With these components of motion in sports, athletic performance demands upon the individual can be studied and described quantitatively.

In each of the above six categories of motion, player performance will vary with environmental conditions, ie, in water, on land, in the air, on inclined planes. In addition, many combinations of movements exist, some of which initiate a pathological process or aggravate an existing one. We object to the use of "tennis elbow" as a synonym for epicondylitis. "Thrower's elbow" would be just as accurate. Pole vaulting for example, would consist of a multitude of performance elements, eg, running, jumping, throwing, kicking. In such instances a "jumper's knee", throwing arm lesion of the shoulder or hamstring pull might be caused by the demands of this particular sport.

In this way the diverse motions of sports can be studied on a more rational, objective basis. While the physical educator is interested in performance, it is the doctor, and *especially the orthopedic surgeon, who must relate athletic performance to an afflicted athlete's pathology*. Treatment and performance then are related. One cannot successfully treat an injured athlete and expect

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HEALTH AND MEDICINE IN SPORTS
SPORTS MEDICINE
THE ENCYCLOPEDIA OF SPORTS MEDICINE
THE BIOMECHANICS OF SPORTS (Nelson)
THE INTERNATIONAL SERIES OF BIOMECHANICS
(University Park Press)
THE AMERICAN LECTURE SERIES
RESEARCH QUARTERLY

Figure 5—*Numerous journals, texts and publications have become increasingly popular. Requests for references continue to pour in and we have listed some of these.*

him to return to competition without an appreciation of the demands of that sport.

ENVIRONMENTAL FACTORS

Environmental factors (Appendix I) are the area where injury prevention is most apt to be effective. These factors are objectively measurable and can be controlled by rule changes, appropriate coaching and training techniques, and equipment changes. In the nomograms that we use in the summation of our three categories in each sport, the relative importance of the environment is of extreme importance especially in the education of paramedical personnel. A careful search of the literature of these 21 factors has been made by us in order to define the factors, as well as over 15,000 measurements. Simple definitions are appended (Appendix II). We hope this type of research will enable us to relate pathology in sports motion to performance requirements.

STRENGTH AND ENDURANCE

There is much confusion in such areas as strength and endurance. In subsequent papers we shall report a great deal of the accumulated data in this area. We have learned that small, subtle losses of power in distal parts of the upper and lower extremities have a profound effect on the trunk and proximal muscle strength.

MATURATION AND GROWTH

Maturation and growth, as the child reaches puberty, produce risks of injury which in the past have been appreciated by orthopedists and pediatricians. These risks are profoundly affected by requirements of performance. Recently, Gottschall[11] reported how tightness in joints increase each year between 14 and 18 years of age, although he could not relate these changes to injury problems. This is an important observation for it is the first study that an orthopedist has made of the effect of maturity on joint laxity.

RUN
JUMP
WALK
KICK
THROW
STANCE

Figure 6—*The six basic movements of human locon in sports. All acceleration activities utilize some or components. They form a useful basis for the class diverse sports on a common ground.*

FLEXIBILITY

The concept that some individuals have more flexibility than others is not a new one. Orthopedic surgeons, for many years, have recognized the striking relationship between degrees of flexibility to a number of pathological conditions, such as subluxing shoulders, dislocating patellae, chronic instability of the ankle, lordodic backs, and other predilections for subluxation and dislocation. Howorth,[12] Sutro,[13] Sweetnam,[14] Kirk,[15] Ansell,[15] and Bywaters[15] have all alluded to this concept. Indeed, the hypermobility syndrome has been associated with numerous musculoskeletal complications and an assessment of this syndrome was also made in 1964 by Wilkinson.[16, 17] We published a study in 1970, of relationship of knee injuries to limb looseness and tightness in professional football players. We have observed that some athletes while they possess great flexibility, do not have

the same muscle strength as other athletes with less flexibility. In tests performed by Dr. Douglas Jackson and ourselves, significant quantitative differences in flexibility (spinal and upper and lower extremity) were found among West Point Cadets, professional football players, school athletes and gymnasts (Figure 7A). Tests are now being developed to include such activities as soccer, lacrosse, hockey, basketball and ballet dancing.

Recognition of the influence of joint laxity on joint function during running, jumping and throwing, is fundamental to an understanding of joint physiology at extremes of motion.[19] Strength, endurance and anatomical differences are additional factors in the analysis of an individual's performance characteristics.

The ligamentous injuries suffered by loose-jointed individuals are far more difficult to repair than those found in tight-jointed individuals. This observation has been confirmed by Blazina,[21] Slocum, Hughston and Kennedy[22] and bears directly on problems in knee surgery such as over compression of the patella from too tight an attempted repair or laxity in spite of properly repaired ligaments.

Indeed, an attempt has been made to chemically tighten such structures. Hackett[23] tried to produce tightness through prolotherapy, injecting sodium salts and fatty acids into loose ligaments. This work has not been reproduced, but similar attempts in the future with some other chemical modality might be effective. At the present time, however, the best methods to stabilize such joints are: (1) the use of restraining methods such as bracing; (2) increasing power with exercise; and (3) well designed surgery, including the use of synthetic ligaments and appropriate alignment of misdirected axial relationships.

In evaluating athletic demands on the individual, each performance factor listed in Appendix I has been tested and is being refined by many investigators, including ourselves. A screening device involving one performance trait, ie, flexibility, is being used in numerous professional and school programs in our metropolitan area.

TESTS FOR FLEXIBILITY

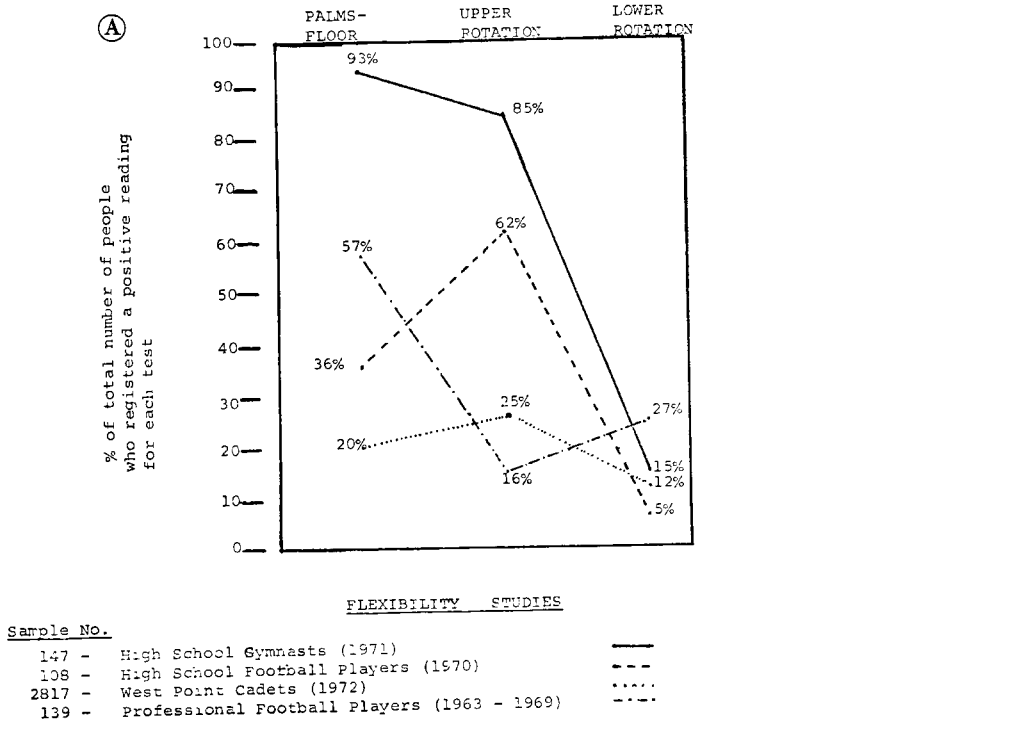
We have devised five screening tests for overall body flexibility. They are designed to measure the ability of the entire extremity to get into extreme positions regardless of where laxity occurs in the extremity. There have been some studies reported, in which no relationship was found between knee laxity and knee injury (Morehouse, Penn State).[24] Such a relationship would have been found, if overall laxity was properly considered, by the investigator, a summation of looseness and tightness. It is possible to have a loose knee with tight ankle enabling overpivot to occur at the knee. It is also possible to have overpivot occur with a tight knee but a loose hip. It is not our function at this time to discuss what consitutes single joint laxity, but rather to outline screening profiles where overall laxity or tightness occurs. (Figures 7a & b)

These tests of flexibility can be used by ancillary personnel.

TEST I.

The ability to place the palms of the hands flat on the floor while maintaining both knees in locked position.

It was found that 93% of 147 young girl gymnasts could do this, but only 36% of 108 members of a high school football team were successful. At West Point only 20% of the class could perform this manevver while 57% of a group of professional football players were successful. The natural ability to place the palms to the floor with knees locked varies from group to group and some individuals can be trained to accomplish this act. Those who can do it are classified as having a loose trait. The ability to perform this maneuver, (ie, palms to floor with knees straight) can represent flexibility from the shoulders down the spine to the hamstrings and calf and can even be a manifestation of long arms. Performance of this test can produce backache or pulled muscles when it is attempted by tight structured people who use toe-touching as a training exercise.



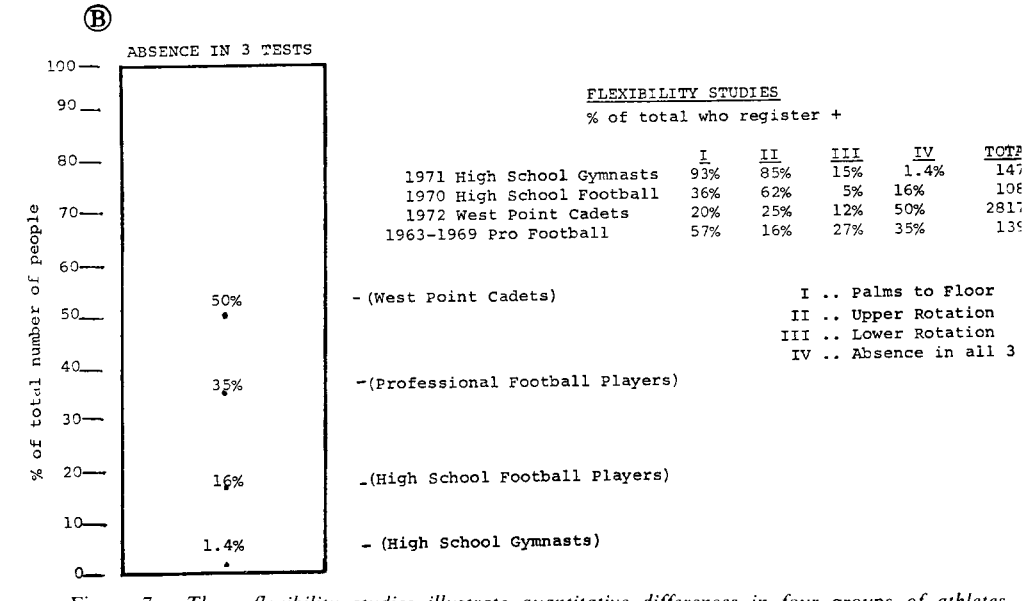


Figure 7a—*These flexibility studies illustrate quantitative differences in four groups of athletes demonstrating how gymnasts differ from other groups.*

Figure 7b—*Note that 50% of West Point Cadets had no flexibility as compared to gymnasts in whom only 1.49% had no flexibility on these specific tests.*

TEST II: UPPER EXTREMITY TORQUE

The ability to place the arms in front of the body with the elbows hyperextended and shoulders rotated out as far as possible to position the hypothenar eminence (on the little finger side of the hand), higher than the thumb side.

This maneuver is made possible, in certain individuals, by laxity at the wrist and hands or an increase in external rotation of the shoulders, or a combination. This trait, when positive, indicates a potential for subluxation of the humerus, radius or wrist bone. This was a trait found in 85% of the female gymnasts; 62% of the high school football players; 25% of the West Point cadets. Only 1 in 7 (14%) of the professional footballers could perform this maneuver. These findings suggest that increased age might be associated with decreased ability to perform this task.

TEST III: RECURVATUM

The presence of recurvatum (or backward flexing) of the knee of 15 degrees or more, with the knees back as far as possible.

A goniometer should be used in determining the condition of such a loose knee. This was found in about one third of professional football players with over 9 years of playing experience. This is an extremely high incidence and we do not know whether it is the result of this trait being "normal" among athletes or acquired through athletic participation. This trait was also found in 25% of the gymnasts and in 19% of the high school football players. When it is present, it is a dangerous sign in those athletes who are exposed to impact or deceleration forces from a sudden blow to the tibia. These are extremely high figures when compared with those of other members of the population.

TEST IV: LOWER EXTREMITY TORQUE

The degree to which the foot can carry torque at the moment of impact to the ankle, knee and hip.

This is a measure of total limb turnout ability. It places the leg in an extremely vulnerable position in sports where one has to cut or pivot hard while in this turnout position. In this test the individual stands with heels together turning the leg out as far as possible to see whether the feet make an angle of 180 degrees heel to heel. This determines valgus at the foot, and knee, and extension of the knee and external rotation of the hip. It is considered a practical measure of the ultimate cutting ability of an athlete. This ability was found in 25% of the professional athletes, in 15% of the female gymnasts and 4% of the high school football players but only 5% of the West Point Cadets. In view of the fact that a higher degree of injury was associated with the test, which is related to agility, it is a valuable tool.

TEST V: LOTUS POSITION

The individual sits on the floor with the knees and ankles parallel to the floor as is commonly performed in Yoga.

This measures increased external rotation of the hip as well as varus laxity at the hip and knee. This test had the least number of successful completions in each category. Only 2% of the gymnasts, 5% of the high school football players and 12% of the professionals could perform this maneuver.

Within the framework of these five tests it is feasible to derive a bell distribution curve. There are individuals who cannot perform any of these tests. They are the tight jointed ones; there are some who can perform all of them and they are the loose jointed ones. The majority of people can perform two of these tests.

STRENGTH TESTS

We have determined, in a large number of cases, that decreased power is usually found in loose persons while increased strength is common among the tight jointed individuals. It has been reported that tight jointed individuals suffer more apophyseal avulsions, and in athletes, the tight jointed individual suffers more muscle and tendon ruptures.[25] Further work is needed to determine why these relationships between joint laxity and muscle strength are present. We feel that these tests are very useful in predicting the potential for injury among

athletes. They are simple tests to perform, they do not require a sophisticated level of knowledge, and they can be done by the patients themselves.

ADDITIONAL TESTS

It should be pointed out that hypermobility can be isolated to any one joint as determined by Carter, Wilson and Sutro.[26] Brown and Rose,[27] in 1966, developed a laxity index, and they tested laxity in individual joints. Since flexibility is so important in so many sports ranging from jai alai to ice skating, judo, wrestling, gymnastics and many others, those individuals who are not flexible enough in playing such sports are most apt to develop muscle pulls. Such individuals should not be playing these sports without specific stretching exercises. Certain joints, in these sports, are over stretched and their muscle control and power should be made maximal.

TREATMENT OF HYPERFLEXIBLE AND OVER TIGHT ATHLETES

We have found, at the Institute of Sports Medicine & Athletic Trauma that the hyperflexible person is more apt to loose power if he does not train. Therefore, when these traits are discovered in performance tests, such individuals should be strengthened by some form of exercise. The most likely weaknesses are in the flexors, the abductors, the ankle evertors and the knee extensors.[28]

When one finds tight individuals, the cause can be found in muscle ligaments and tendons spanning the skeleton from the neck to the toes. A program designed to stretch muscles and ligaments from the spine to the calf should be included. But any such program will have to protect against low back derangement. This is done by *segmental stretching* of the muscle units, spacing the joints, and by isolating the calf and hamstrings as well as erector spinal muscles into different stretch patterns. One good way of developing such abilities is simply to use aquatic exercises such as walking a mile in the water. These exercises should be combined with stretching and resistance exercises (repetitions at sustained three-second intervals). The rate at which these are performed is very important as well as the segment of applied resistance. One must recognize that in many instances, loose shoulders, knees and ankles should be braced. This a valuable tool, but at the expense of some loss of agility. Repeated improvements in strength of the prime moving muscle groups should be accompanied by strengthening the antagonists combined with stretching of the prime movers. This should be applied to other areas of the body in the same manner. In the athlete who has lost some movement because of injury, (ie, the middle aged athlete) the joints must be protected so that they are not forced into incongruent positions. A good rule is not to overflex any involved joint but work on stretching the joint and stretching the proximal and distal muscles while increasing power in the antigravity and antagonistic muscles of such affected joints.

OTHER PERFORMANCE TRAITS

We do not at this time wish to discuss speed, balance, agility, coordination, or the psychometric factors in our rating chart in detail. Suffice it to say we welcome all the additions and corrections that sound research can offer.

PATIENT ADVICE

A systematic and integrated approach to the study of injury as it effects a particular performance factor will be much more rational. Individuals who have only a 0 rating, for example, will not do well in a 3 performance factor area (eg, a tight structured individual who tries ballet).

Body typing is necessary, if individuals are to participate in appropriate sports.

Frequently a patient after undergoing knee surgery will ask an orthpedic surgeon: "Can I play paddle ball"?; "ski"; "play tennis"?. The answer is often difficult. By studying the demands of such sports, and relating it to the patient and his pathology, a reasonable answer might be to lengthen the reaction-time demands of the sport. This would mean, for example, a slower game of tennis with less active opponents; a braced knee; or participation in games which require less agility.

In the young adolescent (5–17 years of age), with high kneecaps which are painful and who wishes to play basketball, tennis,

gymnastics or ballet, a brace may help. For a prime-aged athlete (17-35) who has a bad back, while engaging in endurance sports such as long distance running, a sport demanding less flexibility and endurance should be recommended. The middle aged athlete (35–55) who plays tennis and skis, while he complains of an impingement syndrome of the shoulder, and older individuals who wish to swim, or mountain climb, and who may have had a total hip replacement, should allow the orthopedist and family specialist to make a more appropriate risk assessment of the musculoskeletal system and to recommend a change in their athletic goals.

If we adhere to this philosophy, we should be able to discourage the aggravation of instability, and the development of additional arthritis. Individuals should not be prohibited from playing but, rather, should be diverted from those sports which are not safe for them. This type of approach has been utilized by the New York State Public High School Athletic Association. They have developed a study for the selection and classification of students who are participating in interscholastic activity, directed by Mr. J. Kenneth Hafner,[29] Director of Field Services. This approach is valid and should serve as a model for those who are interested in high school injury protection,[30] and screening studies.

OTHER PERFORMANCE TRAITS

Detection of endurance capabilities, cardiovascular efficiency and oxygen and carbon dioxide consumption, require the efforts of internists and physiologists. However, those of us interested in the athlete should know the meaning of such tests. These areas have been researched for many years and yet functional musculoskeletal analysis has not involved orthopedists until recently. Most fitness programs, in my experience, are not balanced in terms of coordination, speed, balance, agility etc. These factors work with one another. Does a tight body with a more dense composition exert more skeletal and joint demand? What is the effect of one knee, when it is working harder, on the opposite knee in terms of stress and compression on the knee joint, as well as weight transfer to the proximal and distal segments?

The integration of medicine and performance, orthopedic surgery and physical education, training and coaching is truly an exciting challenge. New x-ray scanning techniques produce new information on the structure of muscle mass. The electron microscope reveals the ultrastructure of collagen binding in loose and tight ligaments. Studies of the relationship between leg-arm-trunk strength to reaction time help us to understand an individual's performance characteristics. Such efforts as these will ultimately enable the practicing clinician to greatly improve the care of the injured athlete.

CONCLUSIONS

A. Although it is sometimes impossible to prevent injury in sports in many instances because of high speed, diminished impact tolerance and other excessive risk factors, it should be possible to prevent injury by: (1) appropriate screening of individuals; (2) proper recognition of what individuals have to do in sports; (3) modification of the performance requirements to suit the individual. We think performance data analysis is an important function of the surgeon in relating motion pathology and demand.

B. We must develop the means whereby such information and testing methods can be integrated by national effort and cooperation.

C. Through the use of sports medicine publications, TV and other mass communication media, a public education program in sports injury prevention can be facilitated. Epidemiologic studies are necessary in the control of sports injury at all age levels and will supplement performance requirement data factors in the future.

D. Our goal should be to determine the risks involved in recreation and to assess the relative factors in human performance of various sports.

E. Performance trait analysis will stimulate the development of additional control of environmental factors (eg, conditions and equipment) while allowing competitive minded individuals to continue their participation in an otherwise high-risk activity.

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APPENDIX I

Performance Factors in Sports As Compiled by The Institute of Sports Medicine & Athletic Trauma and the Director, James A. Nicholas, M.D.*

The following charts illustrate the cooperative interrelationship between physical education, orthopedic surgery, and sports medicine. This is a dynamic chart, subject to many continous changes, as the knowledge

*This chart represents an adaptation of work from 1928 by such researchers as Cureton, Hunsicker, Shelton, Larsen, Grueninger, Nelson, and many others. We, at ISMAT, are the orthopedic counterparts to these physical educators.

of sports medicine grows. It is the foundation for future study of the relation of musculoskeletal structure and performance. The subjective measurement scale is the following as used by Hunsicker:

0 = Little or No Involvement
1 = Mild Involvement
2 = Moderate Involvement
3 = Heavy Involvement

NEUROMUSCULAR AND PHYSICAL FACTORS (A)

SPORTS	PERFORMANCE FACTORS															
	Strength	Endurance	Body Type	Flexibility	Balance	Agility	Speed	Coordination	Sub-Total A1	Timing	Reaction Time	Rhythm	Steadiness	Accuracy	Sub-Total A2	Total A
l. Archery	1	1	0	1	2	0	0	2	7	1	0	1	3	3	8	15
!. Auto Racing	2	2	1	0	1	0	0	3	9	3	3	1	3	3	13	22
). Badminton	1	2	1	2	2	2	2	3	15	2	3	2	2	2	11	26
l. Ballet	2	3	3	3	3	3	2	3	22	3	3	3	3	3	15	37
i. Ballroom Dance	1	1	1	1	2	2	1	2	11	2	1	3	1	1	8	19
). Baseball	2	1	1	2	2	2	2	3	15	3	3	2	1	3	12	27
'. Basketball	2	3	3	2	3	3	3	3	22	3	3	2	2	3	13	35
l. Bicycling	2	2	2	1	2	1	1	1	12	1	2	3	2	2	10	22
l. Big Game Hunting	2	3	1	1	1	1	2	3	14	3	2	2	3	3	13	27
l. Billiards	0	0	0	0	2	1	0	2	5	2	0	3	2	3	10	15
l. Bobsledding	2	2	1	1	3	1	2	2	14	3	3	2	2	3	13	27
!. Bowling	1	1	0	1	1	0	0	1	5	2	1	3	2	3	11	16
l. Boxing	3	3	2	2	3	3	3	3	22	3	3	3	3	3	15	37
l. Bridge	0	1	0	0	0	0	0	0	1	3	1	2	2	3	11	12
i. Bull Fighting	3	3	2	3	3	3	3	3	23	3	3	2	2	2	12	35
i. Calisthenics	1	1	2	2	2	1	2	2	13	2	1	3	2	1	9	22
'. Canoeing	1	2	1	1	2	1	1	2	11	3	1	2	2	2	10	21
l. Camping	1	1	0	0	2	0	0	1	5	0	0	0	0	1	1	6
l. Circus Acts	2	2	1	3	3	3	2	3	19	3	2	2	2	3	12	31
l. Cricket	2	2	2	2	2	2	2	3	17	3	3	2	1	2	11	28
. Curling	1	1	0	1	2	2	1	3	11	2	1	2	2	3	10	21
!. Diving	1	1	2	3	3	3	1	3	17	3	2	2	3	3	13	30
l. Equestrian	2	2	1	2	3	2	1	3	16	3	2	2	3	2	12	28
l. Fencing	2	3	1	2	3	3	3	3	20	3	3	3	3	3	15	35
i. Field Hockey	2	2	1	1	2	2	2	2	14	2	2	2	1	1	8	22
i. Figure Skating	2	2	1	3	3	3	3	3	20	3	3	3	2	3	14	34
'. Fishing (Deep Sea)	2	2	1	1	1	1	1	1	10	3	3	2	2	1	11	21
l. Football	3	2	3	2	3	3	3	2	21	3	3	3	3	3	15	36
l. Golf	1	1	1	2	2	0	0	3	10	3	1	3	3	3	13	23
l. Gymnastics	3	2	2	3	3	3	2	3	21	3	3	3	3	3	15	36
. Handball	2	2	1	2	2	2	2	2	15	2	3	2	2	2	11	26
. Hiking	1	2	1	1	1	0	0	1	7	1	1	1	1	0	4	11
. Hockey	3	3	2	2	3	3	3	3	22	3	3	3	3	3	15	37
. Ice Follies	2	2	2	3	3	3	3	3	21	3	2	3	2	3	13	34
. Jai Alai	3	3	2	2	3	3	3	3	22	3	3	2	2	2	12	34
. Jockey Riding	3	3	3	1	3	3	2	3	21	3	3	3	2	2	13	34
. Judo	3	2	1	3	3	3	3	3	21	3	3	3	3	3	15	36
. Karate	2	2	2	3	3	3	2	3	20	3	2	2	3	3	13	33
. Lacrosse	2	2	1	1	2	2	2	3	15	2	2	2	2	2	10	25
. Modern Dance	2	2	0	2	3	2	1	2	14	1	1	3	1	0	6	20
. Motor Cycling	1	1	0	0	2	0	0	3	7	3	3	2	2	3	13	20
. Mountain Climbing	3	3	1	2	2	2	1	2	16	3	3	2	3	2	13	29
. Paddleball	2	2	2	2	2	2	2	3	17	3	3	2	1	2	11	28
. Polo	2	2	1	1	3	3	1	3	16	3	3	2	2	3	13	29
. Rodeo	3	3	1	2	3	2	1	3	18	3	3	2	3	3	14	32
. Racing	3	3	2	2	2	1	1	2	16	3	2	3	3	3	14	30
. Rugby	2	3	1	2	3	3	3	3	23	3	3	2	1	2	11	34
. Sailing	1	2	0	0	1	2	0	2	8	2	3	2	2	3	12	20
. Scuba Diving	1	2	0	1	2	1	0	2	9	2	3	3	2	2	12	21
. Skiing	1	2	1	2	3	3	1	3	16	1	2	2	2	1	8	24
. Snowmobiling	2	2	0	0	2	2	0	3	11	2	2	2	2	2	10	21
. Soccer	2	3	1	2	3	3	3	3	20	3	3	2	2	2	12	32
. Surfing	2	3	2	0	3	3	0	3	16	3	3	2	3	3	14	30
. Swimming	2	2	2	2	2	1	2	2	15	2	2	3	2	3	12	27
. Table Tennis	1	1	1	1	1	2	2	2	11	3	3	2	1	3	12	23
. Tap Dance	2	2	1	1	2	2	1	3	14	3	2	3	2	3	13	27
. Tennis	1	2	1	2	2	3	2	3	16	2	2	2	2	2	10	26
. Tumbling	1	2	2	3	3	3	2	3	19	3	2	3	2	3	13	32
. Volleyball	2	2	2	2	3	3	2	3	19	3	3	2	1	3	12	31
. Water Polo	2	2	2	2	1	3	2	3	17	3	3	2	1	2	11	28
. Yachting	2	3	1	0	2	2	0	3	13	3	2	1	3	3	12	25
formance Totals	111	124	76	97	139	121	91	153		156	139	135	128	146		

SPORTS	Total A	MENTAL AND PSYCHOMETRIC FACTORS (B) — PERFORMANCE FACTORS							ENVIRONMENTAL FACTORS (C)				FINAL TOTAL A + B + C
		Intelligence	Creativity	Alertness	Motivation	Discipline	Sub-Total B	Total A + B	Playing Conditions	Equipment	Practice	Sub-Total C	
1. Archery	15	1	0	2	1	3	6	21	2	2	3	7	28
2. Auto Racing	22	2	3	3	3	3	14	36	3	3	3	9	45
3. Badminton	26	0	1	2	1	2	6	32	3	3	2	8	40
4. Ballet	37	1	3	3	3	3	13	50	1	1	3	5	55
5. Ballroom Dance	19	1	2	2	1	1	7	26	0	0	1	1	27
6. Baseball	27	1	1	3	2	2	9	36	3	2	3	8	44
7. Basketball	35	1	1	3	3	2	10	45	1	1	3	5	50
8. Bicycling	22	1	2	2	1	2	8	30	2	2	2	6	36
9. Big Game Hunting	27	2	2	3	2	3	12	39	1	3	2	6	45
10. Billiards	15	0	2	1	1	1	5	20	2	2	3	7	27
11. Bobsledding	27	1	1	3	2	2	9	36	0	0	3	3	39
12. Bowling	16	0	2	2	2	2	8	24	1	2	2	5	29
13. Boxing	37	1	0	3	3	3	10	47	0	1	3	4	51
14. Bridge	12	2	2	3	2	2	11	23	0	0	3	3	26
15. Bull Fighting	35	2	3	3	3	3	14	49	1	2	3	6	55
16. Calisthenics	22	1	2	2	2	2	9	31	0	0	2	2	33
17. Canoeing	21	1	2	2	2	2	9	30	3	2	2	7	37
18. Camping	6	1	2	2	2	2	9	15	3	3	2	8	23
19. Circus Acts	31	1	2	2	3	3	11	42	1	2	3	6	48
20. Cricket	28	1	1	2	2	2	8	36	2	3	3	8	44
21. Curling	21	1	2	1	2	2	8	29	2	2	3	7	36
22. Diving	30	1	2	2	3	2	10	40	1	1	3	5	45
23. Equestrian	28	1	2	3	2	2	10	38	2	3	3	8	46
24. Fencing	35	1	0	3	3	3	10	45	0	2	2	4	49
25. Field Hockey	22	1	1	2	2	2	8	30	2	2	2	6	36
26. Figure Skating	34	1	1	3	3	3	11	45	2	1	3	6	41
27. Fishing (Deep Sea)	21	1	0	3	2	3	9	30	0	1	2	3	33
28. Football	36	2	1	3	3	3	12	48	2	3	3	8	56
29. Golf	23	1	2	1	2	3	9	32	2	2	3	7	39
30. Gymnastics	36	0	0	3	3	3	9	45	1	1	3	5	50
31. Handball	26	0	1	2	2	2	7	33	1	1	2	4	37
32. Hiking	11	0	2	1	1	2	6	17	1	0	0	1	18
33. Hockey	37	0	0	3	3	3	9	46	2	3	3	8	54
34. Ice Follies	34	1	2	2	2	2	9	43	3	2	3	8	51
35. Jai Alai	34	1	2	3	2	2	10	44	2	3	3	8	52
36. Jockey Riding	34	1	3	3	3	3	13	47	1	2	2	5	52
37. Judo	36	1	1	3	3	3	11	47	1	0	3	4	51
38. Karate	33	2	3	3	2	3	13	46	0	1	3	4	50
39. Lacrosse	25	1	0	2	2	2	7	32	2	2	2	6	38
40. Modern Dance	20	1	3	2	1	0	7	27	0	0	1	1	28
41. Motor Cycling	20	1	2	3	2	2	10	30	2	3	2	7	37
42. Mountain Climbing	29	2	0	3	3	3	11	40	2	2	3	7	47
43. Paddleball	28	0	2	2	2	2	8	36	2	2	2	6	42
44. Polo	29	1	3	3	2	3	12	41	3	3	3	9	50
45. Rodeo	32	1	0	3	3	3	10	42	2	2	3	7	49
46. Racing	30	0	1	3	3	3	10	40	2	2	2	6	46
47. Rugby	34	1	2	3	2	3	11	45	2	2	3	7	52
48. Sailing	20	2	3	3	3	3	14	34	3	3	3	9	43
49. Scuba Diving	21	1	1	3	2	2	9	30	2	3	2	7	37
50. Skiing	24	1	1	2	2	2	8	32	3	3	3	9	41
51. Snowmobiling	21	1	2	2	2	2	9	30	3	3	2	8	38
52. Soccer	32	0	0	3	3	2	8	40	1	1	2	4	44
53. Surfing	30	1	3	3	3	3	13	43	3	1	3	7	50
54. Swimming	27	1	0	3	2	2	8	35	1	0	3	4	39
55. Table Tennis	23	0	2	2	2	2	8	31	0	1	2	3	34
56. Tap Dance	27	0	1	2	2	2	7	34	0	1	2	3	37
57. Tennis	26	1	2	2	2	2	9	35	2	2	3	7	42
58. Tumbling	32	0	1	2	2	2	7	39	2	1	3	6	45
59. Volleyball	31	0	1	3	1	2	7	38	2	2	2	6	44
60. Water Polo	28	1	2	2	2	2	9	40	1	0	3	4	44
61. Yachting	25	2	3	3	2	2	12	37	3	3	3	9	46
Performance Totals		55	94	151	134	142			96	105	154		

APPENDIX II

Performance Factors Definitions*

1) STRENGTH: The contractive power of muscles as a result of a single maximum effort
2) ENDURANCE: The number of successive movements of muscular strength or power at a given rate of speed over an extended period of time determines muscular endurance
3) BODY TYPE: Physical characteristics that involve height, weight, sex, body composition and anthropomorphic differences and similarities.
4) FLEXIBILITY: Looseness and tightness can be within the joint, the extremity, the trunk or a combination to provide a wide range of movements of performance
5) BALANCE: Coordinated neuromuscular response of the body to maintain a defined position (i.e., upright) of equilibrium in response to changing a) tactile b) visual c) kinesthetic or other stimuli
6) AGILITY: Speed plus the ability to make a sudden change of direction in movement
7) SPEED: Capacity to perform successive movements of the same type at a fast rate . . . by all parts of the body . . . it is limited in time by fatigue
8) COORDINATION: The essence of coordination is the ability to integrate the separate abilities in a complex task
9) TIMING: The adaptation, initiation, and integration of stimulus to change
10) REACTION TIME: The elapse of time between appearance of stimulus and motor response . . . they are dependent upon multiple stimuli
11) RHYTHM: Synchronized movements associated with thought, motion, and sound in a particular sport or skill
12) STEADINESS: The ability to control the mental and physical facilities towards maximum efficiency during all situations
13) ACCURACY: Movements with precision, body control and steadiness
14) INTELLIGENCE: The ability to interrelate perception of the environment, integrate these sensations into total configurations, attribute meaning in terms of past experience, and respond to new perceptions
15) CREATIVITY: The ability to create something new, presumed to be a derivative of sublimation
16) ALERTNESS: A degree of immediate awareness of sensory stimulation
17) MOTIVATION: The force or energy that propels an organism to seek a goal and/or to satisfy a need, striving, incentive or purpose
18) DISCIPLINE: Conscious limitations of impulses, wishes, tendencies, etc., that is, to suppression of instincts and affects
19) PLAYING CONDITIONS: The degree to which the playing surface and the surrounding atmosphere of each sport effects performance of that sport
20) EQUIPMENT: All implements as a direct or indirect function of the sport, and their effect on the sports ability to secure top quality performance
21) PRACTICE: The requirement of each sport to assure participation through continual repetition of each sport's movement

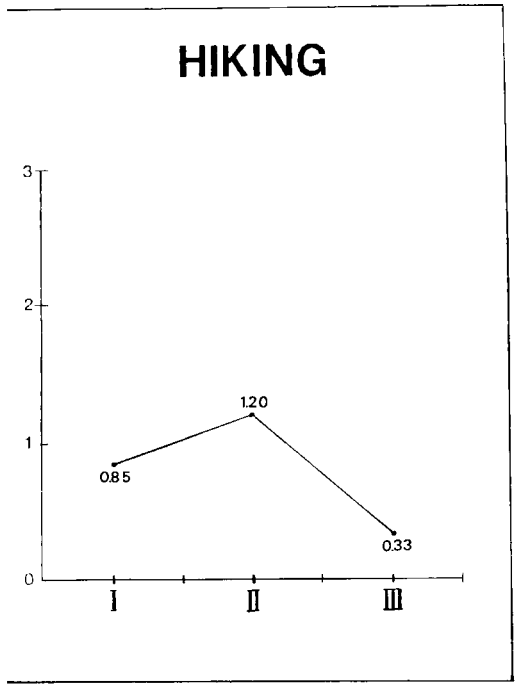
* Definitions result from a compendium of works including Larsen, Hunsicker, Encyclopedia of Sports Medicine, Psychiatric Dictionary, Dr. Nicholas, etc.

APPENDIX III

Sample—Nomograms

These three nomograms compare the demands of hiking and ballet when compared with means of 61 sports.

GROUP I—relates to 13 performance traits
GROUP II—relates to 5 performance traits
GROUP III—three factors as noted in Appendix I


HIKING
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2
1
0
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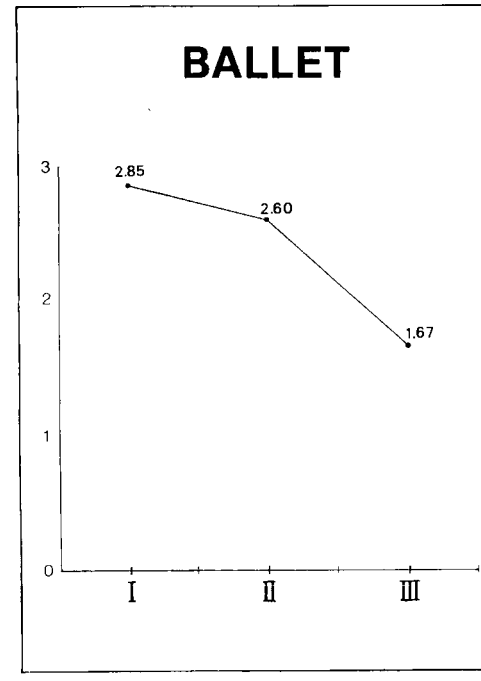
1.20
0.33
I
II
III


BALLET
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2.60
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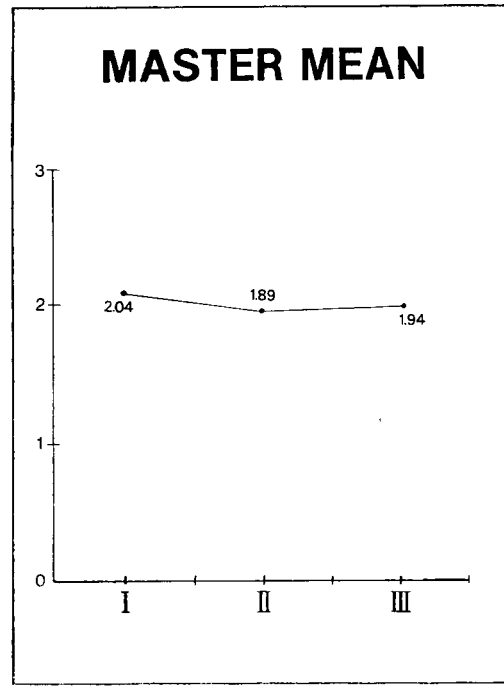
I
II
III


MASTER MEAN
3
2
1
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2.04
1.89
1.94
I
II
III

APPENDIX IV

New York Jets Coaching Survey

Sample

This sample copy demonstrates how the integration of body movements in a given sport are brought together by the doctor in the study of the pathology of movement. Throwing and running are classified on this sample sheet by professional coaches assessing each position. In this manner the differences in positions in sports are studied by movement. This method seems the most promising in which positions, players, and body performance can be studied.

NEW YORK JETS COACHING SURVEY

in cooperation with James A. Nicholas, M.D. & ISMAT

COACH_____ POSITION_____

RUNNING	INVOLVEMENT 0	1	2	3
Right angle pivot				
Crossover or Reverse cut				
Diagonal				
Circular				
Backwards				
Laterally				
Zig-Zag				
Stop and Go				
Jump to Run				
Uphill				
Downhill				
Other (enumerate)				

* 0 = little or no involvement
  1 = mild involvement
  2 = moderate involvement
  3 = heavy involvement